The Influence of Exogenous Abscisic Acid and Carbon Dioxide Enrichment on the Rooting of an Australian Ornamental Plant

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INTRODUCTION

Factors which affect the capability of cuttings to form roots are of great interest to plant propagators and nursery people since a significant proportion of ornamental plants are propagated this way. Plant physiologists also find the events leading to the formation of adventitious roots of interest as there is considerable evidence that the process is under hormonal control. The dramatic effects on root formation of application of synthetic auxins may be taken as evidence for the involvement of naturally occurring auxins in root initiation and development. However, attempts to relate changes in endogenous auxins in cuttings to their ability to form roots has not produced a clear picture and have been summarised by Gasper and Hofinger (1988). For example, Wu and Barnes (1981) found that there was no difference in the endogenous auxin content of two *Rhododendron* cultivars, one of which was difficult to root and the other easy. Tréfois and Brunner (1982) showed that there was no effect of applied auxin on cuttings from a number of *Prunus* species when endogenous auxin content was low but when endogenous auxin content was high at the time the cuttings were prepared a positive relationship could be demonstrated between rooting success and auxin content. This suggests that some other unknown factor is influencing both rooting performance and endogenous auxin level. Gasper and Hofinger (1985) also summarise evidence from the work of Blakesley et al. (1985) which demonstrated a good relationship between auxin concentration and rooting success in *Cotinus coggygria* cuttings. Furthermore, substances such as triiodo benzoic acid (TIBA), which are known to interfere with the transport of auxins from the apex to the basal end of the cutting, also inhibit rooting (Davis and Sankhla, 1988). The precise role of auxins in the induction of adventitious root formation is far from clear, but the weight of evidence suggests that a high auxin content at the time cuttings are taken, which is probably a reflection of the vigour and physiological state of the stock plant, is beneficial to subsequent rooting and that exogenous auxin application at this time may also be beneficial.

Although auxins such as indole-3-butyric acid (IBA) are widely used to promote rooting of cuttings, other plant hormones are also known to influence the formation of adventitious roots. Gibberellins are generally thought to inhibit rooting (Hartmann and Kester, 1983) and synthetic substances which are known to inhibit gibberellin synthesis may have a beneficial effect on rooting (Davis and Sankhla, 1988).

Abscisic acid (ABA) is a naturally occurring plant hormone also known to oppose the effects of gibberellins (Lin and Ho, 1986) and there are a number of reported instances where ABA application has stimulated root formation on cuttings. Davis and Sankhla (1988) summarise these reports but also draw attention to evidence that ABA may have no effect or even inhibit rooting. Since one of the major roles of ABA in plants is to control stomatal aperture, and hence transpirational water loss (Raschke, 1979), we have investigated the possibility that any beneficial effect of ABA in rooting stimulation is through its effect on stomatal behaviour and hence water status of the cutting. Our test system was the Australian ornamental plant *Chamelaucium* 'Lady Stephanie' [*C. uncinatum* (Schauer) × *C. floriferum* (MS)] and rooting performance was studied at ambient levels of CO_2 and in a CO_2-enriched (750 to 800 ppm) environment. This approach was adopted because of the desire to also assess the effects of carbohydrate status on rooting and the known interactive effects of ABA and CO_2 whereby high CO_2 intensifies the effects of applied or endogenous ABA (Raschke, 1975).

MATERIALS AND METHODS

Plant material, propagation medium, CO_2 enrichment methods, and methods of starch analysis have been described previously (Grant et al., 1992). Briefly, terminal cuttings 50 to 75 mm long were taken from *Chamelaucium* 'Lady Stephanie' plants growing in pots in a glasshouse. The basal 20 mm of the cuttings were dipped in IBA solution (1 g litre^{-1} in 50% ethanol) for 20 sec and then placed in a mixture of peat, perlite, and coarse sand in plastic propagation trays. Three trays, each containing about 100 cuttings, were placed in each of two polythene tunnels. One was maintained at approximately 750 ppm CO_2 [range 700 to 900 ppm] and other at ambient CO_2 (approximately 350 ppm). Humidity was maintained at >95% by sonic fogging nozzles using deionised water. The trays were randomised on the benches frequently to avoid position effects. Rooting success was estimated by removal of 10 randomly selected cuttings from each tray at each sampling time. In some experiments cuttings were sprayed with ABA (10 mg litre^{-1}) to runoff every second day. Control cuttings were sprayed with water.

Water potential of cuttings was measured with a pressure bomb. For starch determination, cuttings were oven dried at 80C to constant weight and ground to a fine powder. Samples of this powder and a series of starch standards were hydrolysed with amyloglucosidase and the liberated glucose assayed in terms of changed absorbance at 340 nm following incubation with hexokinase, ATP, NADP, and glucose-6-phosphate dehydrogenase. Abscisic acid was determined according to Loveys and van Dijk (1988). Cuttings were washed with deionised water, surface dried, weighed and frozen at -20C until required. Frozen material was extracted for 5 min in boiling water. After cooling and addition of an internal standard of $(\pm)^2H_3$-ABA, the tissue was homogenised, centrifuged, and the supernatant extracted at pH 2.5 with ethyl acetate. This acidic extract was dried purified by reverse-phase HPLC and a fraction containing ABA was methylated with ethereal diazomethane. Quantitative analysis was carried out by gas chromatography/ mass spectrometry using stable isotope dilution analysis.

RESULTS

The water potential of the cuttings fell dramatically during the first few days in the propagation environment, despite the maintenance of high relative humidity. However, as callus formation at the base of the cuttings commenced water potentials gradually recovered. This recovery was more rapid in cuttings exposed to elevated CO_2. Soon after roots first appeared at about day 17 water potentials stabilised between -0.6 and -0.4 MPa. In another experiment some of the cuttings were sprayed with ABA (10 mg litre^{-1}). The water potentials of the control cuttings were similar to those noted in the previous experiment but ABA-sprayed cuttings had higher water potentials. The effect of ABA was most marked at the elevated level of CO_2.

One of the major factors likely to influence the physiological state and vigour of stock plants and cuttings taken from them is the current photosynthesis and reserves of carbohydrate which may be mobilised to provide the substrates necessary for root formation. We, therefore, monitored the accumulation of starch in *Chamelaucium* cuttings at ambient and elevated CO_2 with and without ABA treatment. During the first 15 days of the experiment, before there were any visible roots, starch levels increased by a factor of two or three in all treatments. The increase was greatest in cuttings with no ABA at elevated CO_2. ABA tended to reduce starch accumulation at both ambient and elevated CO_2. There was little further increase in starch in cuttings which developed roots but accumulation continued if roots were not present.

Roots first appeared at between 15 and 20 days after cuttings first entered the propagation environment. In the experiments reported here there was little difference in rooting performance at ambient and elevated CO_2. However, ABA had a marked positive effect on root formation but again there was no additional effect due to exposure to high CO_2.

ABA was measured in unsprayed cuttings at ambient and elevated CO_2. During the first 8 days ABA concentrations were elevated when compared with the concentration at the time of removal but as root formation occurred the concentration in the cuttings exposed to ambient CO_2 fell. The fall was less marked in cuttings exposed to elevated CO_2. In another experiment ABA was measured in cuttings which had been sprayed with ABA. As expected, the ABA treatment resulted in high levels of the compound remaining in the plant tissues. The concentration was highly variable even though care was taken to remove ABA remaining on the tissue surface by washing and by sampling on alternate days to spraying. On average, the concentration of ABA in the tissues was about ten-fold higher than the endogenous level and higher ABA levels remained in the cuttings maintained at elevated CO_2.

DISCUSSION

Despite the maintenance of high ambient relative humidity and optimum water availability in the rooting medium, water potentials fell during the first few days after cutting removal. This is not surprising since considerable water potential gradients exist between tissue and atmosphere, even in the high humidity conditions maintained in the polythene tunnels. Recovery in water potential was accelerated in the environment enriched with CO_2, probably due to reduced stomatal conductance which is known to occur when ambient CO_2 is raised (Wong, 1980). It has been shown previously that *Chamelaucium* cuttings transpire less

water under conditions of elevated CO_2 (Grant et al., 1992). Callus and root formation, which would allow more efficient water uptake from the rooting medium, did not appear to be advanced by the exposure to elevated CO_2.

As the water potential of the cuttings fell during the first few days in the propagation environment there would have been an accompanying fall in tissue turgor. This fall in turgor would have been the stimulus for the synthesis of ABA in the cuttings and it is this increased ABA which sensitises the stomata to CO_2, resulting in reduced transpiration (Raschke, 1975). It is interesting that endogenous ABA levels and ABA resulting from exogenous treatment remained higher in the cuttings when they were exposed to elevated CO_2. This may have been due to modified patterns of breakdown or to the presence of more root apices able to actively synthesise new ABA. In either case the result would have been a tighter control over transpirational water loss for the cuttings in the high CO_2 environment.

In the experiments reported here the dominant effect on rooting was the presence of ABA but in previously reported experiments (Grant et al., 1992) CO_2 enrichment was shown to be of benefit in stimulating rooting of *Chamelaucium* cuttings. However, the water potentials during these earlier experiments were considerably lower, as was the proportion of cuttings forming roots in ambient CO_2 conditions. Since water status of cuttings is known to be of critical importance for the successful production of adventitious roots (Loach and Whalley, 1978), it seems reasonable to conclude that it is this factor which is of prime importance and that ABA and CO_2 are having their effect through their ability to increase water potentials.

Carbohydrate production and availability during propagation is generally considered to be necessary for the provision of energy and carbon skeletons for the production of new tissues (Veierskov, 1988). Starch reserves at the time the cuttings were taken were low and in all treatments there was a marked accumulation of starch during the course of the experiment but this was reduced in the presence of ABA, especially at ambient CO_2. There was thus a negative correlation between rooting performance and starch accumulation, suggesting that carbohydrate accumulation was of secondary importance to the water relations issues discussed above. Davis (1988) has summarised the evidence for the evidence for the requirement for carbohydrate and concluded that current photosynthesis does positively influence the rooting success of most leafy cuttings but that other factors such as water status or auxin availability may be of overriding importance. Our results support this view.

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The Australian Native Foods Industry: New Challenges for the Plant Propagator

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INTRODUCTION

There is already a broad range of foods currently available which are legitimately native to Australia. In addition to well known edible fauna, we have a diverse range of native food-producing flora capable of being commercialised in a short period of time. Species selection has been strongly influenced by culinary successes from restaurants specialising in Australian native cuisine.

Further development of such an industry will offer a commercially viable supplement to marginal agricultural enterprises, irrigated and dryland. Additionally, in the short-term, it has the potential to offer Landcare groups, aboriginal communities, farmers, bush regenerators, and local councils economic returns on revegetation programs and financial incentives to preserve wild populations.

Our neglect of native foods is a legacy of foreign traditions that has seen land use ethics evolve which have failed to adopt and adapt to indigenous land ethics. It has been naive of us to assume that we can maintain Australia's natural ecosystems whilst continuing to survive on exotic plant and animal species and largely ignoring the biodiversity of our country.

Indeed, our present farming systems have a dangerous dependence on just a few crops with 66% of our foods coming from just three plants (Washington, 1991), yet Aboriginal people have used between 4000 to 5000 plants for food (Cherikoff and Isaacs, 1988).

We now have the opportunity to evolve a land ethic based on biodiversity not eco-simplicity, through combining Aboriginal knowledge and land management techniques with contemporary technologies, farm management systems, and agro-ecologies.

From the broader industry perspective there is already a small but growing native food industry. Two nationally coordinated wild food collection and distribution networks exist with bases in Adelaide and Sydney. Specialty restaurants are thriving in South Australia, Victoria, New South Wales, Western Australia, and the Northern Territory. And there are a number of small-scale food processing activities up and running.

A national workshop on the native food industry was held in Sydney in February 1995. It was convened by the Commonwealth Department of Primary Industries and Energy and demonstrates that there is now a national agenda, and a commitment by Government, to accelerating the development of the industry.

In late 1992, Australian Native Produce Industries Pty Ltd (ANPI) was formed and is playing a pioneering role in the development of the industry. The company is fully integrated in that it is propagating, cultivating, collecting from the wild, processing and marketing a broad range of Australian native foods.

Currently, a combination of western culinary expertise and indigenous knowledge is stimulating a great deal of interest in ANPI's work and Aboriginal culture throughout Australia and overseas, shaking off the more sensational images of "Bush Tucker" and developing a truly Australian cuisine.

Until recently, harvesting from the wild has been the principal source of raw produce supply. But as interest and demand has grown, harvest pressure on the wild is now at an unacceptably high level. Unfortunately, some of these resources are now particularly rare. For example, *Diplogottis campbellii* (small-leaved tamarind) has been reduced to just 12 remaining in-situ individuals. Some species with restricted distributions and particularly tasty fruits are in high demand. *Kunzea pomifera* (muntries) occurs in southeast South Australia and southwest Victoria and has excellent potential as a fresh berry crop, condiment, or fruit-bread ingredient. In the 1994 season, a number of tonnes of these fruits were harvested.

It is imperative that measures to control exploitation of wild resources are implemented (i.e., better natural forest and land use management with supplements for natural production through cultivation) as is now happening through the efforts of ANPI.

In rising to meet these needs ANPI has:

- Developed a commercial plant production nursery which is propagating superior genetic lines for its own plantations and for sale to other growers and the home garden market.
- Commenced development of a "model farm" near Renmark for production, research and demonstration purposes (irrigated and dryland systems).
- Established an export standard processing facility in Adelaide which produces the "Red Ochre" range of gourmet products for the retail and food service sectors.

The current tensions between supply and demand are reflected in the high prices being paid for some native produce, and also their volatility. To date, where cultivation of a particular crop has commenced, there has not been an appreciable drop in prices paid.

A graphic example of the current price situation is that of quandongs (*Santalum acuminatum*). In 1989, a wholesale buyer would have expected to pay between $20.00 to $30.00 per kg for first grade, halved and dried product. In the 1993 season competition was fierce for fruit of all grades. Buyers entered the market in the vicinity of $50.00 per kg for first grade. The price rapidly rose to above $60.00 per kg.

ANPI entered the market with the intention of buying several tonnes of product, but was unable to source anywhere near this quantity at a price it was prepared to pay. On this basis the company withdrew from the market and the prospect of producing processed quandong products for the retail market was put on hold.

To reduce the adverse impacts of harvest pressure, and to provide a "reliable source of high quality raw produce", there is a need to cultivate a range of native food plants. The company has committed a great deal of effort to sourcing the best genetic material from the wild, botanic gardens, the CSIRO, and native plant enthusiasts. The next challenge has been, and continues to be, to develop commercially viable methods of propagation for a number of difficult-to-propagate species.

MATERIALS AND METHODS

ANPI's research work spans a broad range of species from many different ecological niches throughout Australia. Some of the genera are fairly new to cultivation, and certainly to commercial food production (e.g., *Dioscorea* and other yams). Criteria for selecting superior genotypes include such attributes as crop yield, food value, oil contents, disease resistance, and fruit flavour, size, colour, shape, and texture.

For many species, our methods of propagation have been previously untried (e.g., budding, grafting, and hybridisation). Cutting and seed preparations vary considerably in our endeavours to achieve high degrees of success for a wide range of species. Propagation protocols developed range from straightforward to quite complex. For example, quandong seeds (*S. acuminatum*), go through a lengthy but effective process based on research findings of the CSIRO Division of Horticulture.

Different combinations of auxin treatments are utilised using IAA, IBA, GA, and NAA solutions with 1- to 10-sec dips for cuttings. Punnets or Kwik Pot trays are used with mixtures of sand and peat/coco peat (7 : 3, v/v) or perlite and compost (5 : 1, v/v). For seed, the mixtures are either vermiculite or sand and peat/coco peat (7 : 3, v/v). Trays are then placed on a propagation bench with bottom heat in a polyhouse with a low-pressure water and compressed-air fogging system, and hand watered periodically throughout the day (seeds require far less water than cutting materials and so are separated).

Emphasis is placed on the selection of high quality propagules (i.e., fresh seed, actively growing cutting materials). Therefore access to mother stock collections is essential for commercially acceptable results. In our dry climate at Renmark in South Australia, the use of modern facilities such as fog (Envirocare, Melbourne) provides the propagator with a significant advantage.

Despite close attention to hygiene, *Pythium* infections have beena recurring problem in some species prone to this fungal pathogen. As a result we are actively involved in research into non-chemical treatments. Currently we are conducting trials into beneficial fungal soil inoculants, namely *Trichoderma koningii* and *T. harzianum*, as we are committed to pursuing organic production systems wherever practicable.

RESULTS

Some examples of our results are included in the following species.

Backhousia citriodora **(Lemon Myrtle).**

Description. Evergreen, upright and spreading tree 10 to 15 m. Dense canopy of dull green foliage (rounded leaves to 100 mm) has a strong lemon scent. Profusion of white to light-green flowers in summer. Occurs naturally in sub-tropical and tropical rainforest areas of Queensland receiving greater than 800 mm of rainfall, on rich organic, sandy, or heavy textured soils.

Culinary Uses. The strongly lemon-flavoured leaves may be picked at any time of the year, and are becoming highly sought after by the restaurant and gourmet industries. Fresh and dried leaves are used to flavour, seafood, salads, savoury sauces, hot and cold beverages, deserts, and ice creams.

Propagation and Cultivation. Production from seed is reliable, given fresh viable seed. However, for clonal production it is essential to source superior quality selections. Early attempts to mass propagate by cuttings sourced from wild

specimens yielded poor results. Since establishing nursery stock plants with vigorous new growth, rooting can be consistently achieved within 3 to 4 weeks.

***Acronychia oblongifolia* (Southern Lemon Aspen).**

Description. An erect glabrous tree 5 to 10 m, usually in rainforest gullies from the Mitchell River in Victoria, southeast Australia, to Gympie in southern Queensland.

Culinary Uses. The fruit of the lemon aspen is a small, pale-coloured fruit to 13 mm with a unique sharp citrus flavour. The fruit has the versatility of a lemon. Whole lemon aspen fruit (or juice) can be used in pastries, desserts, sauces, dressings, jams, and marinades. The pulp from juicing can flavour shortbread, or be infused to extract its unique flavour.

Propagation and Cultivation. Many propagators have had disappointing results when geminating seed of this genus, with this species recording only "5% germination after 175 days" (Floyd, 1989). Our experience has shown that this species may be germinated reliably if fresh seed is removed from the flesh of the fruit. Rooting of cuttings has proven to be very slow and of poor success. Methods for budding and grafting of vigorous seedlings are being investigated. Early indications are that these methods of clonal propagation will be successful.

***Tasmannia lanceolata* (Mountain Pepper).**

Description. A shrub or small tree normally 3 to 7 m but can reach 10 m. Found chiefly in tall forests on cool moist slopes and in gullies, the lower mountain to sub-alps.

Culinary Uses. Both the pepperleaf and the pepperberries can be used fresh, dry or ground and added to dishes as a seasoning. The hot and spicy leaves, with a flavour between pepper and chilli, can be used whole like bay leaves and develop a subtle flavour when cooked. Ground pepperleaf is used as a seasoning on soups or mains just before serving. The small purple/black berries are hot and peppery and can flavour or garnish almost any sauce, can be baked into bread, or can be used to enhance the flavour of meats and even the traditional pepper steak.

Propagation and Cultivation. The active "hot factor" has been identified as polygodial. The commercial future for this compound includes medicinal uses as well as its culinary potential. Genotype selections are necessary to ensure high levels of polygodial. Due to the need to propagate clonally, we have little experience in germinating this species from seed. Cuttings from vigorous nursery stock plants root in 2 months and yield a success rate up to 80%.

***Podocarpus elatus* (Illawarra Plum)**

Description. An evergreen tree of variable height (5 to 35 m), though smaller in cultivation. Foliage is dark glossy green, new growth is an attractive lime-green. Blue-black plum-like fruits to 3 cm are carried on female trees, with the large seed borne distally on the outside of the fruiting body. The tree occurs naturally in temperate to sub-tropical areas of eastern NSW and Queensland, on a broad range of soils.

Culinary Uses. The fruit ripens in autumn to winter and has a subtle plum/pine flavour, and may be used for both sweet and savoury applications (e.g., plum and chilli sauces, chutneys, jams, pies, desserts, etc).

Propagation and Cultivation. Seed germinates readily, but due to this species' dioecious nature, yields male and female individuals. Cutting propagation has proven to be most successful when cuttings are set in January-February. Cuttings are slow to root (approx. 3 months), and experience slow initial growth when potted. Budding and grafting methods are being experimented with, but it is too early to report the results at this stage. Amenity trees growing in suburban Adelaide have provided 4 years of fruiting information regarding early, mid, and late season cropping, different sweetness, size, bienniality, skin texture, etc.

***Acacia* Species (Wattles).**

Description. *Acacia* species are another plant group which merit serious consideration for commercial food production. As many as 50 species of *Acacia* are known to have been consumed by Aborigines on an Australia-wide basis (Cherikoff and Isaacs, 1989). On average, *Acacia* seeds are about 23% protein; 26% carbohydrate; 32% fibre, and 9% fat (Brand and Maggiore, 1992). While some research has been carried out relating to human nutrition, the culinary benefits of the different species are becoming quite apparent. Wattleseed, aside from being extremely nutritious, provides a wealth of unique flavours and is proving to be extremely versatile (after roasting) in the kitchen.

The oil extracts of some of the acacias are highly palatable and commercial exploitation is feasible because the seed oil content is high. The unsaturated nature of *Acacia* oils means that they are desirable from a health point of view, but as they are readily oxidised they may present problems in food processing and storage.

ANPI is currently propagating a number of targeted species by seed, but clonal methods will soon be important as selections are made on the bases of flavour, culinary suitability, seed size, crop quantity, and ease of harvesting.

Culinary Uses. The seeds of acacias are roasted and ground to produce a coffee-chocolate-hazelnut flavour. The "flour" is used to make wattleseed ice cream, pavlova, pancakes, wattleccinos, or mixed (approximately 10%) with other flours to make dampers and breads.

DISCUSSION

To date, successes have been achieved with species previously considered difficult both from sexual (*Acronychia oblongifolia, Solanum centrale, Leptomeria acida*) and asexual (*Santalum acuminatum, Acrotriche depressa*) methods of propagation. However, we have hardly scratched the surface of Australia's diverse native plant resources which are currently available for the development of a truly native cuisine. If the nation is to derive full commercial benefits it will need strong support from the Government and the participation of many other players.

As is the case in any new industry, we are confronted by a daunting array of important technical and market research topics. Through the pioneering work of ANPI and others, opportunities are being created within the industry. We are confident of delivering some much needed "good news" to Australia's horticultural, environmental, and farming sectors. There are numerous challenges for individu-

als and organisations to conduct further research necessary to develop the industry to its full potential.

Australia's wealth of floral resources points to a need to go beyond its taxonomic classification and cultivation for aesthetics. It should be noted, however, that whilst our research into an Australian cuisine offers exquisite flavours and wonderful perfumes, many of the targeted species are stunning ornamentals as well as being extremely practical in the kitchen.

The reality is that no matter how vigorously we attempt to avoid change, our Australian culture is being shaped by Australian ecosystems. However much we seek to modify and manipulate our environment, it will always dictate our future directions. If we wish to make a smooth change, it is essential that Australians evolve a culture that considers these factors and helps us to prosper long-term on our continent.

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Propagation of the Olive in Italy and Australia

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INTRODUCTION

Man has propagated the olive (*Olea europaea* L.) since it was first cultivated 5000 years ago. Essentially, the various methods of propagation used have not changed. In the last few years there has been a worldwide revival of this ancient crop. This interest has prompted research to develop specific rootstocks and with the same characteristics deemed desirable in other fruit crop rootstocks, e.g., apple, citrus, and grape.

These rootstocks must be propagated asexually and have the following characteristics: (1) Easily propagated by cutting, (2) Resistant to soil-borne diseases and (3) Able to impart vigour (i.e., drought resistance) or reduce vigour (dwarfism) in the selected cultivar.

Rootstocks can be propagated by ordinary semi-hardwood cuttings in spring, summer, or autumn. The following spring these rooted cuttings can be grafted with the desired cultivar. An alternative is to use a "step-graft" (Editor's note: also known as cutting-graft technique). The principle behind this procedure is to graft the scion cultivar onto a cutting (the rootstock) and then strike this combination at the same time.

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Man has propagated the olive (*Olea europaea* L.) since it was first cultivated 5000 years ago. Essentially, the various methods of propagation used have not changed. In the last few years there has been a worldwide revival of this ancient crop. This interest has prompted research to develop specific rootstocks and with the same characteristics deemed desirable in other fruit crop rootstocks, e.g., apple, citrus, and grape.

These rootstocks must be propagated asexually and have the following characteristics: (1) Easily propagated by cutting, (2) Resistant to soil-borne diseases and (3) Able to impart vigour (i.e., drought resistance) or reduce vigour (dwarfism) in the selected cultivar.

Rootstocks can be propagated by ordinary semi-hardwood cuttings in spring, summer, or autumn. The following spring these rooted cuttings can be grafted with the desired cultivar. An alternative is to use a "step-graft" (Editor's note: also known as cutting-graft technique). The principle behind this procedure is to graft the scion cultivar onto a cutting (the rootstock) and then strike this combination at the same time.

PROCEDURE

To perform a step-graft of the olive, a cutting of the desired clonal rootstock is taken from the mother plant. The stock mother plant should be well maintained in a healthy and vigorous condition. The length of the cutting should be 15 to 18 cm with a minimum of four leaves and at least 3 mm in diameter (Fig. 1). The scion to be grafted should consist of two internodes and only two leaves, but must have the same diameter as the stock.

An oblique cut is made in both the rootstock and the scion (as for a whip and tongue graft) and these are then matched as closely as possible. The graft is wrapped and held together with self-adhesive florists tape. After the graft has taken and started to grow this tape will disintegrate.

At all times during this operation the stock and scion must be kept moist.

After a number of cuttings have been grafted, the bases of the rootstocks are dipped into the root-promoting hormone IBA (indolebutyric acid) in powder form at a concentration of 2000 to 3000 ppm. The cuttings are then placed in the propagation medium for callousing.

Rooting can be achieved under mist or in a special box completely enclosed with plastic to maintain high humidity—relative humidity of 95% or greater is best. The step-graft system is widely used in Italy where a heating element is installed at the bottom of each box which maintains the temperature at approximately 22C and the rooting medium consists only of well moistened perlite.

Roots develop in 7 to 8 weeks and it is advisable to water the medium weekly, starting from the third week after sticking, to avoid drying at the base of the cutting.

After the cuttings have developed a sufficient root mass, they are potted on in a mixture of peat moss and coarse sand (1 : 1, v/v) with the pH adjusted to between 6.5 and 7.0. During the hardening-off process the cuttings must be kept in a humid environment (70% to 80% relative humidity) and a temperature range of 15 to 16C until they have established. High temperatures or low humidity are detrimental to the cuttings at this stage.

The timing of this operation should coincide with the beginning of the ripening of the olives, i.e., in Manjimup during the first week of April until the end of June/early July. Reasonable success rates have also been achieved in early spring (September), when the sap has started to move again.

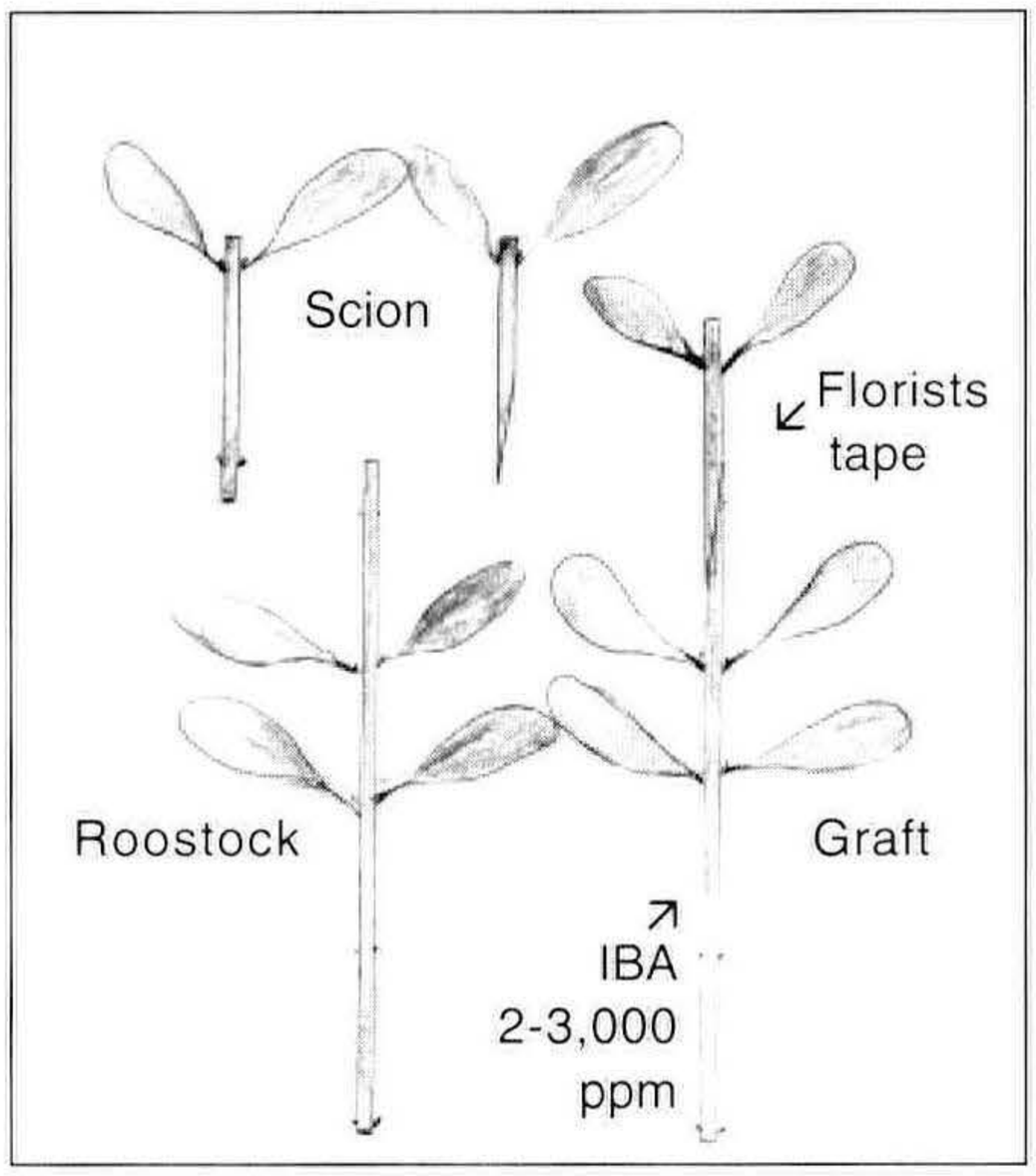

Figure 1. Diagrammatic representation of the mechanics of a step-graft using olive.

The Role of Combustion Products (Smoke) in Stimulating *Ex Situ* and *In Situ* Germination of Western Australian Plants

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Smoke derived from the combustion of plant material enhances seed germination in a wide range of native species not previously able to be germinated under nursery conditions. Almost 100 species from the families Rutaceae, Restionaceae, Epacridaceae, Thymeleaceae, Proteaceae, Dilleniaceae, and others have responded under controlled nursery conditions to application of aerosol smoke and smoked water. Thirty species which responded have not previously been reported as easily germinable by conventional whole seed propagation, although some had previously (though partially) responded to scarification, boiling, or hormonal treatments. The effect of smoke is highly species-specific and influences seeds of the same species from disparate provenances and different ages to varying degrees. Genera known to be highly recalcitrant to conventional seed propagation which responded to smoke treatment included *Geleznowia* (Rutaceae), *Hibbertia* (Dilleniaceae), *Stirlingia* (Proteaceae), *Verticordia* (Myrtaceae), *Actinostrobus* (Cupressaceae), and *Pimelea* (Thymeleaceae). Germination percentages of species which normally germinate in small numbers were also positively influenced by smoke treatment. Seed size varied amongst all positively responding taxa. Within the Epacridaceae, small-seeded (*Lysinema* and *Sphenotoma*) but not larger, woody-fruited species showed smoke stimulated germination. Significant applications now exist for the use of smoke in germinating a wide range of species for horticulture and land restoration. Smoke appears to be one of the more significant missing links in understanding the horticulture of many Australian species. This technology is now opening up new opportunities for commercial horticulture of Australian plants.

INTRODUCTION

Fire has played a significant role in the evolution of the Australian flora at least since the arrival of arid conditions in the mid-Tertiary (Kemp, 1981). For many taxa, response to fire has moulded plant growth and development and been responsible for the derivation of analogous structures and life forms often in disparate taxonomic groups. In fire-prone floras, particularly those of mediterranean zones, fire has been shown to be crucial for the recruitment from seed of a wide variety of taxa. For fire-sensitive species and fire ephemerals, habitat burning is the single most important cue for triggering germination of the dormant soil seed bank (Bell et al., 1993; Meney et al., 1994). For many fire-responsive taxa, germination of viable seed under controlled conditions has been difficult or impossible using conventional treatments other than excised embryo culture (Meney et al., 1994) or special pretreatments including hormonal applications (Bell et al., 1993).

The Role of Smoke in Germination. Following the discovery that smoke stimulated germination of the rare South African plant *Audouinia capitata* (De Lange and Boucher, 1990) the exploration of the benefits of smoke-mediated germination has expanded to different continents with applications in nursery, land management, and rare-flora conservation.

As crude smoke or aqueous extracts applied to seed directly or to the surface of seed trays or as smoke to the soil surface in habitat sites, germination has been stimulated for a wide variety of species (Brown, 1993; Dixon et al., 1995).

The study of Dixon et al. (1995) found that smoke applied in a variety of ways was able to stimulate germination of Australian species both *in situ* (in bushland) and *ex situ* (nursery and laboratory). This study established for a wide range of species the importance of smoke as a cue for germination with resultant and sometimes spectacular improvements in germination.

This paper overviews development of smoke-stimulated germination of native Australian species and describes recent applications of the process for germination of horticulturally significant species.

Smoke-Stimulated Germination of Australian Species. Research by Dixon et al. (1995) has shown that smoke is a key principle in breaking seed dormancy in a wide variety of native Australian species. Though this study has concentrated on Western Australian plants, general principles have emerged regarding the benefits of smoke for germination:

- Smoke can promote earlier and more uniform germination under controlled greenhouse and laboratory conditions.
- Smoke enables germination in species previously thought difficult or impossible to germinate by conventional means, e.g.,*Geleznowia* and *Eriostemon* (Rutaceae); *Hibbertia* (Dilleniaceae); *Stirlingia* and*Conospermum*, *Grevillea*,and*Hakea* (Proteaceae);*Verticordia* and *Calytrix* (Myrtaceae); *Pimelea* (Thymeleaceae); *Blancoa* (Haemodoraceae); and *Stylidium* (Stylidiaceae).
- Smoke substantially promotes germination in species with low levels of germination. For example, *Anigozanthos* and *Conostylis* (Haemodoraceae); *Thysanotus* and *Burchardia* (Liliaceae); *Patersonia* (Iridaceae); *Lechenaultia* (Goodeniaceae); *Gyrostemon* and *Codonocarpus* (Gyrostemonaceae); *Stackhousia* (Stackhousiaceae); and *Hybanthus* (Violaceae).
- The promotive effect of smoke is independent of seed size and shape; plant life form, i.e., whether annual, perennial, herbaceous, seeder (fire sensitive) or resprouter (fire tolerant).
- Aerosol smoke, smoke dissolved in water or direct smoked solids (activated clays, sand particles) or direct smoked seeds are effective methods for delivery of smoke for seed germination.
- High doses of smoked water can inhibit germination of many species.
- Paper daisies (*Rhodanthe, Schoenia*) are suppressed by smoking.
- Germination over time in response to smoke can change with taxa, i.e., (1) Control and smoked seed attained final germination at the same rate, e.g., *Conostylis* species. (2) First seedling emergence occurred earlier in smoked seeds. (3) Control germination was

limited to first week or so whereas smoked seed continued to germinate over a longer period. (4) Difference between control and smoked treatment became apparent only after several weeks.

Species not responding to smoke treatment include *Persoonia* and drupaceous Epacridaceae (those species with large, woody fruits compared to small-seeded species which do respond positively to smoke). These groups have been extensively investigated to determine possible barriers to smoke entering the seed but all attempts to acid or mechanically scarify the seed have not been effective in eliciting a germination response. *Persoonia* has been found in other studies to respond to gibberellic acid treatments suggesting that factors involved in seed dormancy in this species may require other dormancy breaking mechanisms for germination to proceed.

SMOKE METHODS

Sown seed trays or whole seed are placed on an open mesh, two-tiered frame in a sealed, plastic tent approximately 2 m × 2 m × 1.4 m high. Smoke is generated by slow, controlled combustion of a mixture of fresh and dry leaf and twig material from a range of plants. Prunings of native species are usually used to emulate the natural smokes likely to occur after a wildfire in bushland habitats. The drum is fitted with an inlet through which air is pumped at the rate of 100 to 300 litres per min, and an outlet connected to a 1.5-m-long pipe. A 2-m length of flexible stainless steel exhaust piping approximately 50 mm in diameter is then connected to the plastic enclosure ensuring that smoke is injected towards the roof of the tent. This ensures that there is adequate spread of smoke inside the tent.

After smoking for 60 min, trays are transferred to the glasshouse and watered carefully for the first 6 to 10 days to ensure that the soluble promoter in smoke comes in contact with the seeds but is not washed through the mix before reacting with the seed. Watering is then continued as for normal germination.

Seeds can also be direct smoked. In this instance, seed is laid out in a single layer in trays. The trays are smoked for 60 min in the fumigation tent (as described above) and the air dried seed is then sown or stored dry until required. Smoked seeds are watered as with normal seed trays.

Smoked Water. Smoked water can be useful for direct priming or pregermination of seeds prior to sowing. Smoke-water-treated seeds have the advantage of not requiring the use of the smoke tent and the convenience of priming seeds at will. Smoke-water-primed seeds may germinate better than smoked seedling trays with the process applicable to handling potentially large quantities of seed such as, for land restoration or automated seed-sowing devices.

Smoked water is produced by drawing smoke produced from the combustion drum operating as for aerosol smoke through a 20-litre container of water. Smoke bubbling is done for approximately 60 min and the resultant solution is frozen till required.

Seed to be treated with smoked water is soaked for 12 h in a 10% solution of the neat solution and the seed is then sown or dried for later sowing. Seeds treated with smoked water can be watered normally after sowing. Although this method has been shown to be useful for a number of native species, caution is recommended as seed of some species can degenerate if soaked in water for prolonged periods. Also pregermination as a horticultural practise for seed of Australian native plants

requires some experimentation to ensure the process is applicable. In some cases pregermination can lead to decline in seed quality and viability and it is recommended that species to be treated in this way should be tested for tolerance to imbibing and drying treatments.

Habitat Germination Studies. Smoke fumigation treatments can be applied directly to habitat sites and for a range of species germination will happen in 6 to 8 weeks after treatment.

Smoke is generated as above and applied to sites where excess leaf litter and larger plants have been removed to prevent "shadowing" of the soil from smoke. Tents are erected over the sites—usually 5 m × 1 m × 40 cm high—and smoke pumped into the tent for 60 min. Best results are achieved if smoking is done in early autumn so that the wash down of the smoke factor coincides with the onset of the first rains (for temperate regions of Australia). Smoking undertaken at other times of the year appears to yield less germination for taxa which respond to autumn smoking.

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Use of Low Concentration NAA Sprays to Suppress Sprouting on Rootstocks

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Scions of both a variegated cultivar of *Agonis flexuosa* [Willd.] Sweet 'Pied Piper' on seedling rootstocks and *Hakea francisiana* F. Muell. on seedling *Hakea salicifolia* (Vent.) B.L. Burtt rootstocks are rapidly overgrown by rootstock sprouts if no control measures are taken. Naphthaleneacetic acid (NAA) sprays have been used to impose sprout control in rootstocks. Due to phytotoxicity on the scion of single, high-concentration NAA sprays, the time of application, frequency and concentration of multiple low concentration NAA sprays have been investigated. For grafted *A. flexuosa* weekly 100 mg litre-1 NAA sprays to rootstock tissue only reduced sprouting without significant reduction in scion growth. Repeated pre-graft sprays of 200 mg litre-1 NAA three times per week for 2 weeks initially reduced stock sprouting but this effect was lost by 7 weeks. Post-graft NAA sprays (100 mg litre-1) significantly reduced sprout length for the duration of the experiment. There was large variability in scion growth and budburst. NAA sprays at the above pre- and post-graft concentrations and frequencies could not be recommended due to the high level of bud dormancy or death in these scions compared with control scions which all sprouted. *Hakea salicifolia* stocks, treated with the same pre-graft and post-graft spray regimes as *A. flexuosa,* showed total stock sprout control without stock phytotoxicity if post-graft sprays were applied. Pre-graft sprays, either separately or in combination with post-graft sprays, gave phytotoxic stock responses of callusing and leaf necrosis. The combined sprays controlled all stock sprouting but the pre-graft sprays only reduced sprout growth to half of that of the control. Dormant hardwood scions of *H. francisiana* did not burst during this 9-week experiment.

INTRODUCTION

Rootstock sprouting is a major problem with grafted plants in commercial nurseries necessitating costly hand removal of sprouts. Sprouting is thought to be caused by loss of inhibitory effects of auxins which originate in the apex (Yang et al., 1992). Sprout control strategies have aimed to replace this through application of synthetic auxin analogues such as NAA as a single high-concentration (0.5% to 8%) spray (Boswell and Nauer, 1979; Morris and Cawthon, 1981). These treatments have caused inhibition or death of scions when sprayed on a number of species (Boswell et al., 1979; Nauer and Boswell, 1978; Nauer et al., 1978). Investigations of low-concentration NAA spray applications aimed to achieve rootstock sprout control with *A. flexuosa* grafted with the variegated cultivar *A. flexuosa* 'Pied Piper'. This attractive weeping cultivar is difficult to propagate from cuttings. *Hakea francisiana* F. Muell., a small tree with spectacular flowers, is difficult to grow in eastern Australia due to its intolerance of heavy soils. McKenzie

(1994) reported that this species was propagated commercially using seedling scions grafted onto seedling *H. salicifolia* at the cotyledon stage to minimise rootstock sprouts. I have also tested low-concentration NAA sprays for suppression of rootstock sprouts in this *Hakea* combination. Grant and Loveys (1996) showed that CO_2 enrichment of the fog environment improved scion growth of *A. flexuosa* 'Pied Piper' compared with ambient fog conditions but the expected reduction in transpiration or improved carbohydrate status (Grant et al., 1992) did not lead to superior grafting success. For this environment they showed that weekly rootstock sprays of 50 to 100 mg litre^{-1} NAA controlled sprouting without adversely affecting the scion. Clonal cutting-derived stocks eliminated the problem of lignotuber tissue which was prone to epicormic bud sprouting. It was thus possible to select clonal stocks for reduced sprouting in combination with NAA sprays (Grant and Loveys, unpublished). The effect of rootstock pre-graft and post-graft NAA sprays needs further investigation. These experiments investigate the timing and frequency of NAA sprays for both *Agonis* and *Hakea* sprout control.

MATERIALS AND METHODS

Plant materials and methods used are described by Grant and Loveys (1996). Briefly, seedling and cutting *A. flexuosa* and seedling *H. salicifolia* stocks were grafted with 1- to 2-mm or 2- to 3-mm diameter micro-wedge grafts, respectively. Both scions were two nodes with leaf blades trimmed in half. All 10 to 20 nodes below the graft were disbudded, leaving intact green leaves. *Agonis flexuosa* stocks and scions were soft to semi-hardwood and actively growing. *Hakea salicifolia* stocks were similar but *H. fancisiana* scions were semi-hardwood and dormant. All grafts were placed in a fog igloo maintained at 95% relative humidity. In the first *Agonis* experiment NAA was sprayed basipetally from below the graft with either 0 or 100 mg litre^{-1} NAA in 5% ethanol. In the second and third experiment with *A. flexuosa* and *H. salicifolia,* half the stocks were initially pruned of all lateral shoots/buds prior to spraying with NAA. After grafting half of these pre-graft NAA plants were not sprayed again while the other half pre- and post-graft NAA plants were sprayed with 100 mg litre^{-1} NAA. The unpruned and unsprayed stocks were grafted having removed lateral shoots and buds, then half were left as unsprayed controls while the rest were sprayed with NAA (post-graft). Scion and/or sprout lengths, including all lateral shoot lengths, were measured and records were made of scion death, bud dormancy, and sprouting. Data was analysed by analysis of variance, Welch's test, or the Mann Whitney test.

RESULTS

Weekly applications of 100 mg litre^{-1} NAA to *A. flexuosa* rootstock tissue, from the time of grafting reduced mean sprout lengths to 11% of control plants by Day 57, whereas treated scion lengths were not significantly different to the control during this period (Table 1).

TABLE 1. The effect of 100 mg litre^{-1} NAA sprays on scion and sprout lengths of grafted variegated *Agonis flexuosa*. 'Pied Piper'.

Treatment	Scion length	Sprout length
Control	1275.7 a	447.0 b
NAA	227.0 a	50.7 c

Note: Plants were measured after 57 days in fog propagation conditions. NAA sprays commenced within 24 h of grafting and were repeated weekly. Data represent the mean of 10 replicates. Values within each column followed by the same letter were not significantly different at $P<0.05$ measured by students t test.

Further treatments tested an increased frequency of NAA application prior to and/or after grafting, in combination with pre-graft pruning of all stock lateral shoots and buds just prior to initial spray application (Table 2). At Day 22 scion lengths were the same for all treatments but both post-graft NAA treatments were controlling sprout growth to less than 3 mm and were significantly less than both the pre-graft NAA treatment and the control. Controls showed no sprout inhibition and were greater than the pre-graft NAA which retained some residual sprout inhibition. Day 48 was similar except that the residual sprout inhibition for the NAA pre-treated control was declining from 24% of control sprout length at Day 22 to 54% of control at Day 48 (Table 2).

TABLE 2. The effect of repeated rootstock 200 mg litre^{-1} pre-graft and/or 100 mg litre^{-1} post-graft NAA sprays on scion and sprout lengths and percent scion sprouting, dormancy, or death of grafted *Agorlis flexuosa* 'Pied Piper'.

	Day 22		Day 48		Day 48		Scion
Treatment	Scion length (mm)	Sprout length (mm)	Scion length (mm)	Sprout length (mm)	Sprout (%)	Dormant (%)	Dead (%)
Control	2.6 a	387.0 a	49.3 a	781.0 a	100	0.0	0.0
Pre-graft NAA	3.9 a	91.0 b	69.6 a	424.0 a	56	22	22
Post-graft NAA	1.1 a	2.9 c	13.6 a	7.1 b	29	71	0.0
Pre-/post-graft NAA	0.4 a	1.8 c	20.3 a	2.9 b	22	56	22

Note: Plants were measured after 22 and 48 days in fog propagation conditions. Pre-graft sprays (six) commenced 13 days prior to grafting and post-graft sprays within 24 hours of grafting and were repeated 10 times in 25 days, then weekly. Data represent the mean of seven or nine replicates. Values within each column followed by the same letter were not significantly different at $P<0.05$ measured by analysis of variance and the Mann-Whitney test.

Control *H. salicifolia* rootstocks sprouted within 2 weeks of grafting (Table 3). If six 200 mg litre^{-1} NAA spray treatments were given only prior to grafting the upper stock leaves showed some necrosis and stock sprouting was largely inhibited over 38 days. When 100 mg litre^{-1} NAA post-graft sprays were continued in conjunction with pre-graft sprays then sprouts were controlled but necrosis was more extensive and callusing occurred at each leaf axil. If post-graft sprays were used alone then necrosis was avoided but stock sprouts were still fully controlled (Table 3). Scions remained dormant during the course of the experiment.

TABLE 3. The effect of repeated 200 mg litre^{-1} pre-graft and/or 100 mg litre^{-1} post-graft NAA sprays on sprout lengths of *Hakea salicifolia* seedling rootstocks grafted with *H. francisiana* scions.

Sprout length (mm)	Day 16	Day 24	Day 38	Day 64
Control	6.8 a	97.8 a	470.0 a	626 a
Pre-graft	0.0 b	6.0 b	70.0 b#	288 b
Post-graft	0.0 b	0.0 c	0.0 c	0 c
Pre-/post-graft NAA	0.0 b	0.0 c+	0.0 c+#	0 c

Note: + = callus, # = necrosis. Plants were measured after 16, 24, 38 and 64 days in fog propagation conditions. Pre-graft sprays (six) commenced 13 days prior to grafting and post-graft sprays within 24 h of grafting and were repeated 10 times in 25 days, then weekly. Data represent the mean of four replicates. Values within each column followed by the same letter were not significantly different at $P<0.05$ measured by Welch's test and analysis of variance.

DISCUSSION

In the second experiment both post-graft and pre- and post-graft NAA applications were very effective for sprout control but could not be recommended due to the high level of inhibition and death of scions. It would appear that 10 post-graft 100 mg litre^{-1} NAA spray treatments in 25 days were most likely responsible for the high level of scion bud dormancy and death (Table 2). All repeated NAA treatments caused some scion death and/or bud dormancy in Experiment 2, probably due to translocated NAA. The cumulative effect of these repeated sprays was similar in damage to the sum of the active ingredient sprayed only once such as for avocado (Boswell et al., 1979) and valencia orange (Nauer and Boswell, 1978) where scion death or bud dormancy resulted. Further testing should either reduce the NAA concentration (e.g. 50 to 100 mg litre^{-1} NAA) or the frequency of application. The optimum concentration and frequency should aim to simulate the lost endogenous auxin production until scion growth achieves sprout suppression via apical dominance. Actively growing semi-hardwood *H. francisiana* scionwood was not available so dormant hardwood scions were used instead. This was probably the reason for lack of scion growth in both treated and control plants which is similar to observations by Grant and Loveys (1996) for dormant *A. flexuosa* scions. Despite this lack of scion growth and the consequent reduction in endogenous auxin production (Yang et al., 1992), NAA sprays maintained control of sprouts for the

9-week duration of the experiment. This result should allow *H. francisiana* cultivars, rather than seedlings as described by McKenzie (1994), to be grafted onto *H. salicifolia* seedling rootstocks without uncontrollable sprouting. An obvious benefit would be that superior forms could be propagated readily and they would flower years before the seedling scion material. Beardsell et al. (1993) described the need for effective means of vegetative propagation as a major obstacle to the availability of superior selections of Australian native trees. The above methods can be used to rapidly propagate such clones.

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Propagation of Grape Vines by Micrografting

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INTRODUCTION

The French have a world patent on the green-grafting process. Green grafting has been used in commercial production of grape vines in both France and California. A personal interest in the work being done in France led me to apply for a Churchill Fellowship. This award allowed me to travel to California, Italy, France, Holland, and Germany during 1994 and witness the process of green grafting.

THE METHOD OF GREEN GRAFTING

All rootstock and scion selections are screened for viruses and have certified health status prior to introduction to the growing house. The growing house is a strictly controlled environment. Lights control day length and ventilation controls the temperature and humidity. Rockwool, is used as a hydroponic-type substrate for the vines which receive a constant nutrient feed. The rootstock is ready to graft when the stems reach a length of 1.5 to 2.0 m and are 2 to 4 mm in diameter. Rootstock and scion are sprayed with a systemic fungicide 3 days prior to green grafting. Grafting material is collected as close to the time of grafting as possible. Scions are cut to 3 cm in length with one bud. Rootstocks are cut to 30 cm in length with two to three internodes. One leaf per scion and rootstock is retained but the area is reduced to half. Grafting is carried out using green grafting machines. The machines use a V-shaped knife to cut scion and rootstock. The machine manufactured in Germany uses an aluminum tape to wrap the graft, while the French machine uses a peg to hold the new graft together. After grafting the vine cuttings are incubated in a callusing house for 5 to 7 days. Humidity is maintained at 90% with the temperature between 28 to 30C. Rockwool, is used as the growing media. Fluorescent lights with dimmer switches are used to slowly increase the light intensity as the vines callus. After 7 to 10 days the temperature is reduced to 20 to 24C but humidity is maintained at 90%. After 14 days rooting is sufficient to transfer the graftlings to a growing house to harden off. This growing house is ventilated but the temperature is maintained at 20 to 25C, light levels are still low with screens being used to provide 90% shade. The light levels are slowly increased to normal levels. The graftlings are then carefully potted into individual containers, watered, and left in the growing house for a further 3 to 4 weeks. The remaining leaf on the rootstock, including the bud, is removed at this stage. This ensures that no suckering occurs below the graft union. Finally the grafted vines are placed in a shaded area to grow on until they lignify, which can occur as early as 4 months from grafting.

DISCUSSION

Green-grafting technology allows rootstock and scion mother vines to produce green cutting material all year round by optimising growing conditions. With this technique the time required to get commercial numbers of new clones or cultivars into the field is significantly reduced. The virus status of the graftlings is known

as the parent material is tested and constantly monitored. A green-graft union knits better than with dormant grafting because the cambium layers are joined together while actively growing. The resultant plant has a significantly stronger graft union which is often difficult to detect with the eye after one years growth.

CONCLUSION

There are several advantages to the green-graft system. Firstly, due to the efficiency of the technique only a small number of stock mother vines are required and, therefore, have to be tested for disease. Pathogen-free clones can be preserved in vitro. In vitro culture results in high multiplication rates. During production, infection of graftlings by virus or bacteria can be excluded. Production can take place 12 months of the year, significantly increasing the number of plants produced. Finally, green grafting offers propagators a viable alternative to quickly multiply clean clonal planting material and keep up with the constant cultivar changes.

Improving Grafting Techniques for Apples

Allen Gilbert
Box 480, Richmond, Victoria 3121

This paper examines minor systems changes to the grafting techniques of old aimed at obtaining better grafting results with a variety of types of grafts on apples. Specific reference will be given to the use of open-ended, humidified plastic caps over the grafts to protect the graft, and to increase the humidity within the graft environment to prevent the graft scions from dying due to dehydration.

INTRODUCTION

The basic grafting techniques, such as, "T" budding, cleft grafting, chip budding, patch budding, whip and tongue, peg grafting and most of the methods used today were in effect the best of the techniques used by the original experimental grafters. Most of the literature available on budding and grafting techniques repeat this early information, e.g., R. J. Garner's *Grafters Handbook*, and add slightly to the systems used within the grafting techniques. Only a few books discuss the merits of the use of open-ended plastic coverings over apple grafts to increase humidity, and very few papers discuss specific effects.

METHODS

Field trials were conducted over a period of 3 years at various locations in Melbourne, Australia, but primarily in the apple orchard of the National Trust property Rippon Lea. Grafting took place at different times of the year to test the seasonal effect. Selection of budding and grafting wood at different times of the year was made and traditional grafting techniques employed. These included early and late scion grafting, summer and late summer budding, and chip budding at various times of the year.

as the parent material is tested and constantly monitored. A green-graft union knits better than with dormant grafting because the cambium layers are joined together while actively growing. The resultant plant has a significantly stronger graft union which is often difficult to detect with the eye after one years growth.

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Innovative techniques using green grafting, fully leafed scion grafts, leaf-bud budding (chip and "T" bud), different sized scions, old-wood scions, old-spur scions, and multi-sectional grafts were used. Whole tree multi-budding and multi-grafting will be discussed. At all times an open ended, humidified, protective, narrow plastic bag which was sealed at one end, was placed over the graft area and allowed to remain in place until the graft had "taken". The following is a description of the type of graft or budding method used, the various treatments, if any, used, and the observed results.

Normal Sized Scions. The first trials were done in early spring, using normal sized scions of about 100 mm containing three to five buds. Later experiments in early winter and mid summer using stored scion wood were also trialed.

The scion wood was collected in early June and the longer laterals cut into 300 mm lengths, tied in bundles, moistened, then wrapped in black plastic before storage. Using whip and tongue and side whip and tongue grafts, scions with three to five buds, were attached to new (1 year) and old (3 to 5 years) growths on the stock trees.

The open ended plastic bag which was sealed at one end, had some drops of water added to the inside of the tube, then the excess poured out. The tube was placed over the scion and extended below the graft area. The plastic covers were pinned into place using an ordinary pin, or a plug of grafting wax, leaving the open end of the tube open to allow air circulation. The plastic bags placed on the experimental grafts were removed at various times, starting from when the grafted scions begin to grow shoots.

A few of the scions that were grafted onto the trees were allowed to flower. Some of these actually produced mature fruit by the following mid-summer period. Although late grafts in December did not produce accompanying lateral growth, early spring grafts did produce fruit and substantial lateral growth. Some of the plastic covers were left on until the plastic tube was filled with new leaf growth before being removed.

The results showed that scion grafting can be done very early in winter (June-July), in spring (Aug-Sept), and mid summer (Dec-Jan) using winter-collected scion wood that had been stored in the crisper section of a refrigerator. An observation was made that late-grafted scions in the December period tended to form flower bud spurs on the scion instead of vegetative lateral growths. Indications are that the plastic bag can be left on the grafts in the initial stages of growth, with little adverse effect except during heat-wave conditions (above 40C) when the leaves inside the plastic may be slightly burnt. The degree of leaf burn was directly correlated to the amount of leaf coverage and subsequent shading supplied by the tree onto which the grafts were placed.

Old Wood Scions. Most grafting books do not recommend the use of this type of material because of the high failure rate and the supposed difficulty of old wood to form callous tissue to initiate union formation. Scions of wood of 2- to 3-year-old growth were chosen and used for grafting in early spring. The old scion wood chosen had few visible buds, the bark was aged and tightly adhered to the wood. Most of the grafts used were whip and tongue or a variation—side whip and tongue and scions were about 100 to 150 mm long.

The grafts were tied with budding tape or covered in Kendon™ grafting wax, then a tube of plastic, sealed at the top end and containing a few droplets of water, was

inserted over the graft area and held in place with a pin stuck into the bark of the tree below the graft. Although only few of these grafts were trialed, excellent results were achieved and the scions grew spur systems or both spurs and lateral growth during the following growth season.

Long Scions. Traditionally, grafting scions from 1-year-old wood are usually cut to contain only 3 to 5 buds. Long scions were too prone to dehydration before the graft knitted and thus the scion often dehydrated and died. Because of the field trial success with short scion growths using the humidified plastic tube covering, it was decided to try extra long scions attached with a normal graft (whip and tongue). Long scions of up to 300 mm were tried and covered with an extra long plastic tube. These scions also grafted well and showed no signs of stress.

Very Short Scions. Encouraged by the success of normal sized scions and long scions, short scions containing only one bud were trialed. These were treated in the same way as other grafts and worked well. The plastic covering preventing the dehydration of the tiny graft piece.

Chip Bud and Leaf. A variation of chip budding was trialed in mid summer. The chip buds were taken from current growth and inserted with the whole of the leaf on the chip bud still attached. The bud was tied with budding tape leaving the actual bud and leaf still exposed. The lateral to which the bud was attached was shortened to a bud just above the graft point, shortening the lateral to enable the insertion of a humidified plastic bag over the graft area. These chip buds grafted successfully.

Shield Bud and Leaf. "T" budding using a shield bud with the whole leaf still attached were trialed in late summer. The lateral was cut back to just above the inserted bud and the budded area was covered with a humidified plastic bag. These shield buds and attached leaf buds were successful.

Scion and Leaves. During late summer (February) 1995, some 150 mm fully leafed scions were collected from trees and whip and tongue grafted to new lateral shoots. The grafts were covered with the plastic bags. Although extreme heat wave conditions followed the grafting operation and the leaves eventually burnt and died off, the grafts seem to have taken.

Green Graft. During the November-early December period, grafts using young, sappy, new, active-growth scions were trialed. The scions chosen were about 20 to 25 mm long with all leaves except the top two and the growing tip removed. A simple "V" graft was made, cutting the rootstock piece down the centre and sharpening the scion piece to a "V" point. The graft was tied with 3-mm strips of grafting tape, cut for the occasion, and the whole graft covered with the humidified plastic cover. These green grafts were also successful, although some scions died back at the tip. Other scions were trialed using a scion section with the growing tip removed, these were more successful and the tip did not die back.

Chip Bud into Old Wood. Chip buds from 1-year-old scions were placed into old wood of apple limbs 5 to 7 year old. The chip buds grafted, but often remained dormant until the branch was cut back to the chip bud insertion point. In some cases, the injury caused by the cutting of the bark to insert the chip bud activated dormant buds on the tree branch.

Whole-Spur Grafts. Whole-spur systems, containing 3 to 5 spur buds were grafted onto 2- 3-year-old branch stubs using a whip and tongue or side whip and tongue method. The whole system and the graft were covered with a humidified plastic bag. These scions grafted and produced good fat flower buds on the spur system by the end of the following summer period.

Small Spurs. Small, one-spur systems were cut from the donor plant with a shield-shaped base. Some of these were placed into "T" cuts in the bark (as with budding), others were treated as a chip bud. They were tied to allow the actual spur to be uncovered and a plastic sleeve inserted over the graft area. Some grafts were also done without using the plastic bag coverings. Most of the one-spur grafts that were tried grafted very well.

Double Graft. Two different cultivar scions were joined together with a whip and tongue graft. These joined scions were then placed onto the rootstock using a whip and tongue graft. A plastic humidity cover was placed over the scion and graft area. Both grafts were successful and produced a short-spur system containing two varieties of apples. This system could probably be used to graft several varieties at once.

Scion/Rootstock Cuttings. For this trial a scion piece and a cutting from an above ground sucker of a rootstock were grafted together using a whip and tongue graft in late spring. The rootstock cuttings were wounded by removing a 20-mm bark strip from the cutting base and then treated with plant rooting hormone powder to initiate roots. The grafted cuttings were placed into a well drained propagation mix and individual plastic humidity covers placed over them.

All of these joined cuttings grafted well, many initiated roots on the rootstock and the result was a fully grown, grafted apple tree in one season. Field trials on this system were very limited and proper care and watering of the material was not carried out so many of the cuttings failed. Results show, however, that this system does work and will be a very useful method of producing saleable trees in one season.

Multiple Budding. Access to many heritage apple varieties was available at the orchard where the trial grafting was carried out. One rootstock-initiated tree in the orchard was cut back in spring 1994 and all the new growth on the tree budded with about 100 different cultivars of apple in February 1995. Most of the buds have grafted well and will eventually produce a tree with apples ripening at different times from January to June. This particular tree will also be used for short-course demonstrations and to preserve the rare heritage apples at the National Trust Orchard at Rippon Lea, Victoria, Australia.

Multiple Grafting. One rootstock tree at Rippon Lea was grafted with other heritage apple varieties and in spring 1994 over 100 separate grafts were done on the tree. Most of the scions grafted well and the tree will be used for demonstration purposes. Eventually this tree will have 300 to 500 different apples cultivars grafted to it. The idea of multi-grafting a single tree is ideal for home gardeners as it gives them a wide-ranging apple season and negates the need for pollinator trees.

DISCUSSION

The results discussed in this paper were from limited field trials sometimes carried out under less than ideal conditions. However the positive results from so few

experimental grafts suggests that humidified plastic covers to aid grafting are useful in difficult conditions, especially with apples (*Malus*). The ease in which grafting can be carried out using humidified plastic tent covers should enable the popularisation of this craft with home gardeners.

More efficient and effective grafting increases the gardening and production capacities of home gardens and plant nurseries. This paper suggests that modern techniques, such as plastic caps, can enhance time-tested traditional techniques.

LITERATURE CITED

Garner, R.J. 1988. The grafter's handbook. 5th ed. Cassell, U.K.

Quality Management for Nurseries

Richard Bennett
Australian Horticultural Corporation, PO Box 1968, Shepparton, VIC 3632

INTRODUCTION

Quality management systems are here to stay. Most production and manufacturing industries have been progressing down this path for some time with positive results in productivity, profitability, and customer satisfaction.

Horticulture and agriculture, being out of the manufacturing mainstream, have not been exposed to quality management systems thinking or activity until relatively recent times. The individual or combined powers of compulsion, competition, and self-interest are now quite active and many horticultural businesses have responded to the message.

There are a number of options available to the nursery industry to capitalise on this trend. These range from basic knowledge and skills training to high-powered programs tailored to a specific business enterprise. In the middle are a range of quality management systems which endeavour to cover the key activities of a business, through a step-wise process to more complex systems. The latter includes support activities which ensure that the system not only performs, but is self-improving.

It is up to individual businesses in the nursery industry to evaluate the merit of quality management systems, decide which option best suits their needs or aspirations, and then implement the preferred option.

What is Quality? There are three main reasons for implementing quality management systems: compulsion, competition, and self-interest.

Some consumers are requesting that their suppliers have certification to a recognised quality system standard. A number of horticultural businesses have been requested by their export customers to have certification to AS/NZS ISO 9002. Some governments are moving the same way. This is not strictly a compulsion, but is necessary to ensure continued business with that customer.

It is widely believed that it costs five times more to win a significant new customer than to retain an existing one and so quality assurance is the obvious choice to protect your customer base.

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It is widely believed that it costs five times more to win a significant new customer than to retain an existing one and so quality assurance is the obvious choice to protect your customer base.

Another significant reason to implement a quality management system is competition. Other businesses competing in the same market are using quality system certification as a marketing tool. Similar added value schemes have been successful in the past such as pictorial labeling, pot colour, a range of pot sizes, and a variety of maturities.

Customer insistence and competition are valid factors which must be considered in formulating plans for a quality management system. Initiating a quality management system purely to keep up with the competition rarely achieves a satisfactory result. Businesses that do achieve maximum benefit do so because their motives are largely out of self-interest. The managers of these businesses realise that quality management systems can improve profitability by reducing the costs of doing business, improving productivity, and reducing both waste and down time. They implement the system with these objectives in mind and aspects such as customer insistence and competition are secondary. The motive is to consistently meet the needs and expectations of key customers in order to maximise profitability.

What are the Quality Management System Options? There is considerable confusion in the nursery industry and horticulture generally because there are so many options available. Firstly, most nurseries already have a quality management system of some description. Records of some form exist everywhere. The most common existing procedures are for water treatment, fertiliser application, bench construction, and handling sales. However, these systems are not always documented, comprehensive, or integrated.

The Nursery Industry Accreditation Scheme Australia (NIASA) is a good start in the direction of more formal quality management systems and all nurseries should be aiming for at least this target. Beyond NIASA are models or guides for quality systems that are equally applicable to all production and service businesses irrespective of what they produce. These range in order of complexity and credibility as follows:

Higher

- Quality Awards
- AS/NZS ISO 9002

Lower

- Australian Horticultural Quality Training Program
- Nursery Industry Accreditation Scheme Australia (NIASA)

But who assesses quality systems in nursery businesses to give recognition of achievement? In the case of NIASA, it is the State Technical Officers contactable through the State Association or Department of Agriculture/Primary Industries. The technical officer conducts an initial assessment and then ongoing inspections or audits to ensure continuing compliance with the NIASA guidelines. For generic quality system standards there are currently 11 accredited independent quality management system auditors who ensure continuing compliance.

Where to From Here? Nursery businesses keen to progress down the way of quality systems are recommended to firstly obtain more information. The initiation of a quality management system is a significant commitment and can take up to

2 years to implement. The Australian Horticultural Corporation (AHC) can provide advice on training, funding assistance, and consultancy services. The AHC has also developed a training package specifically designed to meet the needs of horticulture. Australian Horticultural Quality is a series of self-directed training modules which will provide the knowledge and skills required to implement quality systems. It examines the key tasks which should be included in any system and assesses the quality system options available.

The principle benefit of this training resource is that businesses will develop and implement a quality management system that is specifically tailored to their needs. Participants will develop quality management skills through activities which can be directly applied to their work places. On completion of the training, participants will have a hands-on understanding of quality management systems based on a customer focus. Participants will be able to use the knowledge and skills gained to evaluate the applicability and potential benefits of quality system certification to international or other standards.

RECOMMENDATIONS

NIASA has been generally well received and has a reasonable level of industry participation—although this level could be improved. The scheme covers the important day to day and long-term activities of a nursery business, particularly technical and hygiene-related activities. Accreditation under NIASA is a logical recommendation for all nurseries in order to improve customer satisfaction, strength of industry purpose, and ultimately profitability.

A further recommendation is to put those with more than just a passing interest in this subject in a better position to make their own decisions. While the background presented in this paper could be useful, commitment to the non-threatening self-paced Horticultural Quality Training Program would be the most logical step to build upon NIASA accreditation. This decision can be made by an industry association or any other potential facilitator who then solicits participants or individual businesses on their own behalf. Beyond this, nursery businesses will continue to see certification to the international standard AS/NZS ISO 9002 as the ultimate target.

The key tasks for progressing from here are:

- Seek and analyse further information.
- Set an achievable and realistic goal.
- Plan an implementation strategy.
- Don't look back.

Experiences with Accreditation under the National Scheme

David O. Cliffe
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INTRODUCTION

Accreditation schemes have existed in at least four States of Australia for a number of years. More recently, those individual schemes have been brought under the umbrella of a National Scheme called the Nursery Industry Accreditation Scheme, Australia (NIASA) to enhance the effectiveness of the accreditation process.

Accreditation is a well established business concept that has been used to attract markets and increase levels of consumer confidence for many years. It is a voluntary process, no one is obliged to join. The decision to seek accreditation must be based on an individual study of its economic relevance to your business. There has to be a clear recognition that adhering to the accreditation guidelines will either improve your productivity or your marketing performance or both.

Accreditation is available to all categories of nursery business and to some allied traders, e.g. growing media suppliers.

In the case of Narromine Transplants the process of accreditation was seen as a necessary step towards quality management and the eventual goal of accreditation under the Australia/New Zealand Standard (ISO 9002).

This paper endeavours to demystify the process leading up to accreditation under NIASA and to distinguish its place in the quality pathway.

THE PROCESS

The NIASA is administered by the National Accreditation Committee and each state has a designated Technical Officer. It is through these Technical Officers that the first approach is made to seek accreditation. An excellent booklet has been produced by the Australian Horticultural Corporation on the subject as well as a 12-minute video. Both these aids should be purchased before entering into the process.

It is important to understand the place of accreditation in the overall scheme of quality management :

No formal quality management	Low quality output	Low credibility
NIASA	Better quality output	Better credibility
Aust/NZ ISO 9002	High quality output	High credibility

NIASA is not a quality-assurance programme, it is a step towards quality assurance embracing crop hygiene, regulatory requirements, crop management practices as they pertain to nutrition, environmental control, and site appearance.

As our operation is a reasonably sophisticated containerised seedling nursery many of the practices required under the scheme were already in place.

Of particular importance is that all growing areas are above ground and that the media components used—peat, vermiculite, and polystyrene (provided they are well stored)—are generally free of pathogens.

Compliance with state environmental laws, particularly as they apply to irrigation runoff, is essential and will become a more important part of the scheme as more emphasis is placed on water management by Environmental Protection Agencies.

Attention has also been paid to washing facilities, container storage, weed control, the prevention and control of insects and other invertebrate pests, and crop protection programmes in general. Complete records are kept of all chemicals used, including the rates and dates of application as they apply to each individual crop.

A great deal of attention has also been paid to irrigation practices and the reduction of runoff water. The water supply in our case, from underground, is also pathogen free and is of exceptional quality.

Our growing medium has been carefully formulated so that it has a suitable range of physical properties, in terms of water-holding capacity and aeration, to cope with our environment and watering regime. Tests are carried out weekly on media both new and old and on the water supply to ensure consistency.

Low humidity at Narromine excludes us from many of the diseases experienced in environments of 85% relative humidity or greater. Greenhouse design allows good airflow and root pruning for cell-grown seedlings. Windbreaks and greenhouse side curtains minimise wind damage and reduce the possibility of disease transmission from dust.

The nutrition of container-grown seedlings is relatively complex and requires careful management to ensure the end product will survive field conditions. Programmes are specific to genera in many cases and are changed on a seasonal basis. The assessment of the nutritional status of plants ready for sale is a major consideration for the Technical Officer at the time of examination. Testing also takes place for the incidence of *Phytophthora* at points around the nursery, particularly wet spots caused by runoff. The tests must show the disease is not present.

Examiners will also assess the site to ensure it is visually attractive, tidy, and has a professional appearance. Buildings, fences, roadways, and parking areas should be appropriate for the purpose and in good repair. Gardens and display plants need to be in immaculate condition.

CONCLUSION

Accreditation for our nursery has meant participation by all staff. It has given them a sense of achievement and a set of criteria by which they can gauge themselves for management. It is a powerful tool which can best be demonstrated as follows:

- Improved consistency
- Improved outputs
- Improved management
- Improved profits
- Improved quality
- Lower production costs
- Lower labour costs
- Less waste and rework
- Less disease

Acknowledgements. Use has been made of The Handbook, the Nursery Industry Accreditation Scheme, Australia available from the Nursery Industry Association of Australia; and "Profits in Quality", a video on the subject of Nursery Accreditation available from the Australian Horticultural Corporation.

Practical Experience with Total Quality Management

Howard Bentley
Plant Growers Australia Pty. Ltd., Harris Rd, Wonga Park, VIC 3115

INTRODUCTION

This paper does not claim to be a "how to" guide in the preparation of a Total Quality Management (TQM) system, but aims to give an insight into the basic guidelines that must be followed when embarking on TQM. The process is still in its infancy at Plant Growers Australia (PGA) and from our experiences I will attempt to recount the processes and problems encountered to date.

There is growing world-wide recognition of the importance of the relationship between quality, productivity, and competitiveness. TQM can improve all three of these key business areas. TQM was first instigated in the USA but has been further refined and developed in Japan over the last four decades. Companies in Australia and the U.S.A. have been slow to take up this management approach but the process is now starting to gain momentum. According to business experts, TQM will be a requirement of all businesses that wish to remain competitive both in Australia and internationally.

The main objectives of TQM are economic production, service, and customer satisfaction.

To achieve these objectives the following are considered as vital elements when introducing TQM.

Principles of TQM. The fundamental management principle of TQM is to gain continuous improvement in the quality performance of all processes, products, and services of an organisation. Managers must focus on the entire process to ensure consistency and improvement of the final output. The message at the core of this principle is that maintenance of quality throughout the organisation will lead to higher returns.

The concept of "total quality" is the vital element and conveys that an organisation-wide improvement effort is required. This involves every person regardless of their position or function using their individual skills and experience to improve all processes and their outputs. Total quality is about leadership, clear goals, plans, and benchmarks in an on-going pursuit of improved performance.

For TQM to succeed, it must be driven by and have the total support of the top management. When managing and improving processes TQM favours the gradual approach where management and staff are equally involved in managing and improving processes that serve the customer. People are the key to a successful enterprise and TQM relies on people to make it work.

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As customer satisfaction is one of the main objectives, methods must be devised for measuring and understanding customer expectations and acceptance of quality both now and in the future. Everyone understands the importance of the external customer but another important element is that of the internal customer. Recognising that the next person or department in line is your customer. For example:

Propagation > Production > Greenlife > etc.

This is an area that will impact greatly on both quality and production through each department supplying their "customer" with the best possible product produced by the best possible method.

In essence TQM does not view quality as just a feature of a finished product but also as quality deriving from well designed processes, standardisation, improvement of processes, understanding variation, and from sharing and using data. It is also about readiness to accept change and a balance between achieving control over quality, improvement, and innovation.

Personal Experience with the Implementation of Total Quality Management Program. My first experience with TQM was a short training course with a tertiary institution. It became apparent after completing this course that TQM was the direction in which our company should be heading.

As a company which is a recognised industry leader, quality does play a major role in our business success. But we are realists and are aware that we do not always achieve what we believe, and more importantly what our customers believe, is the best quality of product or service. The drive to do better, to improve our quality and service, to increase productivity, and to improve and continually improve in all aspects of our organisation as well as gaining a further advantage over our competitors were all reasons why we decided to implement a TQM Program.

This decision was given total support by all top management.

As customer satisfaction is one of the main objectives it is important to have an understanding of their requirements in both product and service. Our perception was that we did understand reasonably well what our customers required, but it was decided that we should put this to the test. The best way to do this was with a customer survey conducted by an independent party. We gained some very useful suggestions and information, both positive and negative, about our quality and service. It is important to look at the information in the right context and to respond to the criticisms positively and to ensure that the good points are recognised and maintained. The results of this survey gave us an understanding of the areas that needed the most attention and enabled us to set priorities.

Once the commitment had been made to TQM, the next step was the introduction and implementation of the system to the staff. As this was a new system for the entire organisation we adopted a "learn as we go" policy. It was decided that before endeavouring to apply the system to the entire nursery we would first experiment with one department. Focusing on one department enabled us to work with a small group, making it easier to get the information across and receive input into the development of the job process. It also allowed us to hone our writing techniques for the preparation of procedures and the development of procedures for conducting meetings with staff. Once we had put the process in place it was also easier to check for mistakes,rectify them, and get feed back that would be of benefit to the other department processes which were to be covered.

The department selected was the one responsible for potting production. We decided to start with the potting process because we had experienced significant stock losses shortly after potting with the potting machine.

A meeting was called to brief the potting staff on what TQM was all about, to reiterate the importance of the role that potting played in the overall quality of our product, and to show where the potting crew fit into the internal customer chain. That is, the quality of the product coming off the machine was not only critical in satisfying the external customers needs, but improved quality could reduce losses and make the caring for and selection of those plants a much easier task for the internal customers (namely the greenlife care department and the sales and dispatch department). A flow chart of all the departments in the nursery was used to impress the point of the internal customer system.

One of the benefits of this system is the involvement of the staff. The people who are actually doing the work are providing the input for the formulation of the process. If the staff are involved in the process and their thoughts and ideas play a major part the development of the process then they are more likely to embrace the system than if it was purely another management enforced "good idea".

As a manager I was used to initiating new ideas and formulating changes to processes, so it was at first a little strange to take a back seat and not be the focal point in these discussions. It was certainly an interesting and enlightening experience to receive ideas from people who would have been least expected to contribute. In some instances the changes that were made to our processes were only minor but it was quite amazing the impact that they had on the effectiveness of the process. Even these minor changes had only become apparent because of the way each process is built or rebuilt from the ground up through the active involvement of all staff.

There were some reservations at the start, but it was encouraging to see the enthusiastic way in which this system was embraced and the number of good ideas and problem solving that was generated from our meetings. The cooperation of the staff is a vital element for not only the development of the processes but also for maintaining and improving them. Without this cooperation the whole system would be impossible to manage successfully.

The processes were written in such a way that they could be used for training new personnel in all aspects of any given process. Every detail of the job process was included whether large or small and instructions were written, starting from the first task performed through to the last one completed. Training new staff has always had its problems, how they performed different tasks often depended on who was doing the teaching. A common complaint from new staff was that they were confused as to which method was best. This can lead to variability of both product and service. However, TQM standardisation and documentation of each process has solved this problem.

When formulating this process using TQM, every care was taken to firstly ensure the quality of the product and secondly to carry out the task in the most efficient and productive manner. Because of the in-depth way in which the potting process was developed, the problems we experienced before hand quickly became apparent and procedures were put in place to ensure that these problems didn't arise again. Once the revamped potting process was documented we again had a meeting to check that it was correct and to make sure that there was nothing more to add or

alter. Copies of the document were displayed in the potting area and extracts pertaining to each section of potting were displayed prominently in the appropriate place. This provided help for new personnel as well as staff who only occasionally worked on the potting machine and needed a reminder of the procedure. Once the potting protocol was up and running, audits were carried out on the process to ensure that it was being performed according to the documentation.

We did make some mistakes, one of which was not reviewing the process often enough after its initial implementation and audit. We also made some minor changes to the process over a period of time but these were not properly documented and implemented. It must not be forgotten that continual improvement of all processes is a vital element of the system, but those improvements must be implemented according to set procedures and corrected documents reissued. We have learned from those mistakes and have made a commitment to avoid those situations in the future.

As the number of departments covered by TQM increased it has became difficult to control the reviews and the updating of the procedures. With this in mind it was decided that the staff would elect a spokesperson for each of the various departments. Because these people are involved in the day-to-day activities, any problems or ideas for improvement could be relayed through the spokespersons. These people could then arrange a meeting with the TQM officer and the staff to discuss the possible changes.

Setting aside time for the implementing and reviewing processes has presented problems for us especially during the busy periods where we have had a tendency to keep putting them off. The best solution to this is to schedule meetings for a certain day of each month.

As stated earlier the TQM processes mentioned are still in their infancy at PGA. Obviously, as time goes by, additional problems will be encountered but I feel if we follow the procedures relating to change we will overcome any difficulties encountered. The process of change is never ending and TQM will provide sustainable long-term gains. It is my hope that this paper has stimulated your interest in the subject of TQM and that you endeavour to investigate its obvious benefits through your own study. Your investigations may be time consuming but any sacrifices made will be returned many times over through productivity gains and customer satisfaction.

Classical Biological Control of the Rose Aphid (*Macrosiphum rosae*) in Australia

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INTRODUCTION

Classical biological control (CBC) can be described as an attempt to regulate pest populations (mites, insects, mammals, weeds, pathogens) by using their natural enemies (parasites, predators, pathogens) that are imported and released into a new environment for this purpose (De Bach, 1974). The underlying hypothesis of CBC is that populations are regulated effectively by natural enemies and that exotic pest species have escaped this regulation by geographic isolation from their natural enemies (Van den Bosch and Messenger, 1973). Successful CBC combines permanency, selectivity, environmental safety, and economy in pest management (DeBach, 1974) and can be considered as a cornerstone in integrated pest management (IPM). Data from Huffaker et al. (1976) shows a return of $30 (U.S.A.) for each dollar spent in biological control of agricultural pests in California. Despite these positive benefits CBC is still a minor method of pest control compared to the use of pesticides. The main reason for the reluctance to CBC is that it is widely perceived as an unreliable method of pest control (Beirne, 1985). The overall rate of establishment of natural enemies of insects and arachnids worldwide was 34% (Hall and Ehler, 1979) and only 60% of those resulted in some kind of control. Particularly disturbing is that the rate of establishment of natural enemies in CBC is declining (Hall and Ehler, 1979). Another major concern regarding CBC is the possibility of an undesirable impact of the control agent on non-target species and the environment.

Unfortunately many CBC attempts are poorly described in the literature. Only a minority provide comprehensive data to enable detailed case studies of either success or failure that may provide useful hints for further experimentation (Hughes, 1989). The reasons for failure or success of CBC attempts are often not understood. This is very well described by Hughes (1989) who states that CBC is still considered as a kind of art rather than a science.

Since there was no urgent need to control the rose aphid, *Macrosiphum rosae* L., we had the rare opportunity to undertake some fundamental investigations on the principles of CBC with the release of the control agent *Aphidius rosae* Haliday. This paper is an introduction to the biology of the pest and its control agent. Aspects of the spread, establishment, and impact of *A. rosae* will be discussed.

CBC FOR ROSE APHIDS

Roses. Species of *Rosa* have been modified through selection and hybridisation in cultivation in many cultures giving rise to some 20,000 cultivars (Bailey and Bailey, 1976). However, the number of species is comparably small, probably comprising no more than 150 selections (Bean, 1980). As hybridisation has gone on, the system of cultivar classification has become complicated and inexact, so that it is now nearly impossible to classify accurately. Rose aphids feed on all cultivars, although susceptibility may vary between cultivars.

The Rose Aphid. *Macrosiphum rosae* is a large aphid and can vary in size between 1.7 and 3.6 mm for apterae and 2.2 to 3.4 mm in alatae. Colour ranges from dark green over deep pink to red brown or magenta. The green and brown stages are the most prominent forms and may change to the other over at least two generations in the field. Pink is often the intermediate colour during this changeover (Maelzer, 1977). In the field adults of *M. rosae* are easily recognised by their long deep shiny black siphunculi and black knees.

In regions with a mild winter *M. rosae* may be completely anholocyclic on roses, e.g., South Australia (SA) (Maelzer, 1977) and New South Wales (Wöhrmann et al., 1991). In these cases the aphids reproduce parthenogenetically and viviparously all the year around, despite small numbers in winter and midsummer, sexuals and eggs are not produced (Maelzer, 1977; Wöhrmann et al., 1991). *Macrosiphum rosae* is probably native to Eurasia and was introduced into Australia as a result of colonisation (Maelzer, 1977). In SA *M. rosae* is the most serious insect pest on roses. The growth of a colony of *M. rosae* on a rose bud and its potential for damage depend upon a complex interaction between seasonal rose growth, temperature, rainfall, predation and density-dependant mechanism of dispersal (Maelzer, 1977; Tomiuk and Wöhrmann, 1980). The population dynamics of *M. rosae* coincide mainly with the growth of the host-plant (Maelzer, 1977) and reaches two peaks in spring and one in autumn in SA. A number of native insect species including ladybirds, syrphids, and lacewings prey upon the aphid (Maelzer, 1977).

Macrosiphum rosae feeds mainly on the young shoots and buds of roses, up to the stage when the sepals start to fold back (Maelzer, 1977). By sucking and removing sap from the vascular system the aphid reduces the amount of nutrients available for the bud and the plant as a whole. Direct visible damage to the bud is rare and only heavily infested young shoots tend to wither or dry up. Maelzer (1977) describes the economic damage threshold as an infestation of 50 aphids per bud, at this level the plant responds by the reduction of growth and the inhibition of new buds shooting. However, roses which are grown for cutting or display have a much lower damage threshold, since minimisation of cosmetic damage is critical. In addition, indirect damage is caused by rose aphids as the accumulation of their honeydew excrement promotes the growth of sooty mould which causes cosmetic damage and reduces photosynthetic activity.

The role of *M. rosae* in transmitting viruses is unknown. However, compared to the other sources of infection, such as vegetative propagation with virus-infected buds, pruning with contaminated equipment, natural pollen transmission, and transmission by free-living soil-inhabiting nematodes (e.g., *Xiphinema* spp.) the role of *M. rosae* in virus transmission is probably minor (Horst, 1983). According to Blackman and Eastop (1985) the aphid is able to transmit at least 12 viruses, including the persistent virus strawberry mild yellow edge but not the important rose mosaic or rose streak.

The rose industry in Australia is valued at around $100 (A) million per annum. Seventy percent of this is attributed to the cut-flower industry. Pot and bare-root growers for garden supply account for the other 30%. CBC of *M. rosae* was considered to be of most benefit for commercial pot and bare-root growers since many of their plants are sold pruned and a light infestation with aphids is tolerable during their main growth period. Local councils and home gardens would also benefit from CBC on roses, as the control agent increased in numbers and spread naturally through

urban areas. Replacing pesticidal sprays with biological control agents was considered highly beneficial, not only in terms of cost but also with regard to environmental pollution and public health.

The introduction of an effective predator for *M. rosae* was considered to be a potential cornerstone in a future IPM program on roses and an invaluable investment in the future. The use of an effective natural enemy reduces dependence on chemical control methods and alleviates the ever increasing problem of insecticide-resistant strains of rose aphids (DeBach, 1974). An effective biological control agent for rose aphids will also complement the use of predatory mites which are often used in the management of pest mite species. An IPM Program for the Western flower thrips (*Frankliniella occidentalis)* is being developed in Australia. This is unlikely to work on roses unless a concurrent programme for aphids is in place. A combination of control agents is necessary where there is more than one significant pest species. The long-term effects of an IPM program for roses will be of significant value. However, even in the short-term direct feeding damage or indirect damage through virus transmission by aphids occurs in proportion to their abundance (Dixon, 1985). Therefore, any decrease in aphid numbers resulting from the introduction of a CBC agent will be potentially beneficial (Hughes, 1989).

The Control Agent. In seeking a control agent of *M. rosae* a parasitoid seemed most promising. The existing parasitoid predators for rose aphids in Australia were negligible and other native predators did not provide sufficient control potential. It was hoped that a specific parasitoid could fill in the missing niche of parasitic control and, if not being effective by itself, at least augment the impact of existing predators. Specific parasitoids are the most promising group among CBC agents, especially when the pest occurs in permanent, stable environments on woody plants.

Aphidius rosae was selected. This aphid parasitoid is up to 3 mm in length and lays its eggs inside all instars of the rose aphid. Parasitised aphids are eaten and finally killed by the developing parasitoid. A paper-like skin is all that remains of an aphid after parasitism. The larvae of the parasitoid attaches the skin of the aphid to the plant and uses it as shelter in which to spin a cocoon. These round, shiny structures are called mummies and are easy to detect on roses. Inside the mummy the insect pupates. Depending upon temperature it takes 2 to 3 weeks from egg deposition to the emergence of the adult wasp from the mummy. Females have the potential to kill more than 800 aphids. *Aphidius rosae* is considered to be specific to its host (Pennàchio, 1989). To reduce the need for acclimatisation *A. rosae* was collected in Italy.

Specificity Assessment of *A. rosae* in Australia. In the past more than a dozen species of Aphidiinae were released into Australia (Hughes, 1989) including polyphagous species such as *Aphidius ervi* Haliday. To my knowledge there is no record of any of these introduced parasitoids parasitising species other than non-native aphids. In Australia, of 156 known aphid species, only 20 are indigenous, the rest are exotic and mostly pests (Carver, 1989). The few species of aphids which are native to Australia are found on species which are quite different to roses and live mainly in habitats which are very unlikely to attract *A. rosae*. It is expected that *A. rosae* will rarely encounter most aphid species occurring in Australia. Only on roses would the wasp have to distinguish between different aphid species.

Macrosiphum euphorbiae is the only aphid species other than *M. rosae* expected to be occasionally parasitised by *A. rosae*, but in this case offspring would not complete development. The long association of *M. euphorbiae*, *M. rosae*, and *A. rosae* on roses in other parts of the world indicates that no sudden change of host suitability is likely. Because of the specificity of *A. rosae*, the special composition of the Australian aphid fauna and the history of introduced aphidiine wasps into Australia, environmental risks resulting from the release of the control agent were extremely low.

Establishment. The release of *A. rosae* was used to test the hypothesis that a threshold of about 1000 insects released at a single site is needed for establishment (Hopper and Roush, 1993). Mummies (16, 64, 256, and 1024) of *A. rosae* were released in eight cities throughout Victoria. Six months after release, recoveries could be made in the three sites in which 64, 256, and 1024 mummies were released. After 1 year, mummies were also found in a place where only 16 were originally released. The establishment of *A. rosae* shows good prospects for its distribution over the country. Institutions and commercial rose growers should be able to establish this parasitoid without little effort and therefore achieve quick distribution in suitable parts of the continent with minimum outlay.

Spread. The ability of parasitoids to disperse is important in CBC since control agents cannot be released everywhere. Insect populations are usually clumped in time and/or space, and the distribution of these clumps can change from season to season. The patchy distribution of pest outbreaks may disrupt synchrony of parasitoids with their host population in space, even if they may be in synchrony with the host in time (Vinson, 1981). These uncertainties make dispersal a critical issue for the success of parasitic wasps in biological control, especially in CBC attempts where augmentative releases might not be considered. The dispersive movements of an established population of control agents in a patchy environment are of special interest at the beginning of a new season. Seven months after the first release of only 1600 individuals of *A. rosae*, the parasitoid inhabited an area of approximately 200 km^2 and could be found 18 km away from the nearest release site. Results suggest that parasitoids spread mainly in the direction of prevailing winds and that most individuals do not travel far.

Impact on Aphid Populations. Surveys during the first 2 years showed a significant reduction of aphids in spring with up to 80% parasitism. In autumn the abundance of rose aphids was less obviously influenced.

CONCLUSION

Since release, the wasp displays all the qualities of an effective CBC agent:

1) Despite small release numbers the wasp was easily established and is now abundant in wide areas around the initial release points.

2) The wasp has spread over more than 200 km^2 in the Adelaide region in less than 7 months.

3) The wasp is present as an adult in late winter, a short time before the build up of host aphid populations.

4) The wasps potential for population increase is at least comparable with that of its host.

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Biological Control Agents for Damping-off Disease in Bedding Plants

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INTRODUCTION

Damping-off diseases are common wherever seedlings are grown. Nurseries experience disease outbreaks despite the use of good hygiene and fungicides, and would welcome an economical, environmentally safe biological control product (Harris, 1995). Some bacteria and binucleate *Rhizoctonia* isolates can control the fungi that most commonly cause damping-off diseases in nursery seedlings: *Pythium* spp. (Broadbent et al., 1971; Harris and Adkins, 1993; Harris et al., 1993b, 1994c), and *Rhizoctonia solani* Kühn (Cardoso and Echandi, 1987; Harris et al., 1994a,b; Howell and Stipanovic, 1979; Kommedahl and Windels, 1978). Plant growth promotion in the absence of known pathogens also has been reported for soil bacteria (e.g. Broadbent et al., 1977; Lifshitz et al., 1987) and binucleate *Rhizoctonia* (Harris et al., 1993b, 1994b).

This paper summarises experiments designed to screen several isolates of soil bacteria and binucleate *Rhizoctonia* for biological control of damping-off diseases and growth promotion of *Capsicum* seedlings in pasteurised potting medium.

MATERIALS AND METHODS

The following methods were common to all experiments. Bacteria and fungi were isolated from samples of potting media collected from plant nurseries around Adelaide, South Australia (Harris et al., 1993b, 1994a; Schisler et al., 1993). Fungal isolates were cultured on sterilised rice hulls or wheat bran, and added to pasteurised potting medium in plastic punnets (seedling trays) (Harris et al., 1993a). *Rhizoctonia solani* anastomosis group 4 (AG 4), isolate D1B1, on organic substrate was mixed with potting medium, and 7 cm^3 of this mix was added to the bottom of each punnet cell. Punnets then were filled with potting medium with or without a binucleate *Rhizoctonia* isolate. *Pythium ultimum* var. *sporangiiferum* Drechsler isolate 2 was mixed throughout the potting medium in punnets.

Seeds were sown near the top of the potting mix in each punnet cell, and covered with 5 to 10 mm (approx. 7 cm^3) of sterilised, washed coarse sand. Bacterial isolates were grown on 1/2- or 1/5-strength tryptic soy agar (Difco) at 25C, suspended in sterile deionised water at different concentrations, then 2.25 ml of suspension was pipetted onto the sand in each punnet cell. Doses for each experiment are indicated below.

Biological control by our microbial antagonists was compared with *Bacillus subtilis* Cohn emend. Prazm. isolate A13, and the fungicides quintozene and propamocarb. *Bacillus subtilis* A13 controls *R. solani* (Broadbent et al., 1971) and is used commercially for biological control of several soil fungi on field crops. Unformulated *B. subtilis* A13 was obtained from P. Barkley (nee Broadbent), NSW Agriculture, Rydalmere, Australia. Quintozene (PCNB) (Terraclor, Uniroyal Aus-

tralia) was suspended in deionised water at 5 g litre^{-1} and propamocarb (Previcur, Schering AG) at 1.78 ml litre^{-1}. An aliquot (2.25 ml) of each suspension was pipetted onto the soil in each punnet cell to give doses of 8.4 mg a.i. quintozene, or 2.4 mg a.i. propamocarb, per punnet cell, which approximate the recommended commercial rates.

Punnets were arranged in randomised complete block designs in either a glasshouse or growth chamber at 25C (±7C) (Harris et al., 1993b). When most seedlings had four true leaves and damping-off had apparently ceased (3 to 4 weeks), the seedlings that had survived or collapsed were counted separately. Seedlings that were still standing were excised at soil level, and the tops were dried at 60C and weighed. Data for each variable were subjected to analysis of variance, and treatment means were compared to the controls by Fisher's protected least significant difference (PLSD).

Experiment I. Effects of Biological Control Organisms on *Capsicum* With or Without *R. solani*. We tested the efficacy of selected micro-organisms at different doses to suppress damping-off, caused by *R. solani* AG 4, in seedlings of *Capsicum annuum* L. 'Green Giant' (capsicum, syn. bell pepper). We also assessed their ability to stimulate shoot growth in the absence of added *R. solani*. For treatments with *R. solani*, the fungus on wheat bran substrate was mixed with potting medium at 0.28% (v/v), then 7 cm^3 of this mix was added to the bottom of each punnet cell. Binucleate *Rhizoctonia* isolates BNR1 or BNR2 on wheat bran substrate were mixed with potting medium at doses of 0.018, 0.035, 0.07, 0.14, or 0.35% (v/v), and punnets were filled with these mixes. Bacterial isolates *B. subtilis* A13, BAC1, BAC2, and BAC3 were suspended at concentrations of $10^{2.5}$, 10^4, $10^{5.5}$, 10^7, and $10^{8.5}$ bacterial cells ml^{-1}. To determine the direct effects of microbial isolates on plant growth, each isolate was also added at the same five doses to the remainder of the punnets without *R. solani*. There were three replicate punnets for each dose of each biological control organism. Quintozene and control treatments each had nine replicate punnets. Means for the five doses of each microbial isolate were subjected to regression analysis. As no dose responses were observed, the means of the 15 punnets for each treatment (across all doses) were calculated and subjected to analysis of variance.

Experiment II. Suppression of *P. ultimum* var. *sporangiiferum* on *Capsicum*. Microbial isolates were screened for ability to suppress damping-off caused by *P. ultimum* var. *sporangiiferum* on *Capsicum*. *Pythium ultimum* var. *sporangiiferum* on rice hulls substrate was mixed with potting medium at 0.7% (v/v). For the treatments BNR1, BNR2, and BNR3, an isolate of binucleate *Rhizoctonia* on rice hull substrate was also mixed with potting medium at 0.7% (v/v). Each of 15 bacterial isolates, including *B. subtilis* A13, BAC2, BAC3 and BAC4, but not BAC1, was suspended at approx. 3×10^8 bacterial cells ml^{-1}, and pipetted onto the potting medium to give 7×10^8 bacteria per punnet cell. There were four replicate punnets for each antagonist and propamocarb treatment, and 16 for each of the two controls with or without *Pythium*. Plants were grown for 20 days at 25C in a controlled-environment growth chamber with a 12-h photoperiod and daytime illuminance of approximately 250 μEm^{-2}s^{-1}.

Experiment III. Suppression of *P. irregulare* on *Capsicum*. We also tested whether selected microbial isolates were effective against a different species of *Pythium*. *Pythium irregulare* on rice hull substrate was mixed with potting medium at 7.4% (v/v). There were 20 replicate punnets for each antagonist treatment, and eight for propamocarb and control treatments with and without *P. ultimum* var. *sporangiiferum*. Plants were grown in a glasshouse for 35days.

RESULTS

In experiment I, in which *R. solani* was added to potting medium at the same time as the putative biological control organisms, two binucleate *Rhizoctonia* isolates increased survival and growth of *Capsicum* seedlings more than any of the four bacterial isolates. *Bacillus subtilis* A13 did not control damping-off ($P < 0.05$) in Experiment I. In Experiment I the two binucleate *Rhizoctonia* treatments had similar seedling survival to the control without *R. solani*, or quintozene.

In Experiment II, in which *P. ultimum* var. *sporangiiferum* was added to potting medium at the same time as the putative biological control organisms, isolates BAC2, BAC3, BNR1, and BNR2 reduced damping-off in seedlings of *Capsicum*. The biological disease suppression was greater than that achieved with propamocarb. *Bacillus subtilis* A13 gave no significant control ($P < 0.05$). BAC4 increased ($P < 0.01$) survival of *Capsicum* seedlings. *Pythium irregulare* was totally controlled by both binucleate *Rhizoctonia* isolates on *Capsicum* ($P < 0.01$). In pasteurised potting medium without added pathogens, the four bacterial isolates increased ($P < 0.05$) shoot dry weights of *Capsicum* seedlings in Experiment I. The two binucleate *Rhizoctonia* isolates increased shoot dry weights of *Capsicum* seedlings.

DISCUSSION

The two isolates of binucleate *Rhizoctonia*, and quintozene, consistently suppressed damping-off caused by *R. solani*. Damping-off caused by *P. ultimum* var. *sporangiiferum* was suppressed consistently by BNR1, BNR2, BAC2, and BAC3 on *Capsicum*. Both binucleate *Rhizoctonia* isolates were effective against *P. irregulare*. Our five microbial treatments suppressed damping-off more than the commercial biological control bacterium, *B. subtilis* A13, and at least as well as standard fungicide drenches. The beneficial microbial isolates have not been identified conclusively yet. To date, beneficial effects have been demonstrated on five plant species that represent the dicotyledonous families, Amaranthaceae, Cruciferae, Solanaceae,and Violaceae (Harris et al., 1994a, b). The microbial isolates are being tested further for efficacy in various potting media and environmental conditions, and for suppression of other soil-borne pathogens on a wider range of plants (Harris and Adkins, 1993). It is possible that different microbial isolates, or combinations of isolates, may be needed for different nursery situations.

All six selected microbial isolates increased shoot growth of seedlings in pasteurised potting medium without added pathogens. The two binucleate *Rhizoctonia* isolates generally gave the largest increases in dry weights, while *B. subtilis* A13 and BAC2 were the least effective. BNR2 increased mean shoot weights per punnet for *Capsicum* seedlings by 33%. Growth promotion would enable seedling growers to reduce production time for seedlings and thereby reduce costs. We are

now using pure cultures of one plant species with one isolate of micro-organism in sterile conditions, to determine whether the plant growth promotion is due to direct stimulation through supply of plant nutrients or hormones, or to an indirect mechanism, such as biological control of a mildly pathogenic contaminant.

BNR1 and BNR2 were the most consistent organisms for disease control and plant growth promotion over all of these experiments. These binucleate *Rhizoctonia* isolates are known to be dense colonisers of seedling roots (Harris et al., 1991), but the mechanisms they use to promote seedling growth and suppress damping-off are still being investigated. These fungal isolates are effective at low dose (< 0.35% v/v or concentrations < pathogen dose) against unrelated fungal pathogens, and therefore could potentially be developed for economical treatments of commercial potting media.

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Seed Germination of Endangered South Australian Plants

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INTRODUCTION

As part of ongoing studies on the conservation biology of endangered plants of South Australia, experiments were conducted to establish protocols for their effective propagation. The species studied were all endemic to South Australia and were classified as nationally endangered (Briggs and Leigh, 1988).

This paper describes experiments on propagation of five endangered species from seed.

MATERIALS AND METHODS

Seeds were collected from known wild provences and stored dry at 15C until required. Seeds were generally less than 1 year old at the time of testing.

Seed for germination testing was routinely spread on filter paper overlying dry vermiculite in a petri dish, each component having been previously sterilised by autoclaving. Unless otherwise stated, seed was irrigated with distilled water, incubated at 20C in the dark, and each treatment (20 seed/rep) was replicated three times. Germinations were recorded daily.

Moist heat was applied by immersing seed in boiling water for 30 sec or by soaking seed in 200-ml just-boiled water and allowing it to cool overnight. Dry heat was applied by exposing seeds for up to 30 min to temperatures up to 150C in an oven. Microwave treatments involved placing seed in a microwave oven operating at full power (500W) for 1 or 2 min with or without a water load (50 or 100 ml). Seeds soaked in concentrated sulphuric acid (H_2SO_4) or sodium hypochlorite (NaOCl) for up to 40 min were rinsed three times in distilled water following treatment. Manual scarification was performed by nicking seeds individually using a sharp blade. To study the effect of gibberellin (GA) on germination, seeds were irrigated for the total incubation period with 1, 10, 100, or 1000 mg litre^{-1} GA_3 or $GA_{4/7}$. Some seeds were infused with the hormone under reduced pressure for 30 min using a tap-mounted Venturi vacuum pump to evacuate a flask containing seed and 20-ml treatment solution. Again, seeds were irrigated with GA treatments during the incubation period.

Stratification of *Prostanthera eurybioides*. Untreated seeds were placed between two layers of filter paper overlying moist vermiculite in a petri dish, moistened with 1 g litre^{-1} Benlate solution, sealed with parafilm, and incubated at 4C for 1, 2, or 3 months prior to germination testing.

Incubation Temperature and Germination of *Acacia pinguifolia*. Nicked seed was incubated at 15, 20, 25, 30, or 35C. A Zankel thermogradient incubator was used to achieve temperature control for each dish individually, and each temperature was replicated five times.

Storage of Pretreated *Dodonaea subglandulifera* Seed. Seeds were soaked in just-boiled water for 30 sec, air-dried, and then stored at 15C in darkness for

periods of 0, 2, 4, 6, 8, 10, or 12 weeks. Seeds were then sown directly into seedling trays to simulate in situ conditions. Boiling water pre-treatments were staggered in time, to allow seed from all treatments to be sown on the same day. Treatments were replicated four times.

RESULTS

Acacia pinguifolia. Nicking the seed coat produced optimal germination (Table 1). Boiling seeds for 30 sec or soaking seeds in concentrated sulphuric acid H_2SO_4 for 30 min also yielded high germination rates. All treatments tested increased germination significantly above the control.

Table 1. Germination of *Acacia pinguifolia* seed incubated at 20C for 54 days.

Seed pre-treatment	Germination (%)
Nick seed coat with sharp blade	91
Soak in conc. H_2SO_4 for 30 min	77
Boil for 30 sec	88
Soak in 200 ml just-boiled water overnight	60
Heat in microwave oven for 2 min (50 ml water load)	26
Heat in microwave oven for 2 min (no water load)	22
Heat in 95C oven for 30 min	23
Control	3
LSD (P=0.05)	8

Germination increased with decreasing incubation temperatures (Table 2). Optimal germination (97%) occurred following incubation at 20C.

Table 2. Influence of incubation temperature on the germination of *Acacia pinguifolia* seed after 28 days incubation. Seed coats were nicked before incubation.

	Incubation temperature (C)	Germination (%)
	15	92
	20	97
	25	80
	30	11
	35	2
Significance		
Linear		***
Quadratic		***

***Significant at $P \leq 0.001$.

Acacia cretacea. Nicking the seed coat produced optimal germination (Table 3). Boiling seed in water for 30 sec or soaking in 200-ml just-boiled water overnight yielded high germination rates (89% and 75%, respectively). Dry heating seed was not successful as a pre-treatment for germination of this species. A short soak (10 min) in H_2SO_4 yielded 9% germination and it is possible that extending this treatment may lead to further increases in germination.

Table 3. Germination of *Acacia cretacea* seed incubated at 20C for 38 days.

Seed pre-treatment	Germination (%)
Nick seed coat with sharp blade	99
Soak in conc. H_2SO_4 for 10 min	9
Boil for 30 sec	89
Soak in 200-ml just-boiled water overnight	75
Heat in microwave oven for 1 min (100-ml waterload)	5
Heat in microwave oven for 2 min (100-ml water load)	5
Heat in microwave oven for 1 min (no water load)	1
Heat in microwave oven for 2 min (no water load)	0
Heat in 95C oven for 30 min	0
Control	0
LSD (P=0.05)	7

Table 4. Effect of soakage time in 100 ml just-boiled water on *Dodonaea subglandulifera* germination after 30 days.

Soakage time (sec)	Germination (%)
0	7
5	33
10	47
30	50
60	43
120	40
Significance : Linear[1]	**

[1]Linear regression was fitted following $\log_{10}$ transformation of both germination and soakage time.

**Significant at P<0.01

Dodonaea subglandulifera. Soaking seeds in just-boiled water significantly increased germination to a maximum of 50% (Table 4). While soakage times up to 120 sec significantly improved germination according to a double logarithmic relationship, in practice germination rate plateaued rapidly beyond 10 sec soakage.

Table 5. Effects of boiling water and NaOCl (100%) on the germination of *Dodonaea subglandulifera* seed.

Treatment time (sec)		Germination(%)
Boiling water	NaOCl	
0	0	7
	30	13
	45	12
	60	8
30	0	70
	30	80
	45	48
	60	52
Significance:		
NaOCl		*
Boiling water		***
Interaction		*

*,*** Significant at $P < 0.05$ or $P < 0.001$, respectively.

Seeds were treated with 100% NaOCl for up to 60 sec following a 30 sec boiling water treatment. A slight NaOCl-induced stimulation in germination was observed following 30 sec treatment (Table 5). However, boiling water was the more effective germination stimulant and the added effect of NaOCl was insufficient to warrant practical usefulness. Neither $GA_{4/7}$ nor GA_3 stimulated germination significantly at any concentration studied.

Seed treatment with concentrated H_2SO_4 increased germination to over 50% (Table 6). The effect of acid was time-dependant following a double logarithmic relationship.

Seed air-dried and stored at 15C for varying periods following a 30 sec soak in just-boiled water was found to retain its viability for at least 12 weeks. Final germination percentage was proportional to the square of storage time, with optimum germination observed after 6 weeks storage at 15C (Fig. 1).

Prostanthera eurybioides. Pre-treatment of seed with dry heat (150C for up to 30 min), just-boiled water (left to cool overnight), concentrated H_2SO_4 (for up to 40 min), and low temperature (stratification for up to 3 months) applied as treatments in isolation failed to stimulate germination. Irrigation of seed with GA_3 produced some stimulation in germination (4%, 1%, 38%, and 30% germination with 1, 10, 100, and 1000 mg litre^{-1} GA_3, respectively). However, following gibberellin infusion into the seed under reduced pressure, 100 and 1000 mg litre^{-1} GA_3 resulted in 80.3% and 83.3% germination respectively, and 10 and 100 mg litre^{-1} $GA_{4/7}$ in 66.7% and

50% germination, respectively, after 70 days incubation. A further experiment was set up to examine the effect of H_2SO_4 pre-treatment on subsequent response to GA. Seeds were pretreated with concentrated H_2SO_4 for 0, 15, or 30 min, and then incubated with GA. Optimal germination (after 50 days) followed 1000 mg litre^{-1} GA_3 or 1 to 10 mg litre^{-1} $GA_{4/7}$ treatment of seed pretreated with H_2SO_4 for 15 min. Treatment of seed with H_2SO_4 for 30 min or $GA_{4/7}$ at concentrations of 100 mg litre^{-1} or greater proved superoptimal.

Table 6. Germination of *Dodonaea* subglandulifera seed pre-soaked in concentrated H_2SO_4 and recorded after 41 days.

Soakage time (min)	Germination (%)
0	8
30	53
60	50
90	57
120	58
Significance: Linear[1]	***

[1]Linear regression was fitted following $\log_{10}$ transformation of both germination and soakage time.
*** Significant at $P < 0.001$.

Pultenaea trichophylla. Over 95% of seed germinated within 63 days following a 40-min presoak in H_2SO_4 (Fig. 2). Final germination percentage was proportional to the logarithm of H_2SO_4 presoaking time. As well as enhancing the germination percentage, H_2SO_4 also increased the rate of germination as presoaking time increased. The combined effects of H_2SO_4 and GA_3 were also tested, but GA_3 failed to stimulate any further germinations.

DISCUSSION

The results highlight the importance of hard seed coats as a survival mechanism. All five species showed some germination response to manual (nicking), heat (moist or dry), or chemical (H_2SO_4 or NaOCl) scarification. Similar responses have been observed in other Australian species (Aveyard, 1968; Burrows, 1991; Clemens et. al., 1977).

Dry heat was significantly less active than moist heat for acacias, although the response to dry heat varied between the two species, with *A. pinguifolia* being far more responsive to radiated and microwave heat than *A. cretacea*. Tran (1981a) tested the effects of microwave energy on seed of 15 *Acacia* species and results ranged from 0 to 84% germination. He found that the percentage swelling and germination were inversely proportional to seed coat thickness (Tran, 1981b) and that microwaves acted by fracturing the strophiole and seed coat allowing them to become permeable to water (Tran, 1979). Microscopic observations indicated that the seed coat of *A. cretacea* was nearly twice the thickness of that of *A. pinguifolia*

(unpublished data) possibly accounting for their disparate response to dry heat.

Acacia pinguifolia germinated optimally at 20C, and germination declined as temperature increased. Similar results were reported for *A. pulchella* (Bellairs and Bell, 1990), while germination of *A. blakelyi* showed little change over the range 15 to 30C, indicating intra-specific variation in temperature response of *Acacia* seed. Germination rate of *D. subglandulifera* was improved following storage at 15C when compared with seeds germinated immediately after boiling water treatment (data not shown). This suggests that there may be distinct advantages in storing seed for 4 to 6 weeks following dormancy-breaking treatments, resulting in enhanced germination response following subsequent sowing. Both treatment with H_2SO_4 and treatment with just-boiled water yielded similar time-dependant double logarithmic relationships for germination. It is likely, therefore, that both treatments are producing their effect via a common mechanism, that of progressive weakening of the seed coat.

While many *Prostanthera* species will germinate after sowing fresh seed directly onto potting soil (Bonney, 1994), *P. eurybioides* did not germinate without scarification and hormonal pretreatment, and such recalcitrance may be an important factor in the extremely limited regeneration of this species seen in the wild. The improved germination in response to GA suggests that dormancy in this seed may have a physiological as well as a physical component. The physical component could be overcome by treatment with acid, or by infusion of the GA solution into the seed under reduced pressure. This technique of vacuum infiltration has been used successfully on a range of other native species to overcome the effects of mechanical constraints of the seed coat (Loveys and Jusaitis, 1994).

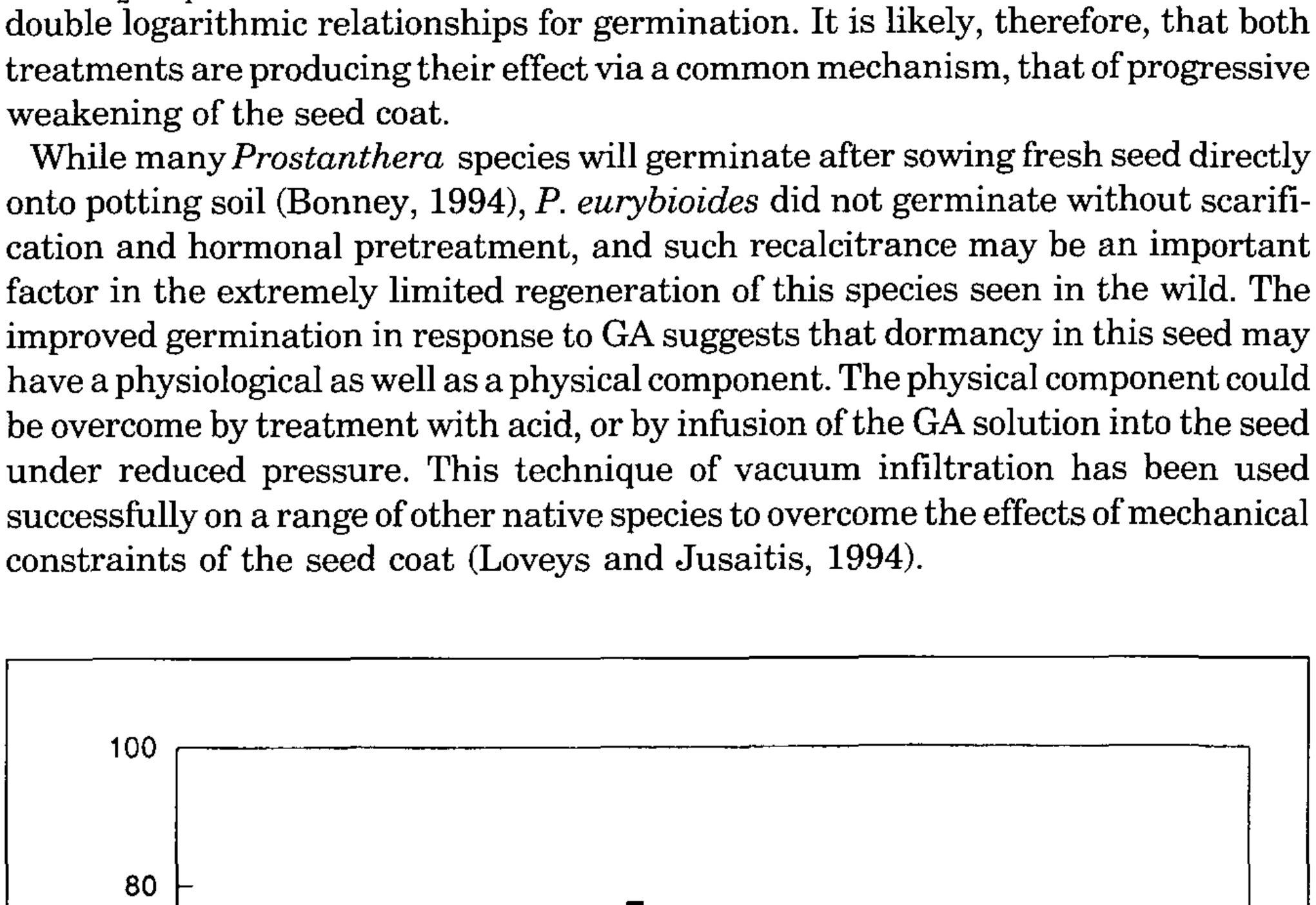

Figure 1. Final percentage germination of pretreated *Dodonaea subglandulifera* seed following storage at 15C for up to 12 weeks.

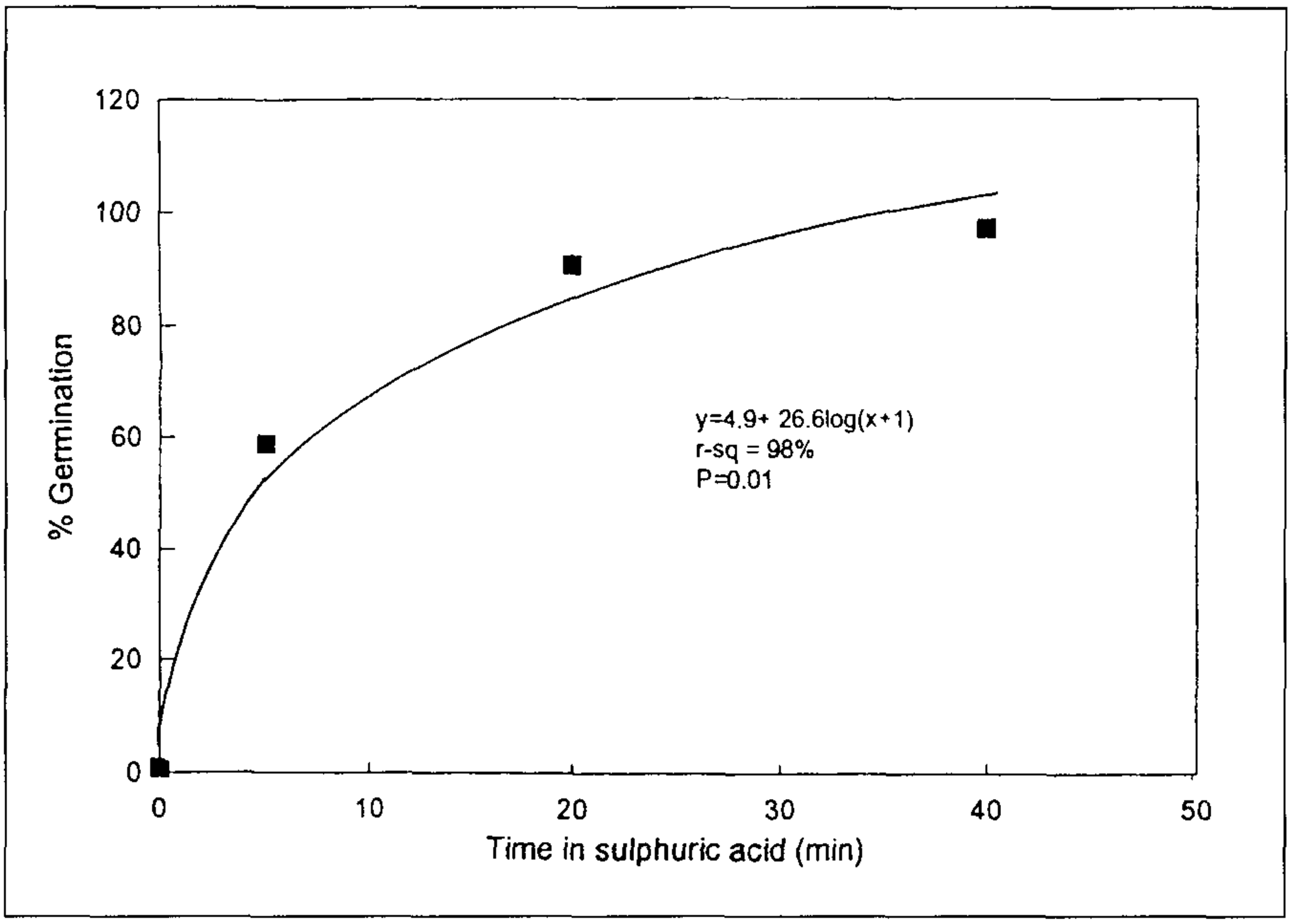

Figure 2. Final percentage germination (after 63 days) of *Pultenaea trichophylla* seed pretreated with concentrated H_2SO_4 for up to 40 min.

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Testing Prevents Disasters

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Imagine the situation in which all of a batch of your most difficult-to-propagate tubestock died soon after potting up because of extreme salinity in the mix. Or imagine the situation in which despite all assurances from your potting mix manufacturer your phosphorus-sensitive plants kept dying in large numbers. Or how about a batch of nice yellow rhododendrons that died, because the supposedly acid mix contained chunks of limestone. Imagine, too, having your income for the year eliminated because your cyclamen seedlings died through suffocation in waterlogged mix.

These are all recent examples of actual disasters in Australian nurseries that could have been prevented through the use of very simple tests that take only minutes of your valuable time. Use of an EC meter, a phosphorus test kit, a pH meter, and a milk carton before potting would have prevented all of these disasters. The $300 cost of this testing gear would have prevented losses of income amounting to well over a million dollars in one case. The incomes of lawyers and companies that manufacture headache relievers would have been reduced. The purpose of this talk is to convince you that:

- Testing is really easy
- Testing is cheap
- Testing can save you big money
- Testing replaces guessing with sound decisions
- Testing can help you to sleep soundly at night, because
- Testing sharpens your management skills, and
- Testing prevents disasters

The emphasis here is on testing before potting, but some of these tests can be used to monitor the plants during the growing period. Here are some details of the tests that you can do.

AIR-FILLED POROSITY

A determination of air-filled porosity (AFP) is spread over a couple of hours, but for 95% of that time a grower can be doing something else. A grower need not spend a cent on the apparatus: simply use a milk carton, a plastic bucket, a kitchen measuring jug, and a baking dish, or ice cream container. However, the nursery will be in business for many years, so a grower will want to use something better than a milk carton. A test vessel that will last forever can be made from two 120-mm lengths of 90-mm diameter PVC pipe and 90-mm cap. The "recipes" for making the vessel and for carrying out the test are given in the Australian Standard for Potting Mixes (Standards Australia, 1993) and in Handreck and Black (1994).

The cost per determination is nil, plus your time. Had the cyclamen grower who lost all seedlings for a year used this test, he would have found that a new brand of peat gave an AFP of only 4%, compared with an AFP of 12% for the previous brand. He would have found another peat or would have modified the formulation of the mix so that its AFP was as needed, or he would have increased the height of the germination containers (Handreck, 1993a)

CHECKING THE CHEMISTRY OF THE MIX

Properties such as pH, EC, and phosphate, ammonium, and nitrate concentrations, are most easily determined on a water extract of the bulk mix. Mix already in pots can also be analysed by this technique, but the "pour-through" technique may be found to be easier. I describe both techniques.

THE VERSATILE WATER EXTRACT OF A MIX

Several key properties of a mix can be determined on one simple water extract. Preparation of the water extract involves the following simple steps:

1) Take a representative sample of the mix and slowly add water to it until you can just hear water squelching when a sample of the moistened mix is squeezed.
2) Measure 50 ml of this moistened mix and put it into a container that will hold at least 150 ml.
3) Add 1.5 volumes (75 ml) of deionised water (or rain water or tap water if it is very pure).
4) Shake or stir the mixture several times, let it sit for 5 min, shake or stir again, and then start testing.

EC and pH. These two tests are absolutely essential and should be done on every batch of mix made or purchased. A pocket-sized EC meter and a pocket-sized pH meter are needed. They may be purchased from hydroponics supply shops or from scientific supply firms. The total cost is about $180 for the two. To determine the pH, simply dip the electrode of the pH meter into the moistened mix and water slurry (1 : 1.5, v/v) and read the digital display. The cost is ½¢ for the water, plus 10¢ for depreciation of the meter over about 1000 samples.

A note of caution is needed. The pH meter must be calibrated against standard pH solutions before it is used for the first time. Instruments may have been set at the factory, but all too often they have gone out of calibration. New ones have been known to be a full 2 pH units wrong! Calibration should also be checked at least once each day that the meter is used.

If only the pH is to be checked a colorimetric pH test kit can be used. To determine the pH with a kit, add a liquid to a small sample of mix, stir, wait 30 seconds, dust the sample with a white powder, and compare the colour produced with patches on the chart. The cost is less than 20¢. The results are interpretted according to the pH requirements of the plants being grown.

For an EC determination, filter the 1 : 1.5 (v/v) slurry through a piece of panty hose held in a small kitchen strainer and dip the meter electrode into the filtrate for a direct reading of the salinity. Total cost is about 10¢. This test will alert growers to events such as excessive release of salts from controlled-release fertilisers in the mix, the use of an excessive amount of soluble fertiliser or, at the other end of the scale, an inadequate supply of soluble nutrients for excellent early plant growth.

An EC of 0.2 dS m^{-1} (deciSiemens per metre) can probably be interpreted as indicating inadequate nutrition, unless a grower is sure that controlled-release fertiliser is still supplying nutrients which are all being taken up by the plants. On the other hand, an EC higher than about 2 dS m^{-1} would probably indicate an excessive level of salts and a need for leaching.

The total time taken to do these two tests will be about 10 min—five of which could be devoted to doing something else—and is very cheap insurance indeed. However, a grower can still go much further with this basic extract.

Phosphate. Every nursery that grows phosphorus-sensitive plants should invest in a kit for determining the phosphate content of their mix before potting. One such kit is the Merck Aquaquant 14449 kit. The filtrate left over from the EC determination can be used. It will probably be rather grubby and need cleaning up by passing it through a slow-filtering paper, such as Whatman No. 54 or 42, held in a small kitchen funnel. Proceed as indicated by the instructions.

The results are interpreted as follows. A concentration of less than 1 mg litre^{-1} is the starvation level for all plants. Three milligrams per litre phosphorus indicates an inadequate supply for most plants, but a non-toxic supply for phosphorus-sensitive plants. A concentration in the approximate range 3 to 6 mg litre^{-1} should be tolerated by plants that are only moderately sensitive to phosphorus. It will be a useful starting amount for other plants. Higher concentrations are unsuitable for plants that have any sensitivity to phosphorus. Concentrations over 40 mg litre^{-1} may indicate an excessive and even toxic supply to many plants (See Handreck and Anderson, 1994 for details).

Ammonium for Propagators. Some seedlings and recently-rooted cuttings are very sensitive to ammonium ions in the mix around their roots. The Australian Standard reflects experience in requiring that mixes for young plants contain less than 50 mg litre^{-1} nitrogen in ammonium form in a 1 : 1.5 (v/v) water extract. The filtrate is prepared as described for the phosphate determination, or the filtrate in the tube to which chemical had not been added for the phosphate determination can be used. A Merckoquant ammonium test kit or similar kit is needed.

Nitrate in the Extract. Nitrate is determined with Merckoquant or similar test strips. A strip is simply dipped into the filtered extract and the colour of the lower paper patch on the strip is read against the colour code provided. Since the reading is for nitrate, actual nitrogen (in nitrate form) is obtained by multiplying the strip reading by 0.226. Some interpretation guidelines for nitrogen are as follows:

- A zero nitrate figure on top of a zero ammonium figure indicates that the mix contains no soluble nitrogen. Therefore, some soluble nitrogen should be added to newly planted small plants so they can start growing before their roots make contact with granules of controlled-release fertiliser.
- A zero or low nitrate figure and a high ammonium figures can indicate that the mix has been made with incompletely composted materials. Its pH may drop sharply soon after potting as ammonium is converted to nitrate.
- Any colour in the upper patch on the nitrate test strip indicates the presence of nitrite in the mix. This is a sure sign of anaerobic conditions and/or incomplete composting. Don't use the mix until it has had time to mature.
- A nitrate concentration in the 100 to 200 mg litre^{-1} range, together with some ammonium, indicates a good early supply of soluble nitrogen.

Other Tests on the Extract? A really keen grower could buy further test kits (for over $1000) that would allow determining concentrations of potassium, sulphur, calcium, and magnesium in the extract. I suggest that this is a waste of money for most nurseries. Analysis for trace elements requires use of an extractant other than

water and the use of specialised laboratory instruments—this should be left to the professionals.

Those who make their own mix are strongly encouraged to occasionally have the mix tested by a laboratory. Certainly this must be done when first formulating a mix. Further checking should be done annually and when one of the components has changed. Ask for analysis according to the methods of the Australian Standard. The less than $200 cost could well save thousands of dollars.

THE POUR-THROUGH TECHNIQUE

The pour-through technique may be used to roughly assess the current pH, EC, and soluble nutrient status of a mix already in a container. A few hours (or the afternoon) before the actual test, pour water onto each of a few pots in the batch to be tested. Pour on enough so that just a little drainage occurs when the pot is tilted. At the time chosen for sample collection pour sufficient water onto the mix surface to give 10 to 15 ml of drainage. The aim is to displace some of the water in the pot. Don't add so much that the added water flows all the way through the mix.

EC and pH are determined directly on the displaced water. For tests for phosphate, ammonium, and nitrate (if needed) the water may need to be filtered. The testing procedures are then as given above for the 1 : 1.5 (v/v) extract. The results give data for the lowermost part of the root ball. Thus, if there is a strong pH profile in the pot, the pH obtained with this technique will be that of this lowermost mix, rather than an average for the whole pot (Handreck 1994). A grower may sometimes need to check the rest of the mix with the 1:1.5 (v/v) method.

Because you are dealing with displaced water rather than a dilution of that water, interpretation for EC and soluble nutrients has to be against different figures. Usually, the EC and nutrient concentrations will be about four times those for an extract for a similar interpretation.

TOXICITY TEST

Pine barks and many sawdusts contain natural chemicals that are toxic to the roots of plants transplanted into them. Aging (for pine barks) and composting (for both) convert these toxins to harmless compounds. It is now rare to find toxicity in commercial mixes, but home-made mixes should be checked before use. Fill some of the mix into a small pot. Into another similar pot fill some thoroughly matured mix that you know is not toxic. Onto the surfaces of each mix place about 10 to 20 radish or cress seeds. Water, loosely cover each pot with clear plastic sheet, and place the pots in a warm place out of direct sun. After 3 to 5 days compare germination and root growth. The new mix should give at least 75% of the root growth found in the matured mix. Any mix that gives markedly lower root growth should be allowed to mature before use.

WETTABILITY

During the dry part of the year, any tendency for potting mix in pots to dry out may lead to it not being fully rewet at the next watering, if it is water-repellent. A gradual loss of water-holding capacity will lead to a lower growth rate and even plant death. This can be avoided through the addition of a wetting agent to the mix before potting, or later as a drench. A grower can easily check whether a wetting agent is needed. Place a sample of mix in a shallow vessel, such as the aluminum dishes in which

cakes are sold, and dry it at 40C. Putting the dish of mix in a warm place for a couple of days, or in the sun, may be suitable. When it is dry, form a shallow depression in its surface with an electric light globe. Pour 10 ml of water into this hollow and note the time that it takes for the water to soak in. The finish point is judged by slight tilting of the dish. Any movement of water indicates a need for more soaking time. A grower should consider using a wetting agent if soak-in time is longer than about 1 min.

NITROGEN DRAWDOWN

The nitrogen drawdown index (NDI) test measures the amount of soluble nitrogen that is being used by microbes as they decompose the woody components of the mix. The lower the index number (on a scale of 1 to 0) the greater the amount of soluble nitrogen being used and the greater the amount of fertiliser nitrogen that is needed to compensate for this drawdown.

A detailed recipe of the method may be found in publications by Standards Australia (1993), Handreck (1991, 1992, 1993b), Handreck and Black (1994), and Bodman and Sharman (1993).

I urge those who produce their own mixes to use and apply this test. Technically competent manufacturers will be able to tell you the NDI of their mix.

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The Use of Mycorrhizal Fungi During Propagation

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INTRODUCTION

It will be well known to some nurserymen that many of the Cupressaceae family of plants are somewhat slow and difficult to propagate (Blythe, 1989). Callus tissue readily forms on the base of cuttings, gradually turning from a white to dark-brown colour, growing slowly larger to a final size of up to 20 mm in width. The cutting may remain in this state for over 12 months, the foliage still retaining a healthy appearance. This problem is also common in other genera, such as, *Grevillea* and *Hakea*. Our interest in this phenomenon arose after the discovery of a seedling variant of *Cupressus arizonica* var. *glabra* named 'Limelight' in the nursery 9 years ago. It also has a tendency to form a callus without readily forming roots. This paper reports the use of mycorrhizal fungi as an aid to root initiation in *Cupressus arizonica* var. *glabra* 'Limelight' at both fresh-cutting and callused stages. In this paper we refer to two main types of mycorrhizae. These are ectomycorrhizae and endomycorrhizae—hereafter referred to as "EctoM" and "EndoM". The EndoM fungi penetrate roots to form characteristic intracellular bodies called vesicles and arbuscles, hence the term VAM applies to EndoM. Moisture and nutrients are transferred from the fungus to the plant. The plant roots provide a source of carbohydrate for the fungus. This is a beneficial (symbiotic) relationship which occurs in about 80% of all vascular plants (Malloch et al., 1980). The EctoM fungi do not penetrate living cells in the roots but instead surround them, forming a sheath which is visible to the naked eye. Moisture and nutrients are transferred as in EndoM. EctoM have a distinctive fruiting body similar to a mushroom, which protrudes above the soil-line. EndoM, however, are rarely visible to the naked eye.

MATERIALS AND METHODS

In 1992, when reading through the index of past I.P.P.S. Proceedings, I noticed that there were a few papers written on the use of mycorrhizal fungi in plant propagation (Linderman and Call, 1977; Dangerfield, 1975; Verkade, 1986). It was then decided to research the subject more thoroughly. Initial inquiries were made with Kevin Handreck at the I.P.P.S. Albury Conference in 1993 in an attempt to locate a source of mycorrhizal fungi. Dr. Clem Kuek, Senior Lecturer at the University of Western Sydney, was recommended. Dr. Kuek is well known for his work on EctoM fungi and the resultant use of the inoculum Mycobead in *Eucalyptus* plantations in Western Australia.

It was also recommended that we contact a company in the United Kingdom named MicroBio Ltd., who produce the EndoM inoculum Vaminoc. Through their extensive grower trial program throughout Western Europe, they demonstrated the benefits of using VAM at the propagation stage in coniferous plants (Cargeeg, 1994). Benefits included increased root and shoot dry weights and a reduction of certain pathogenic fungi. Although literature seemed to indicate that the genus *Cupressus* was host to the EctoM (Malloch et al., 1980), a research scientist for MicroBio, Mr. Piran Cargeeg, suggested we trial Vaminoc, which had proven

beneficial in the propagation of conifers in European studies.

Coinciding with this was the discovery of four naturally occurring EctoM fungi fruiting bodies (Basidia) around the roots of containerized 'Limelight' stock plants at Coachwood Nursery. These unidentified fungi were collected, numbered M1, M2, M3, and M4, and sent the same day to Dr. Clem Kuek who was able to culture each one on sterile agar plates for future inoculation. In all, five separate experiments were carried out during which it was decided to discontinue the use of M2 due to its inefficacy. This paper concerns one of these five trials.

In September 1994, an experiment was formulated to evaluate the effect of M1, M3, M4, and Vaminoc on the rooting of 'Limelight' cuttings. Both fresh and callused cuttings were tested. The presence of rooting hormone IBA 0.8% powder formulation was also tested to see whether or not this would enhance the effect of the mycorrhizal fungi on the cuttings. A bottom heat of 26C was maintained throughout in a plastic-covered propagation house with 50% shading. The cutting medium consisted of perlite, milled coconut fibre, and fine kaolite (6:2:2, by volume). One hundred cuttings were stuck in each tray and placed onto sand beds under intermittent mist. Fresh cuttings were collected the same day from hard-pruned, in-ground stock plants. Callused cuttings were collected the same day from trays of cuttings which had been stuck 10 weeks previously. After 10 weeks the cuttings were removed, washed, and inspected for the presence of roots. Those with roots were root pruned to within 1 cm of the stem and the roots weighed. Standard nursery hygiene was maintained at all times with no fungicides of any type being used to minimise any losses to the inocula.

PREPARATION AND INOCULATION OF MYCORRHIZAE

Ectomycorrhizal Fungi M1, M3, and M4. These three mushroom-type fungi (Basidiomycetes) were cultured on agar plates. Ten plates of each fungus were

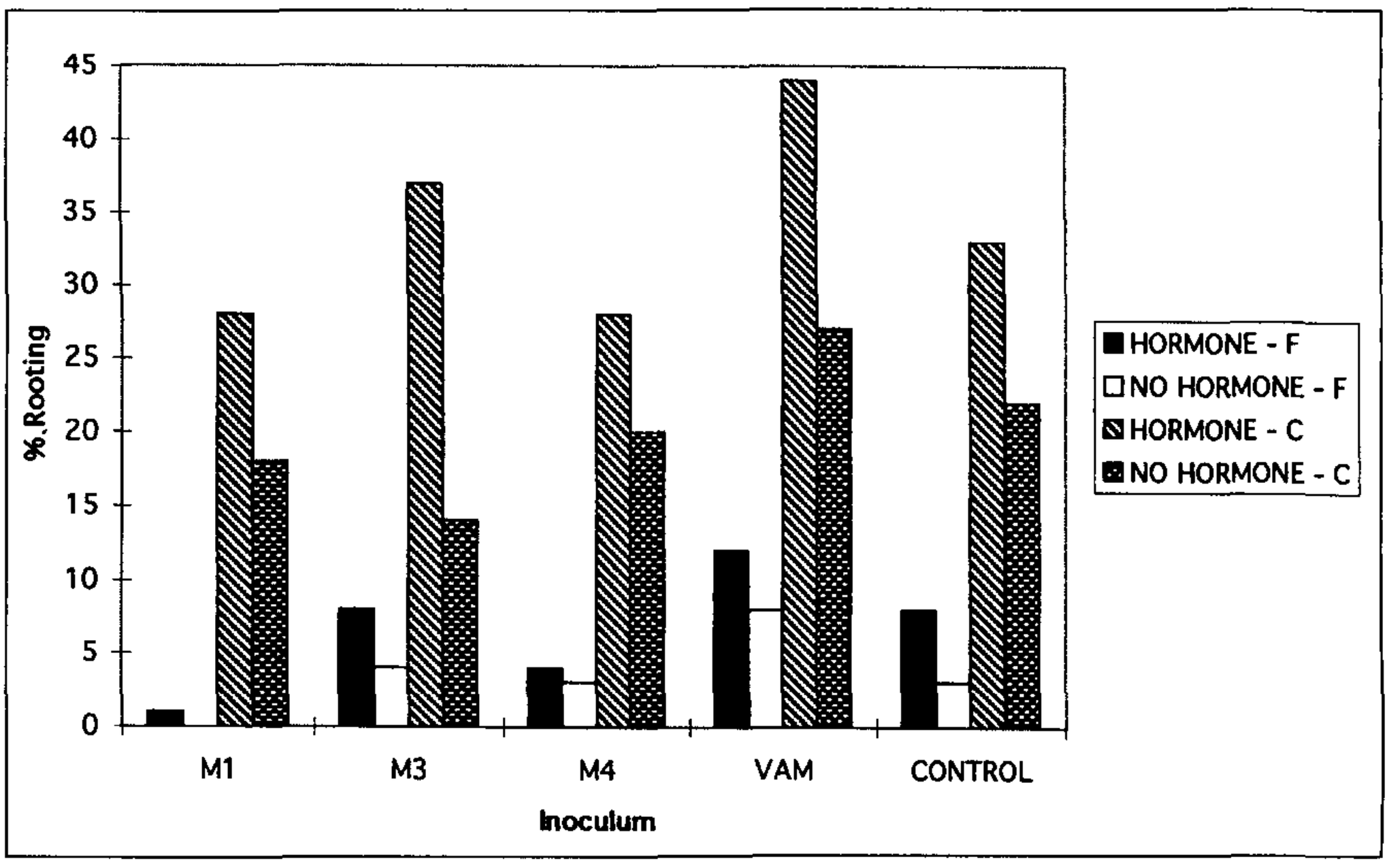

Figure 1. Effect of inocula on root formation (% rooting) with fresh (F) and callused (C) cuttings.

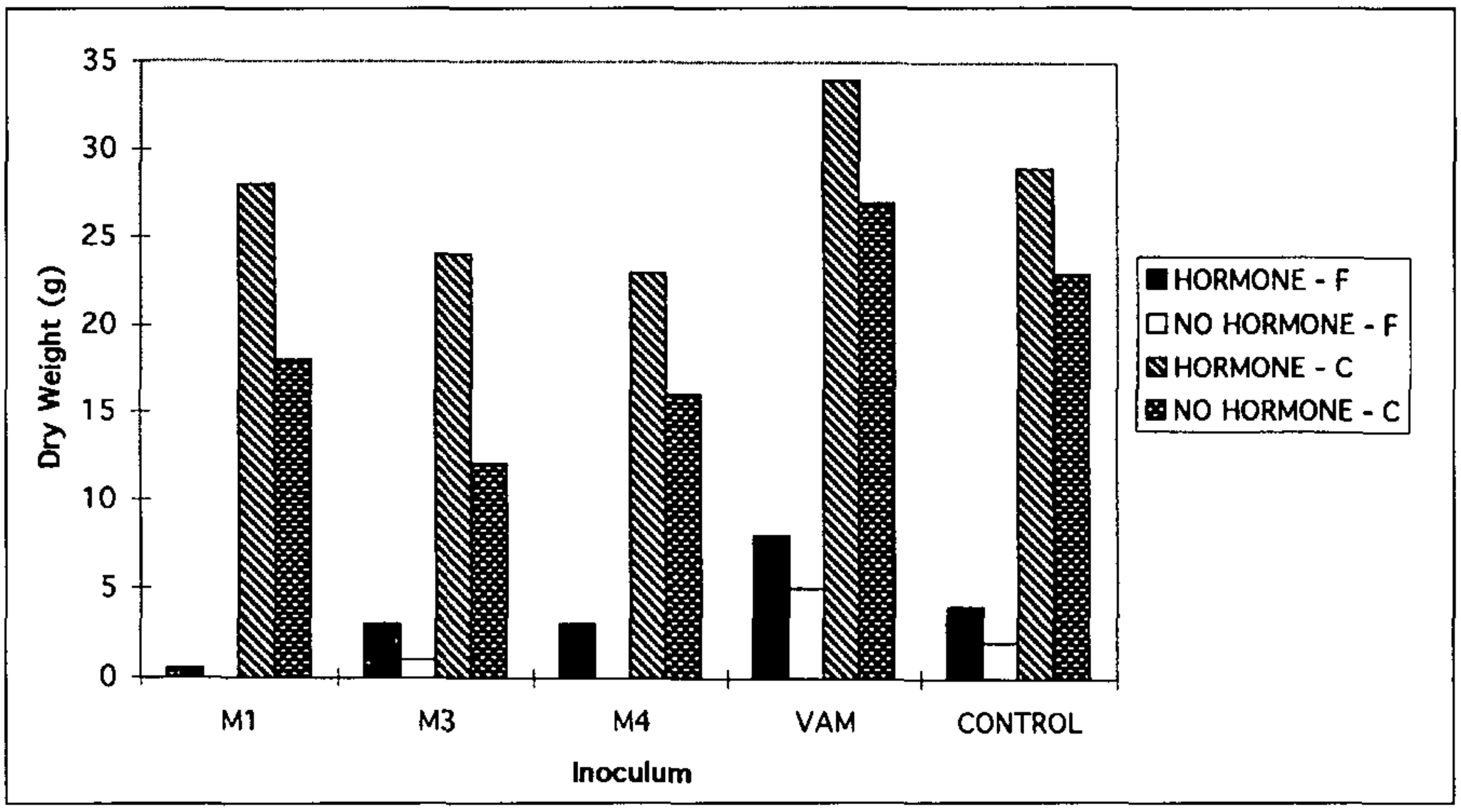

Figure 2. Effect of inocula on root formation (dry weight) with fresh (F) and callused (C) cuttings.

blended with 500 ml of rain water to produce a gel which could be poured directly into trenches. Cuttings were placed directly onto the gel and back-filled with cutting medium.

Endomycorrhizal Fungus Vaminoc. This commercial formulation was in granular form, 2 mm or less in size. It was advised in the guidelines sent to us to direct drill the granules into the cutting medium so that direct contact with the cuttings would be made. This procedure was followed by pouring Vaminoc into trenches, sticking the cuttings directly onto the granules, and back-filling. The recommended rate of 1 g per cutting was used.

RESULTS

The results of this experiment are shown in Figures 1 and 2. The addition of M1, M3, and M4 into the cutting medium did not result in an increase in rooting percentage or dry weight of roots compared to the control, except when M3 was used in combination with hormone on callused cuttings. In each case the addition of hormone increased rooting as expected, however, the cuttings with added M3 exhibited the greatest response. M1 and M4 were less effective than the control on fresh and callused cuttings, with or without hormone. On callused cuttings M4 was comparable to M1 in strike rate but M4 produced slightly less root dry weight. Vaminoc (VAM) was the only inoculum to give an increase in rooting percentage and dry weight compared to the control. VAM with hormone resulted in 12% rooting on fresh cuttings and 44% on callused cuttings. The control yielded 8% on fresh cuttings and 33% on callused cuttings. It was also observed that losses due to fungal infection decreased when the inoculum was present. VAM had almost no losses, M3 and M4 only some, while M1 was similar to the control.

DISCUSSION

The results show that rooting of 'Limelight' is greatest when previously callused cuttings are used. This is to be expected as callus formation is simply a stage closer

to root initiation than fresh cuttings. The fact that M1 and M4 suppressed root formation is interesting. It indicates that they may not form a mycorrhizal association with 'Limelight'. The fact that the fungi were growing in the containers of the plants may be due to the presence of composted pine bark and sedge peat in the potting media. This could provide the fungus with a short-term niche until a suitable host is found (Gianinazzi et al., 1986; Patterson et al., 1986). It would be difficult to explain the presence of the fungi in the containers any other way. They certainly could not have originated on the roots of the plants, as the plants had been grown in every stage in soilless media. The very fact that EctoM can be cultured *in vitro* indicates that they can exist for some time without a suitable host. Even if M1 and M4 are mycorrhizal with 'Limelight', they may be host-specific when it comes to root enhancement. This has been shown in previous trials (Linderman and Call, 1977).

The observed enhancement of rooting in M3 when hormone was added could be due to the catalytic effect which was observed by Linderman (1978). Mycorrhizae produce auxins, cytokinins, gibberellins, and B vitamins in vitro. The presence of one or more of these may in turn enhance mycorrhizal development. However, it is difficult to draw any firm conclusions in this area as the precise way in which mycorrhizae and growth regulators interact is still largely unknown. The fact that M1 and M4 showed a significant increase in rooting (much more pronounced than either M3, VAM, or control) when callused cuttings were used, indicates that these fungi need root tissue to become effective. Callus growth while not root tissue as such, is the stage immediately preceding it. Perhaps the fungi were able to extract the necessary nutrient from the callus to commence the symbiotic process which resulted in root formation. Careful examination under magnification may reveal this in future work.

The most successful inoculum in every case was Vaminoc. This result was not expected as previous literature had indicated that the genus *Cupressus* had a host-specific grouping of EctoM fungi (Malloch et al., 1980). However these results seem to concur with more recent work which suggests that some genera normally considered ectomycorrhizal are readily infected by VAM fungi, especially early in the growth phase (Cargeeg, 1994).The increase in percent rooting and dry weight occurred whether or not hormonewas used. It is possible therefore, that the VAM fungi produce root-promoting substances as mentioned earlier, or they infect the cells of the cutting/callus before roots form, resulting in increased rooting.

CONCLUSION

The use of M1, M3, and M4 in the form of agar gel is cumbersome and time consuming, and the results of the trials do not justify their use in 'Limelight' propagation. A more useable formulation such as Mycobead developed by Biosynthetica, would be necessary before commercial use could be considered. Further research needs to be carried out in relation to EctoM and its effect on root growth, particularly after root initiation, as this may be where its real value lies. Vaminoc in the granular form was easy to apply and gave an increase in rooting which justifies further investigation as an aid to propagating species known to be slow or difficult to propagate by conventional methods. The results of this trial indicate that there is significant potential in the ongoing use of mycorrhizal fungi in the field of plant propagation and in the horticultural industry generally.

ACKNOWLEDGMENTS

Dr. Kevin Handreck for help in accessing information on the supply of inocula. Dr. Clem Kuek for technical information and the supply of ectomycorrhizal inocula. Dr. R.D. Cargeeg and MicroBio for technical information and the supply of endomycorrhizal inoculum Vaminoc.

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In Situ Seed Germination for Rehabilitation of Waste Fly Ash

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INTRODUCTION

The coal-fired power station at Port Augusta in South Australia generates 600,000 tonnes of fly-ash waste each year.

Establishment of a vegetative cover on fly-ash lagoons would stabilise the surface against erosion and considerably improve its microclimate and aesthetics. Plants were required to tolerate the saline and alkaline medium, as well as the hot dry climate and prevailing strong winds at the site. Direct seeding was considered to be an efficient method for revegetating the large areas involved, but little information was available on the germination success of plants sown directly into fly ash, although several reports had demonstrated the feasibility of growing plants on fly ash or fly-ash-amended soils (Holliday et al., 1958; Meecham and Bell, 1977; Rees and Sidrak,1956).

Initial screening of seeds for germination and growth on fly ash, or on fly-ash/soil mixtures and overlays was performed in glasshouse pot trials (Pillman and Jusaitis, 1991). The most promising species were subsequently tested in field trials on the fly-ash lagoons at Port Augusta. Germination and early growth in glasshouse pot trials were much improved if a 3- to 4-cm layer of sandy topsoil was spread over the fly-ash surface as an overlay, and seed was sown into this layer. Early attempts at establishing plants from seed using this technique in situ were hampered by severe winds which eroded a large proportion of the surface layers and seed within a month of sowing. This paper describes the results of field trials designed to screen a range of plant species for their ability to germinate and grow on fly ash, and discusses techniques for surface amelioration to optimise germination, establishment, and growth of plants following direct seeding.

MATERIALS AND METHODS

Most seeds were collected from volunteer species which grew around the edges of fly-ash lagoons or in salt flats at Port Augusta, and from species growing on and around the overburden heaps at Leigh Creek where the parent coal was mined. Plants growing in these areas already showed tolerance to the arid climate and soils containing salt or black coal, and were expected to have a better-than-average chance of germinating and surviving on ash. *Medicago* spp. were purchased from a commercial seed supplier.

A field trial site on relatively fresh fly ash (2 years old) was prepared by deep ripping, leaving the surface in an uneven condition to encourage seed lodgement, and to provide early wind protection for seedlings. The following surface amelioration treatments were randomly assigned to 8 × 1 m plots (separated by 2-m buffer zones) within each of three replicates:

1) Untreated fly ash (control).
2) Approximately 70% of fly-ash surface covered by rocks (50 to 150 mm diameter).
3) Organic mulch (chipped tree prunings) spread 30 to 50 mm deep over fly ash.
4) Hydromulch (an aqueous suspension of pulped, recycled paper) sprayed in a

thin layer over the fly-ash surface.

5) Niche (250 mm high × 500 mm wide mound running the length of the plot with a 100 mm deep furrow at its apex containing the seed), seed covered with hydromulch.

6) Niche (as for 5), seed covered with fine gravel.

7) Local sandy topsoil spread 50 to 100 mm thick over fly ash and stabilised with woven erosion control fabric (Oystershade).

8) Local sandy topsoil spread 50 to 100 mm thick over fly ash and stabilised with hydromulch.

9) Compost plus mulch treatment (an organic compost developed from water filtration sludge was spread to a depth of 100 mm before being rotary-hoed into the upper 150 mm of ash. A further 100 mm layer of compost was spread over this and covered with a 20- to 30-mm deep layer of coarse pine splinters to reduce wind erosion).

A seed mixture of 16 plant species (in the proportions shown in Table 1) was sown without any pretreatment. The number of each species to germinate in a randomly selected 1 × 1 m quadrant was recorded at regular intervals.

RESULTS

The germination performance of the 16 plant species on pure fly ash and on amelioration treatments is shown in Table 1. Only *Minuria cunninghamii* failed to germinate at all across the site. The dominant species across all treatments were *Atriplex lindleyi, Enchylaena tomentosa, Mesembryanthemum nodiflorum* and *Nitraria billardieri*, each with over 300 seedlings surviving a year after sowing (Table 1). *Nitraria billardieri* and *Scaevola collaris* were slow to germinate, with germinants still appearing over a year after sowing. *Mesembryanthemum* spp., *A. holocarpa, E. tomentosa, Medicago* spp. and *N. billardieri* were all observed to germinate on pure fly ash, although only *M. aitonis* and *N. billardieri* still survived on this medium when assessed 12 months after sowing.

The majority of sown species germinated and survived for over a year on sand plus fabric, sand plus hydromulch and compost plus mulch (Table 2). Over 18% of species germinated on pure fly ash, but only 2% survived for 12 months on this medium. The proportion of species surviving after a year was less in all treatments than the maximum proportion to have germinated during the course of the year. This reduction was proportionately less in treatments 7 to 9, where a layer of sand or compost enabled plant roots to become established before coming into contact with fly ash. Similarly, plant numbers per unit area were maximised in overlay treatments, with the most dense growth being observed in sand plus fabric and compost plus mulch treatments.

DISCUSSION

Fly ash reduced not only germination rate and percentage, but also growth and survival of plant species tested in this trial.

Table 1. Seed germination and plant survival on fly ash and amelioration treatments over all replicates.

Family	Genus/species	Seed sown (g/m^2)	Germination		Number of plants at 15 months [1]
			Fly ash	Fly ash-soil [2]	
Aizoaceae	*Mesembryanthemum aitonis*	0.03	**	**	5
	M. nodiflorum	0.03	*	**	311
Chenopodiaceae	*Atriplex holocarpa*	0.2	*	**	54
	A. lindleyi	0.6	-	**	300
	A. vesicaria	0.5	-	**	178
	Enchylaena tomentosa	2.5	*	**	355
	Halosarcia halocnemoides	0.2	-	**	16[3]
	H. pergranulata	0.2	-	**	
	Maireana pyramidata	0.4	-	**	2
Compositae	*Minuria cunninghamii*	0.01	-	-	0
Goodeniaceae	*Scaevola collaris*	1.9	-	**	55
Gramineae	*Danthonia caespitosa*	0.02	-	*	0
Leguminosae	*Acacia victoriae*	0.3	-	*	0
	Medicago truncatula 'Parabinga'	0.5	*	*	0
	M. polymorpha 'Serena'	0.5	*	**	39
Zygophyllaceae	*Nitraria billardieri*	0.7	**	**	358

[1]Total number of surviving plants over the whole trial site (all treatments) at termination of the trial.
[2]Fly-ash soil includes any of the fly ash amelioration treatments tested, excluding the control.
[3]Seedlings of *Halosarcia* species were difficult to distinguish to species level and hence data refer to the genera rather than to individual species.
** indicates that seed germinated and plants were alive at 12 months after sowing.
* indicates that seed germinated but seedlings failed to survive to 12 months after sowing.
- dash indicates that no germinants were observed.

Table 2. Proportion of sown species that germinated and survived during the first year on the fly-ash amelioration treatments, and the number of plants (all species) surviving in each treatment at the termination of the trial.

Treatment	Maximum species germinated (%)	Species surviving after 12 months (%)	Number plants/m^2
1. Untreated	18.8 a [1]	2.1 a	0.1 a
2. Rock mulch	22.9 a	12.5 a	1.4 a
3. Organic mulch	39.6 ab	0.0 a	0.0 a
4. Hydromulch	33.3 ab	14.6 a	1.4 a
5. Niche + hydromulch	45.8 abc	12.5 a	1.3 a
6. Niche + gravel	43.8 ab	6.3 a	0.2 a
7. Sand + fabric	75.0 cd	70.8 c	31.8 c
8. Sand + hydromulch	58.3 bd	52.1 bc	9.3 b
9. Compost + mulch	54.2 bd	45.8 b	24.0 bc

[1]Mean separation within columns by Fisher's l.s.d. (P=0.05) calculated on untransformed data (except for number of plants per m^2 which was calculated on Log_{10} transformed data).

Of the surface amelioration treatments, sand or compost overlays were outstanding in terms of maximising the species range for germination and plant survival. Sand-overlay treatments supported germination rates equivalent to those on compost plus mulch but did not sustain the long-term growth rate or dry matter production observed on the latter (Jusaitis and Pillman, unpublished). The compost overlay treatment had the added advantages of extra thickness, partial incorporation with the ash surface, improved physical (aeration and water retention) and nutritional characteristics, and a cover of pine splinters.

Neither organic mulch nor rock mulch significantly improved germination or survival above controls, suggesting that their effects on surface microclimate were insufficiently beneficial to warrant their use in isolation. They may nevertheless prove more successful if applied onto an overlay treatment rather than directly onto ash.

The niche treatments did not significantly enhance germination, growth, or survival above control levels. The niche technique was developed for revegetation of salt-affected areas, and its effectiveness purportedly relies on the reduction of salinity in the germination zone as a result of concentrated leaching. The lack of response to this treatment suggested that fly-ash salinity levels were unlikely to be solely responsible for the poor performance of plants on control plots.

Hydromulch and erosion-control fabric were applied primarily in attempts to protect seed and germination zones from the effects of wind erosion. To that extent they were both successful, since preliminary trials using uncultivated fly ash or sand overlays alone supported no germinants or were severely eroded by wind respectively. Hydromulch was a more effective and longer lasting surface stabiliser

than bitumen emulsion seal, which reportedly lasted for only two weeks under strong winds (Junor, 1978). Applied directly to fly ash, however, hydromulch provided no germination advantage over controls.

The benefits of surface stabilisation really become apparent when used in conjunction with overlay treatments. When applied in combination with a sand overlay, significantly more plants were established from seed under erosion control fabric (oystershade) than under hydromulch (Table 2). Field observations established that the wind protection afforded to the sand surface by fabric was superior to that by hydromulch, since the latter was not always applied at consistently uniform thickness, leading to small pockets of erosion (pitting). Although the fabric's structure began to disintegrate after the first year's use, sufficient vegetative cover would have established by that time to reduce future erosive effects of wind. Of the three stabilisation materials applied to overlay treatments (treatments 7 to 9), pine mulch was the most enduring.

By improving the physical characteristics of the growth medium and diluting the effects of salinity and nutrient toxicity, overlays encouraged rapid germination and active winter growth, allowing plants to build up sufficient reserves to survive the summer. While this study found that overlays of sandy soils required stabilisation against wind erosion, work at another windy fly-ash site demonstrated that heavy clay to loam soils containing shales and sandstone rocks made equally effective overlays and could be used without any additional stabilisation (Junor, 1978).

Most plant families tested showed some predilection for germination and growth on fly ash or amelioration treatments. It was not unexpected that the plants showing most promise in this dry, saline environment were from the largely xerophytic and halophytic families Aizoaceae, Chenopodiaceae, and Zygophyllaceae. On the basis of this study, the species most suited for fly-ash revegetation were *Mesembryanthemum aitonis, M. nodiflorum, Atriplex holocarpa, A. lindleyi, A. vesicaria, Enchylaena tomentosa, Halosarcia halocnemoides, H. pergranulata, Scaevola collaris*, and *Nitraria billardieri*. These species all occurred naturally around the Port Augusta power station and were also found as volunteers encroaching onto the edges of ash ponds and surrounding levee banks.

ACKNOWLEDGMENTS

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Mycorrhizae of the Epacridaceae and Its Use in Propagation

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INTRODUCTION

Mycorrhizae benefit several commercially produced plants (Galea and Poli, 1994). This paper is a brief overview of mycorrhiza of the Epacridaceae and how they may be used in propagation. Members of the Epacridaceae are difficult to propagate (Thompson, 1986; Williams, 1986). The seeds in some species are extremely small and are not used in propagation, although they appear to germinate readily in the wild (Reed, 1989). Germination rates can be as low as 3% to 7% with *Epacris impressa* Labill. Cuttings are the usual method of propagation; however, success varies enormously—between 0% and 100%. With low survival rates and losses at planting out several attractive epacrids are not grown commercially. This is unfortunate as there is a large public demand for them.

Anecdotal evidence suggested that adding soil from beneath established plants improved the strike rate of epacrids, suggesting that the mycorrhizae which are present in all epacrid roots play a role in establishment. Research was undertaken to investigate the use of mycorrhizae in propagation of *Epacris impressa* and other members of the family. Before continuing with the results of the experiment, it is necessary to review the structure of mycorrhizae and discuss how they benefit plants.

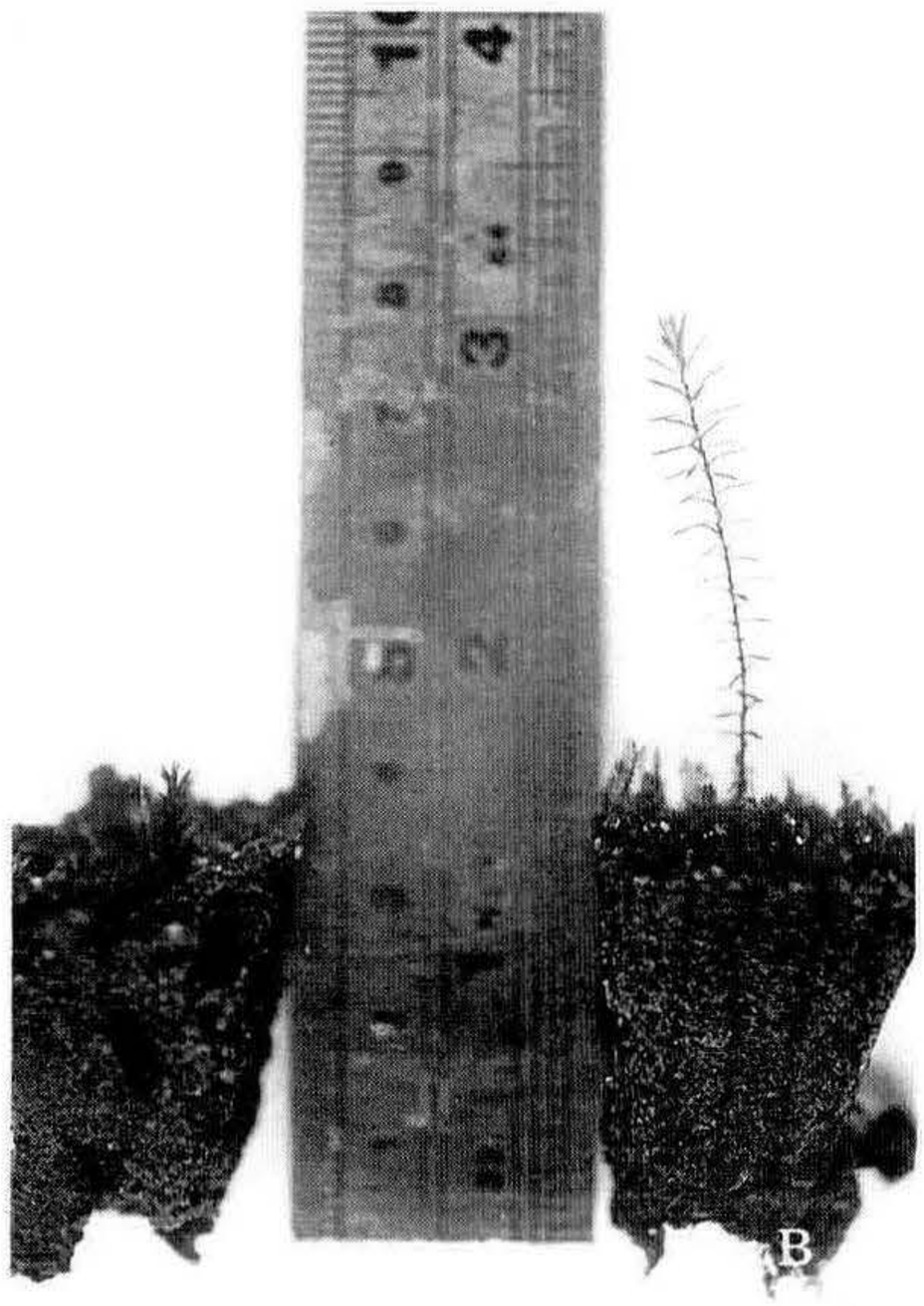

Figure 1. Six-week-old seedlings of *Epacris impressa* grown in non-mycorrhizal (A) and mycorrhizal (B) soils.

MYCORRHIZAL FUNGI

Mycorrhizae are capable of forming a mutually beneficial relationship with the roots of plants (Harley and Smith 1983). Plants that have mycorrhizal relationships are larger and healthier than non-mycorrhizal plants due to increased uptake of water and nutrients, especially nitrogen and phosphorus (Fig. 1). The relationships can be complex, with more than one mycorrhizal fungus inside a plant's roots simultaneously.

Although there are differences in morphology, mycorrhizae can be divided into two broad groups: ectomycorrhizae and endomycorrhizae. Ectomycorrhizal fungi do not penetrate the cortical cells of the root but form a fungal sheath and network of hyphae around the root. This type of relationship is found in woody plants such as Fagaceae, Myrtaceae, and Pinaceae.

In endomycorrhizal relationships the fungus penetrates beyond the epidermis and forms structures in the cortical cells. Several commercially important plants have this type of relationship, such as *Grevillea* spp., *Chamelaucium uncinatum*, and *Impatiens walleriana* (Galea and Poli, 1994). Some plants, such as eucalypts, can have both ectomycorrhizal and endomycorrhizal mycorrhizae simultaneously.

ERICOID MYCORRHIZA

Over the past 30 years there has been extensive research into the identity and culture of ericoid fungi and into the physiological aspects of the relationship in the Ericaceae. Due to similarities in ancestry and structure with Ericaceae, many assumptions have been made about the role of mycorrhizae in the Epacridaceae.

The Epacridaceae and Ericaceae have a similar root structure.These simple roots are described as "hair roots", consisting of a central vascular stele with one or two rows of cortical cells (Harley and Smith, 1983). The mycorrhizal fungus forms a fine weft of hyphae over the root as well as internal structures variously described as arbuscules, coils, or peletons.

Ericoid mycorrhizal fungi can synthesise the plant hormone IAA from the amino acid tryptophan in culture, suggesting a possible role in root initiation in the Ericaceae (Berta and Gianninazzi-Pearson, 1986; Gay and Debaud 1986). This may have implications for nursery production of epacrids.

MYCORRHIZAE AND PROPAGATION OF EPACRIDS

Research was undertaken to determine if mycorrhizae could increase the strike rate and improve rooting in *E. impressa* collected from the Royal Botanic Gardens Annexe at Cranbourne, Victoria. As no pure culture of the fungus was available, soil taken from underneath established plants in the wild was added to pasteurised potting mix into which the cuttings were placed. The presence of mycorrhiza improved the strike rate and health of cuttings (Table 1), but the root areas of mycorrhizal and non-mycorrhizal plants were not significantly different (McLean et al., 1994).

Table 1. Effect of soil inoculum on survival and development of cuttings of *Epacris impressa*. Figures with the same letters are not significantly different in each column by GLIM analysis using binomial (survival, roots) or Poisson (health, root area) data.

	Survival (%)	Health (%)	Strike rate (%)	Mean root area (cm^2) per cutting	Mycorrhizae (% present per cutting)
Inoculum	88a	80a	56a	1.32a	89
No inoculum	66b	46b	44b	1.20a	0

(Data from McLean et al., 1994)

Further research investigated whether other epacrid cuttings responded favourably to the addition of soil containing mycorrhizae. Cuttings of *Astroloma pinifolium* R.

Br., *A. conostephioides* (Sond.) Benth, *Brachyloma daphnoides* (Sm.) Benth., *Styphelia adscendens* R. Br, and *Epacris impressa* from a site in the Grampians were propagated in mix with and without mycorrhizal inoculum.

Increased strike rate and health of cuttings grown in soil containing mycorrhizal inoculum has been observed for *A. pinifolium*, *E. impressa*, and *S. adscendens*. *Astroloma conostephioides* and *S. adscendens* have not shown a significant difference between mycorrhizal and non-mycorrhizal cuttings.

Results from both experiments suggest that the difficulties in propagating these epacrids may be overcome by adding soil containing mycorrhizae. However, using soil as inoculum is not satisfactory for nursery production since it may introduce plant pathogens. It is therefore necessary to produce the fungi in pure culture. If different plants require specific mycorrhizal fungi for growth, inoculation becomes a complicated procedure. However, recent research suggests that this may not be the case (McLean and Lawrie, 1996).

There is likely to be more than one mycorrhizal fungus infecting epacrid roots. At least two morphologically different types of mycorrhizae have been observed in the roots of eight epacrids from three sites. At two of the sites (Cranbourne and Rye) the endophyte had a similar morphology and size (diameter of hyphae). However, at the Grampians' site the morphology of the fungus was different and the hyphae were three times larger. This suggests that the fungi involved in the relationships at the sites are different. Our results are consistent with research in Western Australia (Hutton et al., 1994).

However, this does not necessarily result in specificity of infection. Cuttings of *A. pinifolium* from the Grampians were grown in Cranbourne soil. When the roots were harvested 'Cranbourne-type' mycorrhizae were seen suggesting that there was little host-mycorrhizae specificity. Although several fungi form mycorrhizal relationships with Australian epacrids, it may thus be possible to produce one isolate that can be used in the nursery production of most species.

CONCLUSION

Research so far has shown that the addition of soil containing mycorrhizal propagules can improve health and survival of some epacrids. For this information to be of use in routine propagation, the fungi need to be identified and grown in pure culture. Isolation of the fungi is currently being undertaken in a number of laboratories across Australia (Hutton, et. al., 1996; Steinke and Ashfor, 1996).

Once the mycorrhizal fungi are identified and cultured, the next step in this research will be to investigate directly (using pure isolates) the effect of mycorrhizae on the health and survival of cuttings of *A. pinifolium*, *A. conostephioides*, *B. daphnoides*, *E. impressa,* and *Styphelia adscendens* from the Grampians site and *E.impressa* and *Leucopogon ericoides* from Cranbourne.

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Improving Nutrient and Water Management in Nurseries

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INTRODUCTION

Inefficient irrigation practices have had a major influence on the development of container media and on fertiliser use in nurseries. In New South Wales (NSW) more than 80% of nurseries with automatic watering use overhead sprinklers (Doumit, 1991). Sprinklers have two main short comings. Firstly, they water an area of ground or bench regardless of whether plants are present. At plant spacings normally used in nurseries, just 20% to 30% of the bench or floor area is covered with pots (Rolfe et al., 1994). Consequently up to 80% of irrigation water either falls between pots or on unproductive ground such as roads or pathways. The second shortcoming is that sprinklers generally do not distribute water evenly over the production area. Large irrigation volumes are needed to ensure that pots in dry areas receive adequate water. In some commercial nurseries, there can be a 6 to 7 times difference in water applied between the driest and the wettest pot and the average rate of water application over the area can be 3 to 4 times what should be needed to replace water loss. This heavy water use promotes high rates of leaching and runoff.

With over-watering common in nurseries, it is not surprising that potting media have been developed which are free draining and well aerated. These characteristics reduce the risk of water logging and reinforce the need for over-watering. This is because media which drain readily must be watered more often than those which don't.

A survey of 13 NSW production nurseries has revealed that concentrations of nutrients in leachate tend to vary substantially both within and between nurseries (Table 1). The highest nutrient concentrations are found in leachate from recently potted plants and from propagation areas and the lowest in leachate from established plants which have not been fertilised for some time. Concentrations of nitrogen, phosphorus, iron, and manganese in leachate regularly exceed NSW water quality guidelines. Although environmental regulations generally target nitrate, the survey revealed that calcium, sulphur, and potassium are usually present at higher concentrations in leachate.

Monthly nutrient losses (Table 1) are high relative to the amounts normally applied as fertiliser. Given the leaching rates recorded in this survey, preplant applications of N, P, and K would last 11, 20, and 5 months, respectively. However, additional losses from plant uptake, N drawdown, volatilisation, and chemical fixation mean that deficiencies are likely. Huett (pers. com.) found that growth of several short-term ornamental plants receiving recommended rates of organic or inorganic fertilisers was around 50% of that obtained where nutrient supply was not affected by leaching. The major limiting nutrient in this experiment was nitrogen.

Leaching of fertilisers from pots is more severe in summer than in winter (Table 2). Heavier water use at this time (in Sydney around 60% more water in summer

Table 1. Leachate, dam water composition and seasonal effects on nutrient losses in Sydney nurseries.

Element	Mean conc. (mg litre^{-1}) Leachate[z]	Dam water	Rate of loss g m^{-2} per month Summer	Winter
Calcium	64 (900)	16	180	38
Sulphur	61 (1712)	16	158	38
Potassium	60 (457)	9	113	29
Nitrogen (NO_3)	48 (776)	3	155	31
Sodium	36 (476)	26	72	19
Magnesium	26 (741)	8	58	16
Phosphorus	5 (152)	0.3	6	1
Iron	0.6 (7)	0.3	0.3	0.2
Zinc	0.3 (3)	0.01	0.5	<0.1
Manganese	0.2 (10)	0.08	2	<0.1
Copper	0.1 (1)	0.09	0.2	<0.1
Boron	0.1 (1)	0.05	0.4	<0.1

[z] Maximum recorded concentration in brackets.

Table 2. Monthly leaching losses of nutrients from nursery containers during summer and winter.

Element	Rate of loss (g m^{-3} per month) Summer[1]		Winter[2]	
Calcium	180	(186)	38	(35)
Sulphur	158	(136)	38	(31)
Nitrogen (NO_3)	155	(204)	31	(42)
Potassium	113	(92)	29	(27)
Sodium	72	(36)	19	(16)
Magnesium	58	(44)	16	(17)
Phosphorus	6	(8)	1	(2)
Manganese	2	(3)	<0.1	(<0.1)
Iron	0.8	(0.8)	0.2	(0.2)
Zinc	0.5	(0.4)	<0.1	(<0.1)
Boron	0.4	(0.3)	<0.1	(<0.1)
Copper	0.2	(0.2)	<0.1	(<0.1)

[1]Based on 10 estimates from data obtained in January and February from four Sydney nurseries.
[2]Based on 18 estimates from data obtained in August and September from four Sydney nurseries.
Note: Standard deviations from the mean are in brackets.

than in winter), accelerated release of nutrients from CRF (controlled release fertilisers) at high temperatures, and the higher incidence of freshly potted plants in the nursery in summer would also contribute to high leaching losses.

Nutrient losses are highest in the first 2 weeks after potting up. This initial flush of nutrients comes from basal fertiliser including damaged CRF prills and organic sources if used. Nutrients (particularly urea) incorporated during the production of wood-waste based media to overcome nitrogen drawdown are also subject to early leaching (Huett, pers. comm.).

This brief review of the current status of nutrient and water management in nurseries was intended to draw attention to two points. Firstly, that some irrigation and fertiliser practices which have wide acceptance in the industry are inherently inefficient, and secondly that these inefficiencies are both costly to the nursery and potentially damaging to the environment.

Four main areas of nutrient and water wastage can be identified in nursery systems: (1) delivery of water to pots, (2) retention of water in pots, (3)retention of nutrients in pots, and (4) the collection and reuse of waste water.

DELIVERY OF WATER TO POTS

More of the Irrigation Water Must Reach Pots, Less Must Fall in Unproductive Areas of the Nursery. Drip or subirrigation systems offer water savings of 75% or more over sprinklers (Neal and Henley, 1992).

The efficiency of overhead sprinkler systems can be increased by improving the uniformity of water application and increasing the density of pots within an irrigation bay. Sprinklers must be correctly spaced, matched with line pressures and properly maintained for optimum performance (Rolfe et al., 1994).

Losses from water falling between pots can be reduced by increasing pot density. Changing from a square to a triangular pattern allows closer spacing.

RETENTION OF WATER IN POTS

Less Water Must Drain from Pots After an Irrigation. Work by Biernbaum (1992) and in Australia by Huett (pers. comm.) has shown that a leaching fraction (LF) of 12% is sufficient to wash away salts without reducing plant growth.

However, Nelson (1990) reports that in the United States 40% to 50% leaching is normal and the author has found leaching fractions in excess of 80% in NSW. Clearly the potential for saving water in nurseries by minimising leaching is good.

This can be done by watering only when needed and keeping the length of the irrigation to a minimum. Watering programs controlled by clocks should be periodically reset to account for seasonal changes in crop water use. When irrigation is controlled by soil moisture instead of a clock, water savings of 75% to 90% are possible (Lieth and Burger, 1989). Ideally, pots should be watered when 60% to 70% of the available water in the medium has been used (Biernbaum, 1992). Moisture sensors have been used to detect this condition (Lieth and Burger, 1989; Groot, 1993) but weighing of pots is also effective. Irrigating according to need works best when plants with similar water needs are grouped together.

Nursery container media can differ greatly in their water-retention capabilities. In recent trials of wood waste and peat-based media some were found to retain as much as 80% of applied water, with 20% draining away to waste whereas others retained just 20%, with 80% lost in drainage. Naturally the ability of potting mix

to rewet has a major impact on how long an irrigation cycle must be run. For example, to replace 100 ml of water lost through evapotranspiration from the most retentive medium would require 125 ml of irrigation water but would require 500 ml of irrigation water for the least retentive medium.

Clearly, water-efficient media are important in nurseries with overhead sprinkler irrigation. Efficiency can also be improved by:

- Avoiding media which are difficult to rewet or tend to shrink during drying (use a wetting agent).
- Using the lowest rate of water application possible. Somewhere between 10 and 20 mm h^{-1} is recommended. At higher rates, water drains through most media too quickly for efficient absorption to take place.
- Irrigating more often but for shorter periods ("pulse watering").
- Using mulch matting to encourage more even wetting of media and to reduce evaporation. Biernbaum et al. (1991) found that pot covers could reduce water use by 20% to 50%.

RETENTION OF NUTRIENTS IN POTS

Reducing the leaching fraction not only saves water but also means that less fertiliser is washed from pots in irrigation water. In turn, this means less nutrients in runoff water and better plant growth at lower fertiliser rates. Yelanich and Biernbaum (1990) found that poinsettias could be grown at 100 ppm N instead of 400 ppm N when the LF was reduced from 50% to 12%. This change in nutrient and water management gave a 10-fold reduction in fertiliser costs, a 40-fold reduction in N runoff with no reduction in plant growth rate or quality. Significant savings can also be expected when CRF are used (Huett pers. comm.).

Controlled-release fertilisers are less prone to leaching than other soluble fertilisers or liquid feeding. Uncoated inorganic fertilisers and organic fertilisers must be supplied in regular, small amounts to minimise leaching losses.

Wood-based media used in Australia have a CEC (cation exchange capacity) around 56 meq $litre^{-1}$ which is low compared with a clay soil (100 to 300 meq^{-1}). Minerals such as zeolite, vermiculite, and kaolite can be used to increase the CEC of growing media. Increasing CEC will stabilise pH and assist the retention of cations, including calcium, magnesium, potassium, and ammonium but not nitrogen which is normally supplied as nitrate, an anion.

COLLECTION AND REUSE OF WASTE WATER

Capturing runoff water for reuse benefits the nursery in three ways.

Minimises the Risk That Environmental Laws Will be Breached. The nutrient content of waste water will be diluted by fresh water draining into a dam from unproductive areas of the nursery including walkways, roads, carparks, and buildings. Nutrients will also be removed by chemical fixation and exchange with soil and by nutrient scavenging by weeds, turf, and trees. The extent of dilution and nutrient scrubbing that normally takes place can be appreciated from the difference in nutrient composition of leachate and nursery dam water (Table 1).

Reduces the Water Bill. Collection and recycling of runoff can bring considerable savings. In one large Sydney nursery the money spent on building dams and concrete

drains as well as the equipment used to disinfect the captured water was recovered within 3.5 to 4 years from savings in excess water rates.

Reduces the Fertiliser Bill. With proper monitoring of water quality, nutrient contaminants in recycled water can be used to supplement the supply to plants, reducing the need for fertiliser.

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Water Quality of Stored and Runoff Water in Plant Nurseries and Implications for Recycling

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INTRODUCTION

This project was initiated by the Australian nursery industry and the Horticultural Research and Development Corporation in response to the increased impact of water use on available water resources and government strategies to reduce the environmental effects of water use and improve the quality of discharged wastewater. Its aim is to provide information and practical advice for Australian growers wishing to recycle excess water from the irrigation of nursery and cutflower crops.

Australia has a water quality management strategy which is developing a national approach to the environmental management of water use. It is important to consider the whole catchment when determining environmental management goals, and the emphasis of water management in Australia will become increasingly catchment-based. Legislation is currently enacted separately in each State and so regulations differ. In the future, it is hoped that the States will follow guidelines developed for a cohesive national approach to environmental management. The most recent government document, *Australian Water Quality Guidelines for Fresh and Marine Waters* (Australian and New Zealand Environment and Conservation Council, 1994) provides guidelines for States to follow in the development of policy.

Information is scarce on the quality requirements of stored water for use for irrigation, and also on the composition of irrigation run-off which may either leave a property or drain into stored water reserves which are subsequently used for irrigation.

In addition to being a further source of irrigation water, run-off water usually contains plant nutrients and can contain water-borne plant pathogens and chemical residues. In small concentrations, the nutrients can provide valuable input as fertiliser. However, high or uncontrolled concentrations of various dissolved substances can be damaging to plants. The acceptable levels of the various parameters for optimum plant growth depend on the particular crops grown and method of production, guidelines for irrigation water are given by Biernbaum (1993) and Aikman (1983). Individual management practices will enable growers to produce good quality crops with water which varies from the analyses therein. The composition of the water also affects the suitability of the water treatment methods which can be used to minimise the risk of spreading plant pathogens in irrigation water.

This paper describes the results of a water-quality survey conducted at nurseries and cutflower farms in Australia and discusses them in relation to plant production and disease control.

MATERIALS AND METHODS

Irrigation run-off water or stored water was sampled nine times over a year (March, April, June, August, October, November, December 1994, and January and February 1995) from a total of 29 properties in Queensland, New South Wales, Victoria, and South Australia, a total of approximately 250 samples per parameter. Samples were kept cold and transported to the State Chemistry Laboratories, Victoria, for analysis. Samples were analysed for the parameters listed in Table 1. Samples collected in December were also tested for ultraviolet transmission at 254 nm either unfiltered or filtered through 80, 45, 25, or 5 μm filters.

Table 1. Water quality parameters measured at nurseries and cut-flower properties participating in the water quality survey.

Parameters measured (mg litre^{-1} unless specified)	
Carbonate alkalinity pH 8.3 (mg $CaCO_3$ litre^{-1})	Colour (hazen)
Bicarbonate alkalinity pH 4.5 (mg $CaCO_3$ litre^{-1})	Electrical conductivity (dSm^{1})
Silicon dioxide	Total calcium
Chloride	Total magnesium
Fluoride	Total sodium
Nitrate	Total potassium
Phosphate	Total copper
Sulphate	Total zinc
pH (unit)	Total iron
Turbidity (NTU)	Total boron

RESULTS

Results are given for selected parameters only. Nitrate was detected at least once in all nurseries surveyed and in 74.8% of samples. In 46 samples (18.1%) the nitrate level exceeded 44 mg litre^{-1}. Phosphorus was detected in 20 nurseries and in 43% of samples. At five nurseries, concentrations of P exceeded 20 mg litre^{-1}. Iron was detected at all nursuries and in 69.8% of samples. Eight samples (3.1%) exceeded 1 mg litre^{-1} iron. The pH ranged from 7.0 to >9.0 with most samples above 7.5. Electrical conductivity ranged from 0.01 to 3.24 dS m^{-1} with 62% of nurseries with readings always below 0.8 dS m^{-1} (general safe limit). Of the remaining nurseries where readings exceeded 0.8 dS m^{-1} on at least one occasion, samples were equally likely to be from run-off water or from dam water. Ultraviolet transmission rates are shown in Table 2. Fluoride was detected in all but one of the nurseries sampled on at least one occasion. It was detected in 47% of samples and in 2.5% of samples the concentration exceeded 1 mg litre^{-1}. Copper was detected in four out of the 29 nurseries sampled and in 9.8% of all samples analysed. Copper concentrations were below 0.2 mg litre^{-1} in 19 out of the 27 samples containing copper with the remaining samples containing less than 0.4 mg litre^{-1} except for one sample of run-off water, the copper concentration was 6.32 mg litre^{-1}. Boron was detected in all nurseries sampled and in 51.2% of samples analysed. All samples contained less than 0.31 mg litre^{-1} boron except for one sample with 0.79 mg litre^{-1} boron. Potassium was detected at all nurseries and in 96.5% of samples. The concentra-

tion was below 45 mg litre^{-1} in all cases except one where the potassium concentration was 133 mg litre^{-1}. Zinc was detected infrequently. It was rarely above 0.1 mg litre^{-1} and never over 0.42 mg litre^{-1}.

Table 2. Percentage UV transmission (254 nm) of water samples before and after filtration.

	Filter size (μm)				
Sample	unfiltered	80	45	25	5
Tap water	89				
Nursery:					
Mean %±sd	42.1 ± 21.7	42.3 ± 21.4	42.4 ± 21.3	43.0 ± 21.6	49.6 ± 19.8
Range %	6 - 87	7 - 87	8 - 86	7 - 87	10 - 89

DISCUSSION

Few nurseries had consistently high nutrient or other water quality factors which could be detrimental to plant growth, but many had peaks of various nutrients which could cause problems. These peaks and troughs will only be detected if monitoring is done on a regular basis over the year. Comprehensive monitoring will enable the identification of factors which are likely to vary. It may then be possible to monitor fewer parameters. The quality of run-off water is a combination of the quality of the source water plus the nutrients, organic particles, and acids which are picked up as the water passes through a container and over the drainage surface.

Nitrate levels greater than 44 mg litre^{-1} (equivalent to 10 mg litre^{-1} nitrogen in the form of nitrate) in run-off or dam water may not be a problem for plant production, but could contravene some state environmental legislation depending on the fate of the water. If water is to be treated with chlorine or ozone before its re-use, the presence of organic material, including nitrate, will increase the amount of chemical required before disinfection would occur. The use of a combination of chlorine and bromine or chlorine dioxide is advisable where the amount of nitrogenous matter may be high. The compounds formed from the reaction of bromine and nitrogen, bromamines, are effective biocides, whereas those formed with chlorine, the chloramines, are only weak biocides (de Hayr et. al., 1994). Chlorine dioxide acts directly as a biocide and is less sensitive to nitrogen levels (Armitage, 1993). The use of chlorine gas is subject to strict occupational health and safety regulations and the use of liquid chlorine compounds (sodium hypochlorite) is preferable.

Phosphorus levels below 30 mg litre^{-1} are generally considered to be safe for irrigation, however, phosphorus levels above 10 mg litre^{-1} may cause toxicity in sensitive plants such as some members of the families Proteaceae and Mimosaceae. Elevated phosphorus and nitrogen levels in dam water can result in algal blooms causing blockages to irrigation equipment (Rolfe et. al., 1994).

Readings of pH were 8.0 or above in 79.3% of nurseries at least once over the sampling period. The use of liquid chlorine to disinfect water will be ineffective unless the pH can be reduced to pH 7.5 or below. Acidification is an option. Alternatively, a combination of chlorine and bromine or chlorine dioxide could be

used, as they are effective biocides at more alkaline pH.

The use of ultraviolet (UV) light for water disinfection requires that the UV can penetrate the water sample as it passes the UV lamp. Pathogens are irradiated directly by the UV beam and cannot replicate. The transmission of UV light through water depends on the presence of UV-absorbing compounds such as iron and organic acids, colloids and particulate matter. Although UV disinfection systems can be designed for water with very poor transmission rates, the costs become uneconomical. Filtration of samples through 5 μm filters did not greatly improve the UV transmission of a wide range of samples (Table 2). If 50% UV transmission is taken to be the lowest rate for economic reasons, then only 44.8% of nurseries sampled in December could consider UV disinfection as an option without specialised pre-treatment.

Fluoride levels of 1 mg litre^{-1} have been shown to cause damage to cutflowers (Tija et. al., 1987) but container-grown stock are less sensitive (Conover and Poole, 1982). The levels measured in the water samples are unlikely to cause damage.

Boron, potassium, and zinc were not detected at high enough levels to cause damage.

Monitoring must be an integral part of production management because the levels of various compounds can differ significantly at the same nursery at different times. A good understanding of the water composition is essential if water is to be re-used. Changes to production protocols may be required to reduce the levels of nutrients and physical quality indicators in water to ensure that disinfection systems in place for pathogen control are effective and that nutrient imbalances are minimised.

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Growing *Kalanchoe blossfeldiana* in the Subtropics

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INTRODUCTION

Kalanchoe blossfeldiana are spectacular in flower as either an indoor plant or a bedding plant. It is native to Madagascar and belongs to the Crassulaceae family. From experience, there is a set way of propagating and growing each plant species. Every crop has a set of optimum growing conditions, including propagation material, ideal temperatures, specific nutrient levels, and other relevant growing requirements.

Decisions regarding the growing requirements for new crops must be made with the benefit of experience gained over time, especially in the subtropics.

STOCK PLANTS

Stock plants are kept in 300-mm pots, this allows control over the propagation material, which in the nursery (Birkdale) is only taken once a year. The nursery is only growing *Kalanchoe blossfeldiana* as a seasonal line, as the facilities do not permit year round production.

The stock plants are selected from the plants for sale. Only the best plants (strong, full flowering, good colour) are selected. The plants are triple planted in the 300-mm pots. All flowers are removed at the end of the season when the days become longer than 12 h. (Equinox 20th September). Plants are fertilised with Osmocote Plus, 3-4 month, at this stage (approximately 5 g litre^{-1} of soil).

Eight weeks before cuttings are taken the stock plants are fed weekly with Aquasol at a rate of 1.5 g litre^{-1} of water. At cutting (end January-early February) they will be lush, green, and full of new growth.

PROPAGATION

Cuttings can be collected throughout the day. These are usually kept turgid, however, it is not detrimental for the cuttings to wilt slightly unless the day is very hot and dry.

Kalanchoe blossfeldiana tolerates a wide range of soil types provided they are well drained and sufficient nutrients are supplied. An EC of 1.6 to 1.8 is desirable, this should be maintained throughout the growing period by top dressing or by fertigation.

Kalanchoe blossfeldiana is sensitive to potting with secondary infections easily setting in. This set back due to potting delays growth and adds to the production time. The preferred method of propagation is, therefore, direct sticking into the sales pot. The cuttings are 2 to 3 node cuttings with two sets of developed leaves. No leaves are removed at planting and no hormone is used. The size of the sales pot can vary between nurseries but Birkdale uses a 125-mm pot. A pot 125 to 140 mm in diameter best suits the growth habit of the plant, if bigger sizes are used it is recommended to multi-plant, or carry over from the previous year.

The media is drenched with a fungicide before sticking. Chloroturf®, (1.5 g litre^{-1}). is applied. It is also possible to drench immediately after sticking. The propagation

shed is a shade house with 50% shade cover. Watering is carried out once or twice per day. *Kalanchoe blossfeldiana* can be propagated under fog or mist, however, the cuttings must be more closely monitored for fungal infection.

PRODUCTION CARE AND TIMING.

After 2 to 3 weeks the plants will have a well developed root system, and should receive a soft pinch to encourage side shoot growth. At this stage they are also fed with IBDU (1 g litre^{-1}) and Osmocote Plus, 3-4 month (5 g litre^{-1}). This application is sufficient for the remaining growing time.

Production takes 4 weeks growing time (including one pinch back to 2 to 3 sets of leaves), 5 weeks of short days, and an additional 6 weeks for flowering (the latter can be normal daylength if controlled environment is used, or short day if natural light is used).

The first equinox in the year (where day and night are equal lengths) is around the 20th of February. There are two equinoxes per year. Most vegetative growth must be completed in the 4 weeks before this day. From personal experience it is possible to obtain a good-sized plant despite later planting, however, planting should not be delayed by any more than 2 weeks. High temperature and humidity, and added fertiliser promote faster growth.

After 4 to 6 weeks the plants should be of a sufficient size to be placed in the open field. The short day period should have commenced by this stage. Pots are spaced evenly at a density of 32 plants per m^2. This allows good air circulation and a good coverage when spraying with chemicals, as well as reducing the number of slugs and snails, which are almost always present in a closely spaced succulent crop. Too close a spacing will also encourage the plant to elongate and develop a weak basal point. Despatch and transport of elongated plants is difficult and labour intensive, because of the additional packaging required.

Kalanchoe blossfeldiana usually have to be sprayed once or twice with a growth-controlling chemical to obtain uniform growth and shape, and to stop flower stalk elongation.

The desired plant habit should be low, compact, uniform, and have all flower heads close to the foliage.

Growing *K. blossfeldiana* in the open field reduces the need for fungicidal and pesticidal sprays, unless a period of cloudy and/or rainy days occur. It is, therefore, important to monitor the crop closely.

CHEMICAL GROWTH CONTROL

Alar 85 (Daminozid 85%) is the product which is commonly used for growth control of *K. blossfeldiana*. The rate of application varies from cultivar to cultivar, as do the intervals between applications. The stronger and faster-growing cultivars should be controlled with a rate of 600 to 900 ppm (6 to 9 g litre^{-1}). Slower and more compact-growing cultivars with 300 to 600 ppm (3 to 6 g litre^{-1}). The growth retardant should be applied when there is an indication that stem elongation is occurring. This takes place around the 6th to 8th week, sometimes even earlier. Depending on the weather and other growing conditions another application might be needed when the flower buds start to set. The very last application to be applied should be as the flower stems start elongating and before any colour shows in the bud. Two to three applications are usually adequate for seasonal growing conditions (open field

growing). Four may be required in controlled (greenhouse) growing conditions.

This year it has been difficult to obtain Alar 85, and Bonzi, has been used as an alternative. At this stage it is unknown if this alternative is as effective and if the application rate has been correct (10 to 15 ml litre^{-1}).

Selection of *Lophostemon confertus* Provenances for Use in Urban Landscapes

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INTRODUCTION

Among the many factors that limit urban tree establishment and growth, drought, compaction, and low soil oxygen levels are perhaps the most critical (Handreck and Black, 1994; Hitchmough, 1994; Kozlowski, 1985; Patterson, 1976). The potential for a given plant to succeed via its genetic make-up rather than the availability of resource inputs must be maximised. One genetic improvement strategy that has proved highly successful and is standard practice in forestry is provenance selection which is the process of tapping into naturally occurring within-species variation (Turnbull and Griffin, 1986). Trials have shown that provenances in many species differ in an enormous range of characteristics, including the factors of interest to landscape professionals such as drought tolerance (Pallardy, 1981) and temperature tolerance (Widrlechner, 1994). *Lophostemon confertus* is a widely used tree in urban south-eastern Australia. It is distributed naturally in habitats associated with rainforest along Australia's east coast. This species has many desirable urban tree characteristics such as an attractive, luxuriant canopy, long life span, and low incidence of limb sheer. While generally reliable under a range of conditions, it is suspect on sites where drought, flooding, or compaction are of above average severity. It is likely that in many cases the current horticultural stocks are derived from the warmer, higher rainfall regions such as coastal northern NSW, simply because these areas are more conveniently located for seed collectors than drier sites further inland or colder sites at higher altitudes. Similarly, where natural variation in flooding tolerance occurs, there is no guarantee that cultivated forms are derived from the most flood-prone populations, which usually means those growing in riparian or other habitats that experience seasonal or prolonged periods of waterlogging (Gill, 1970). The fact that waterlogging tolerance is correlated with compaction tolerance in urban trees makes the identification of such populations even more imperative (Hitchmough, 1994).

MATERIALS AND METHODS

Species Selection and Seed Collection. Seed collection was undertaken in Autumn-Winter 1992 and 1993. Twelve forms of *L. confertus* were collected across its range from coastal north-central NSW to Cairns and from a cultivated form growing in a street in the suburb of South Melbourne.

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Species Selection and Seed Collection. Seed collection was undertaken in Autumn-Winter 1992 and 1993. Twelve forms of *L. confertus* were collected across its range from coastal north-central NSW to Cairns and from a cultivated form growing in a street in the suburb of South Melbourne.

Habitat Analysis. The aims of the habitat analysis were to:

- Assess the degree to which sites varied in specific characteristics and therefore indicate the potential for divergence among various populations within species in various genetic characteristics.
- Assess the climatic extremes under which a given species exists and compare these to the same factors that exist in various urban sites, and identify provenances which may "match" specific urban situations and regions.
- Allow any genetic differences that were identified to be correlated with habitat factors.

Soil moisture stress was measured as the mean ratio between evaporation and rainfall of the four driest months (Gentilli, 1971), and seasonal warmth was measured on a heat summation or degree-day basis, using 15C as the baseline temperature (Yim and Kira, 1975). In both cases, data used as the basis of calculations was obtained from the Bureau of Meteorology National Climate Centre. Drainage was evaluated simply by assessing the evidence for flooding or high water table at each site at the time of seed collection.

Morphology. Leaf area and root system morphology of the *Lophostemon* provenances were examined. Six-month-old seedlings grown in 75-mm tubes were used in each case. Root morphology was considered in terms of the ratio of fine roots (<1 mm dm) to woody roots (>1 mm dm). Roots were separated from the growing media using a sieve, and dry weight of roots in both size classes obtained.

Growth Rate. Seedlings of each *Lophostemon* provenance were established in 25-cm diameter "spring-ring" containers and placed in an irrigated, outdoor nursery growing area in a completely randomised layout. Height of each replicate was measured after 1 year.

Flooding Tolerance. Seedlings of five *Lophostemon* provenances were established in a pinebark-based, soilless potting media in 8-cm-diameter Root Maker pots. There were two treatments; flooding and control, and seven replicates per provenance per treatment. Flooded plants were inserted into a 150-mm bed of sand/loam mix inside a shallow (200 mm), wide, waterproof tank, at spacings of approximately 200 mm. The tank was then filled with water to a depth of 40 mm above the rim of the pot, and this water level maintained throughout the 12-week duration of the flooding period. The control treatment was a replicate of the flooded treatment, except that the tank was not filled with water following insertion of the containers into the sand/loam medium. At the end of the 12-week period, all plants were removed from the tanks, and, still inside the Root Maker pots, potted into standard 14-cm pots containing coarse unsieved river sand. These pots were then placed inside a glasshouse for a recovery period of 4 weeks during which time a weekly application of liquid fertiliser was provided. At the end of this period, the Root Maker pots were gently removed from the surrounding standard pot, and any roots protruding through the holes in the walls of the pots were washed from the sand. Dry weight of all roots outside the Root Maker pots was obtained for each replicate as a measure of postflooding recovery capacity. Provided a species can survive a period of flooding, its capacity to recover rapidly and exploit improving conditions is likely to be more important than its capacity to actually grow during the waterlogged period.

Table 1. Comparison of environmental characteristics of 12 *Lophostemon confertus* habitats and two urban centres.

Site	Altitude (M)	Habitat	Soil moisture stress indicator[1]	Heat[2] Summation (C)
Melbourne			1.62	554
Sydney			2.96	1125
Seal Rocks (nth-cntl NSW, NE of Newcastle)	30	littoral rainforest	4.76	1157
Carrai State Forest (nth-cntl NSW, W of Kempsey)	570	wsf	2.78	653
Dorrigo (northern NSW)	320	srf	4	1107
Bellinger River Estuary (nthn NSW, S of Coffs Harbour)	1	mixed riparian forest adjacent to mangroves, alluvium	3.15	1389
Brunswick Heads (northern NSW)	5	wsf/srf ecotone	3.42	1779
Lamington National Park (sthn QLD, SW of Brisbane)	700	wsf/srf ecotone	4.54	829
Toowoomba (southern QLD)	650	margins of dry rainforest	2.04	1079
Mudlow Gap (sthn QLD, W of Gympie)	300	open, grassy eucalypt woodland,basalt	1.74	1374
Rockhampton (central QLD)	240	dry rainforest on scree	1.19	2136
Eungella National Park (nthn QLD, W of Mackay)	720	mixed riparian forest, alluvial sand, periodic flooding	2.35	1319
Lake Tinaroo (far nth QLD, W of Cairns)	700	open eucalypt woodland	0.87	2019
Crater Lake National Park (far nth QLD, W of Cairns)	1000	tropical forest/wsf ecotone	1.4	1782

[1] Mean ratio rainfall : evaporation for the 4 driest months. Increased soil moisture stress is indicated by lower values.
[2] Degree days above 15C. Cooler climates are indicated by lower values.
Abbreviations: nth=north, nthn=northern, sthn=southern, wsf=wet sclerophyll forest, srf= subtropical rainforest, w=west.

RESULTS AND DISCUSSION

Habitat Analysis. Soil moisture stress, waterlogging, and thermal regime varied significantly from site to site. Table 1 is a summary analysis of the habitats of a selection of the *Lophostemon confertus* provenances. The visual characteristics of the provenances in situ varied dramatically, ranging from very tall, straight forest trees with large leaves in wet, high altitude sites to dwarf, crooked, multistemmed trees with small leaves in dry habitats. The results of the morphology trials indicate that at least some of this variation had a genetic basis.

Morphology. Mean leaf area of *Lophostemon* provenances inhabiting the driest sites was about half that of mesic provenances (Table 1). Variation in leaf area among provenances of several species has been recorded, and is attributed to adaptation in response to soil moisture deficits (Pallardy, 1981), although variation in nutrient availability is also a strong selectional influence on leaf size (Pate and McComb, 1981). Small leaves are more effective heat exchangers, so plants with small leaves are better able to avoid injuriously high temperatures following stomatal closure. More importantly, under xeric conditions, leaf transpiration rate decreases significantly with decreasing leaf area (Pallardy, 1981). There were also significant differences in root morphology among provenances (see below under "Waterlogging Tolerance".

Growth Rate. There were significant differences in growth rate among *Lophostemon* provenances but these did not correlate with growing season temperature; the slowest growing provenances were those from dry or coastal habitats (Table 1). Variation in growth rate among provenances has been attributed to an adaptational response to soil moisture deficit (Pallardy, 1981). Grime (1979) argues that slow growth rate is a common evolutionary response of plants to stressful habitats.

Waterlogging Tolerance. There was significant variation in response to flooding among the five *Lophostemon* provenances tested (Table 1). It was expected that if variation existed, the Eungella and Bellinger River provenances would be the most tolerant since these were both riparian. In fact the Eungella provenance proved to be the second least tolerant, while the Bellinger River provenance was less tolerant than the nonriparian Mudlow Gap form. The Eungella and Bellinger River forms must experience at least occasional flooding, since flood debris was located above the soil level of these plants. Presumably, however, the duration and/or frequency of these floods have not been severe enough to exert sufficient selection pressure on these populations to bring about specialised adaptations to flooding (Gill, 1970). Provenances with finer, less woody root systems showed the greatest tolerance of flooding (Table 1). The Rockhampton and Eungella provenances were the least tolerant and had the lowest ratio of fine to woody roots. These inhabited a rock scree slope and granitic sand habitat, respectively, while the remaining forms originated from sites with finer soil textures. Variation in root system morphology has been correlated with capacity to regenerate new roots following transplanting and root pruning (Gillman, 1990; Struve and Moser, 1984). Capacity to regenerate more roots may explain the better recovery of the fine-rooted provenances.

CONCLUSION

The present study shows that differences among *L. confertus* provenances may potentially be used to directly improve the performance of the species in urban south-eastern Australia. The Mudlow Gap provenance grows in a relatively dry habitat, recovered from flooding more successfully than the other provenances tested (including a cultivated form), and had smaller leaves than any other provenance—a trait that in this species tends to produce a more attractive canopy. The Toowoomba provenance experiences a relatively severe period of soil moisture deficit, and despite its location in south-eastern Queensland experiences a relatively cool temperature regime owing to high elevation. The Lake Tinaroo provenance, originating from a dry, relatively warm habitat with deep sandy soils, may be well suited as an urban tree in the hot climate and dry sands of Perth. In the long term plant breeding could be used to develop forms with the maximum number of desirable characteristics.

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Tissue Culture of Passionfruit

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A protocol has been developed for micropropagation of the passionfruit hybrid 'Super Sweet' (*Passiflora edulis* × *P. edulis* f. *flavicarpa*). Apical shoot tips were initiated on MS medium plus 10 µM kinetin and grown to apically dominant shoots. They were dissected into nodal sections and again cultured on MS medium plus 10 µM kinetin. Shoots that developed from axillary buds were dissected and rooted as micro-cuttings by short exposure to 1/2 MS medium containing either 10 µM NAA or 10 µM IBA before transfer to hormone free medium. Ninety percent rooting was obtained after 7 days exposure to medium containing NAA. Exposure to either auxin for >5 days resulted in increased callus production and reduced shoot growth.

INTRODUCTION

The genus *Passiflora* has been disseminated throughout tropical and sub-tropical areas of the world and is known for both its fruit and its colourful flowers. Of the hundreds of species contained in the genus approximately 50 to 60 bear edible fruit (Martin and Nakasone, 1970), the production of which is strongly influenced by species and climate.

On the east coast of Australia *P. edulis* (purple passionfruit) produces a heavy summer crop but few fruit in winter, while *P. edulis* f. *flavicarpa* (yellow passionfruit) produces fruit from late summer to early winter (Beal and Farlow, 1984). To achieve a more even yield over an extended period the Australian passionfruit industry is based on hybrids between *P. edulis* and *P. edulis* f. *flavicarpa*. Because seedlings from these hybrids are highly variable, scions are cleft-grafted onto rootstocks when they are 30 to 40 cm high and planted in the field after a further 4 to 6 weeks. Grafting is preferred to rooted cuttings as it takes advantage of the disease resistance of *P. edulis* f. *flavicarpa* when used as a rootstock. Micropropagation of passionfruit would be useful both for clonal multiplication of elite scion material and for multiplication of superior rootstocks, as self-incompatibility occurs in some clones of *P. edulis* f. *flavicarpa*.

Micropropagation systems that include a callus or adventitious budding phase are prone to production of genetic off-types. To avoid this complication, clonal propagation has been achieved for other species via production of microcuttings from axillary buds of apically dominant shoots. This technique has been used successfully in vitro for *Carica papaya* (Drew, 1992), *Azadirachta indica* (Drew, 1993), and *Coffea arabica* (Drew, 1991b). This paper reports experiments in the development of a similar protocol for passionfruit.

MATERIALS AND METHODS

Plants were grown in a glasshouse from seed of the passionfruit hybrid 'Super Sweet'. Apical tips were removed and disinfested for 15 min in a vacuum with 1% sodium hypochlorite solution containing a few drops of 7× detergent. After three

rinses in autoclaved water, basal stem sections were trimmed and explants placed on three culture media. Media treatments were MS, MS plus 10 μM kinetin, and MS plus 10 μM kinetin and 5 μM IAA. At the conclusion of this experiment, apically dominant plants were dissected into nodal sections and placed on either MS medium, MS plus 10 μM kinetin, or MS plus 5 μM 2iP. These concentrations of the two cytokinins were optimal in a previous experiment. In both experiments, shoot growth was assessed after 4 weeks.

In the rooting experiments, nodal sections from apically dominant shoots produced in the above experiments were cultured on MS medium containing 10 μM kinetin. After 6 weeks axillary shoots were dissected from the nodal sections and cultured on half-strength (1/2) MS medium containing 10 μM NAA. At various intervals 20 replicates were removed—10 were transferred to 1/2 MS medium and 10 to 1/2 MS plus 10 μM riboflavin. As a control treatment, plants were placed on the latter two media at day 0. In a second rooting experiment, axillary shoots from nodal sections were placed on 1/2 MS medium plus 10 μM IBA for various intervals before 20 replicates were transferred to 1/2 MS medium plus 10 μM riboflavin. After 30 days shoot height and root number were measured and callus growth at the base of the shoot was rated according to size (0 = no callus, 1,2, and 3 = increasing callus production). Root initiation was assessed daily for 30 days and then weekly thereafter.

Media contained 30 g litre^{-1} sucrose for shoot growth experiments and 20 g litre^{-1} sucrose for rooting experiments. All media contained 8 g litre^{-1} Difco bacto-agar and had pH adjusted to 5.6 with 0.1 M KOH before autoclaving at 121C for 15 min. Cultures were incubated at 25±1C with cool white fluorescent tubes providing a light irradiance of 55 mmol m^{-2} s^{-1} for a 16-h photoperiod.

RESULTS

Shoot growth was measured in terms of the percentage of explants with actively growing shoots, and the mean shoot height in cm. Shoot growth was good on hormone-free MS medium [90%, 1.7 cm] and on MS medium containing 10 μM kinetin [90%, 1.6 cm] compared with explants on medium containing 10 μM kinetin and 5 μM IAA [50%, 1.1 cm]. In the second experiment best growth of axillary buds from nodal segments in terms of shoot quality and length occurred on medium containing 10 μM kinetin.

In the rooting experiments, NAA was better than IBA for root initiation. Seven days of exposure to 10 μM NAA before transfer to hormone free medium was optimum in terms of percentage of shoots that initiated roots, however, more than 5 days exposure to NAA significantly increased callus production on the base of the shoot and reduced shoot height per rooted shoot. Similar results were observed with IBA treatments where more than 5 days exposure to 10 μM IBA resulted in increased callus production and reduced shoot height per rooted shoot. Shoot quality was poor after 30 days exposure to both auxins.

DISCUSSION

There are many reports of organogenesis from leaf discs and from petiole and stem sections of *Passiflora* species, however, there are few reports of shoot cultures from bud explants of *P. edulis* and *P. edulis* f. *flavicarpa* (Dornelas and Vieira, 1994; Drew, 1991a; Kantharajah and Dodd, 1990). Although IAA has been useful for establish-

ing adult and juvenile shoots in vitro (Drew, 1991a) and in shoot multiplication systems (Carvalho and Segura, 1994), optimum shoot growth was obtained in these experiments without IAA. In both the shoot and rooting experiments auxin reduced shoot growth as measured by shoot height (Tables 1 and 2). To stimulate growth of axillary buds from nodal sections, kinetin was superior to 2iP which was previously shown to be the best cytokinin for growth of adult shoots (Drew, 1991a).

Table 1. Effect of duration of exposure to 10 μM naphthalene acetic acid on rooting of passionfruit micro-cuttings in vitro.

Duration of exposure to NAA (days)	Percent rooted after 30 days #	Percent rooted after 30 days*	Percent rooted after 42 days*	Callus rating	Mean root number per shoot	Mean shoot height per rooted shoot (cm)**	Mean shoot height per unrooted shoot (cm)**
0	0	10	10	0.1 a	1	1	0.44
1	0	0	0	0.1 a	-	-	0.43
3	20	0	0	0.1 a	-	-	0.58 a
5	60	20	20	0.4 a	1.5	1.2	0.57 a
7	50	60	90	1.5 b	1.5	0.9	0.68 a
10	30	50	50	2.1 b	2.2	0.8	0.42
30	30	40	50	3.0 c	1.8	0.3	0.26 b

\# = *transferred to hormone free MS medium.*
* = transferred to hormone free MS medium containing 10 μM riboflavin.
\+ = callus at base of shoot.
** = after 30 days.
a, b, and c differ significantly at $P<0.01$

As auxin is essential to initiate adventitious roots but is inhibitory to root growth and development, root initiation and growth in vitro for other species has been optimised by controlling exposure to auxin (Drew, 1991b). In these experiments this principle has been applied to in vitro rooting of passionfruit shoots. NAA was more effective than IBA for rooting passionfruit shoots and this is consistent with the findings of Kantharajah and Dodd (1990) for *P. edulis* shoots. Seven days was the optimum duration of exposure to NAA and IBA in terms of the percentage of shoots that rooted. If shoots were exposed to either auxin for more than 5 days there was a significant increase in callus at the base of the explant and reduction in shoot growth of both rooted and unrooted shoots (Tables 1 and 2). Reduced shoot growth limits further multiplication and large amounts of callus at the base of a shoot can make acclimatisation difficult.

In these experiments it was apparent that some auxin was transferred with shoot explants during subculture and continued to affect rooting. When shoots were transferred to hormone-free MS medium containing 10 μM riboflavin, maximum rooting percentage occurred with the 7 days of NAA treatment compared to 5 days

Table 2. Effect of duration of exposure to 10 μM indolebutyric acid on rooting of passionfruit micro-cuttings *in vitro*.

Duration of exposure to IBA (days)	Percent rooted after 30 days #	Percent rooted after 56 days#	Callus rating*	Mean root number per shoot	Mean shoot height per rooted shoot (cm)**	Mean shoot height per unrooted shoot (cm)**
0	0	0	0 a	-	-	0.55 a
1	5	5	0.35 a	1	0.9	0.60 ac
3	5	25	1.0 b	2	1	0.57 ac
5	5	10	1.5 b	1	1.6	0.58 ac
7	15	55	2.6 c	1	0.7	0.93 b
10	20	50	2.5 c	1.5	0.8	0.52 a
15	20	50	2.6 c	1.5	0.6	0.50 a
30	40	50	2.2 c	1.9	0.4	0.42 ad

= transferred to hormone free MS medium containing 10 μM riboflavin.
* = callus at base of shoot.
+ = after 30 days.
Means followed by different letters differ significantly at $P<0.01$.

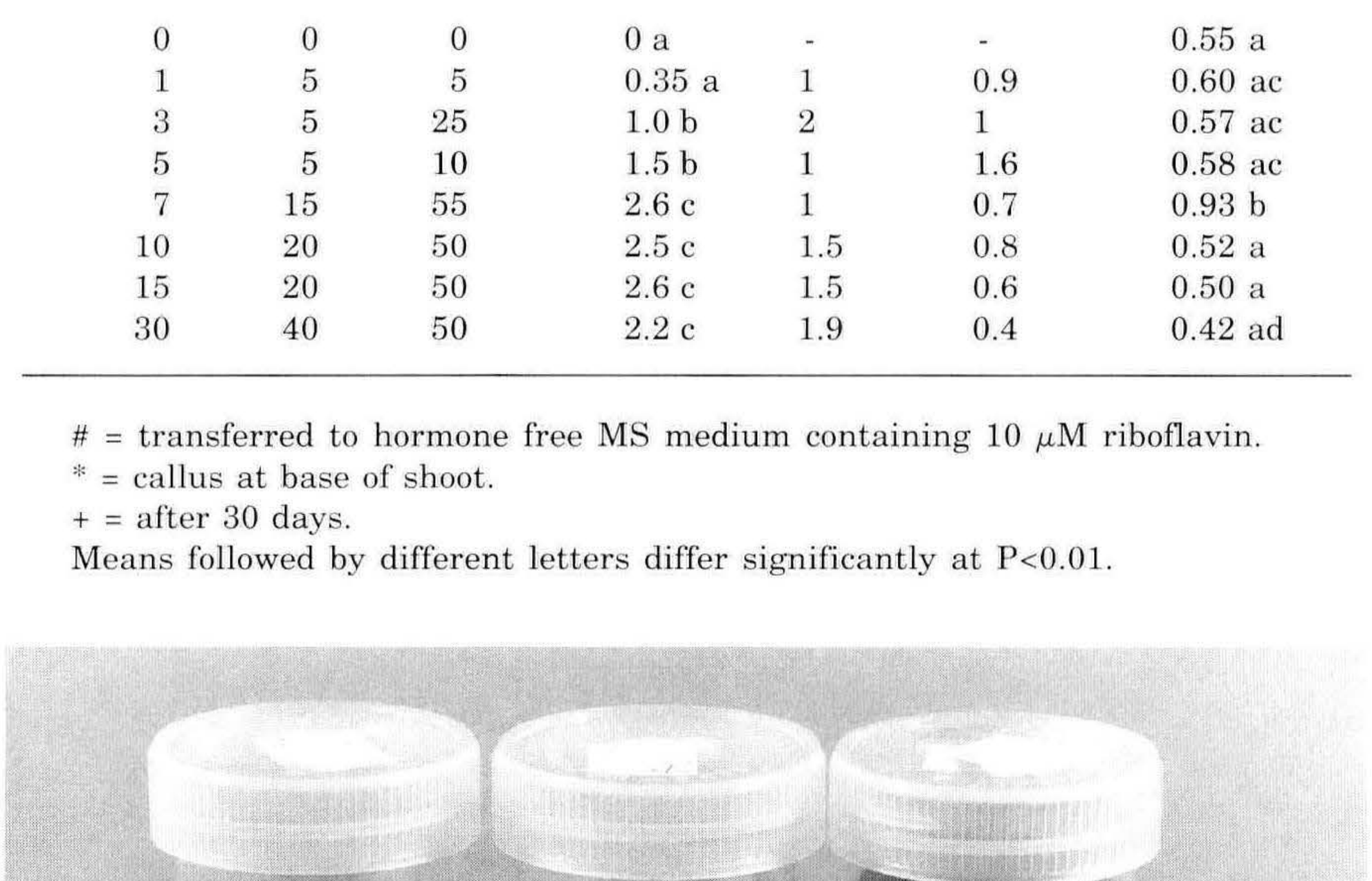

Figure 1. Growth of rooted passionfruit micro-cuttings into apically dominant shoots 1, 3, and 5 weeks (left to right) after transfer to hormone-free medium after exposure to medium containing 10 μM IBA for 7 days.

for shoots that were transferred to MS medium without riboflavin. Riboflavin rapidly photooxidises IBA in tissue culture medium (Drew et al., 1991) and has been shown to photooxidise NAA (Gortner and Kent, 1953). Consequently riboflavin would cause rapid breakdown of any auxin that was transferred from the previous medium with the shoot during subculture. The use of riboflavin in hormone-free medium following culture in medium containing IBA prevented "carry-over" effects of auxin on papaw root quality and callus production (Drew et al., 1993).

These experiments have shown that passionfruit can be micropropagated via rooting of microcuttings produced from nodal sections of apically dominant plants.

Plants of cultivar 'Super Sweet' have been subcultured for 18 months without loss of vigour using these protocols (Fig. 1). Plantlets have been acclimatised in a glasshouse without difficulty.

Acknowledgements. I gratefully acknowledge the contribution of Joanne Vogler in the laboratory work associated with these experiments.

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The Propagation of *Persoonia virgata*

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INTRODUCTION

In southeast Queensland, stems of *Persoonia virgata* are commercially harvested from naturally occurring populations and sold on the domestic flower market. As this product is not yet exported, an actual figure on the quantity of plant material bush harvested is difficult to obtain. It is therefore difficult to determine if permanent damage is being done to certain natural populations by bush harvesters. The arguments put forward for stopping bush harvesting include the risks of spreading diseases, such as *Phytophthora*, and depleting natural seed banks (Baker, 1994).

However, the propagation of this species has not yet been successful enough for the commercialisation and domestication of this potential new crop. This limits its export potential due to the fact that there is no guarantee of continuity of supply, uniformity, or quality of the product.

Most *Persoonia* spp. have been difficult to propagate, either by seeds or by cuttings. Even though there is an abundance of seed produced in natural populations, vegetative propagation strategies need to be introduced to allow for the multiplication of elite genotypes.

SEED EXPERIMENT

Materials and Methods. Drupes of *P. virgata* were collected from the Sunshine Coast of Queensland in September 1993, and stored in paper bags in a cool room at 5C for 20 weeks, before applying the following treatments. The mesocarp was removed by fermenting (for 3 days), or by acid treating (32% hydrochloric acid [HCl] for 3 h), with these treatments compared to a control treatment of drying the fruit intact (drying incubator at 25C until dried). The fruit, with or without the mesocarp, were then scarified with 98% sulfuric acid for 30 min, prior to the endocarp removal treatments. The degree of endocarp removed was either none removed, half removed longitudinally, or the majority of the endocarp removed, with the latter two removals showing improved germination percentages for *P. sericea* seed (Ketelhohn et al., 1994). The fruits were then disinfested following the process outlined for *P. sericea* seed (Ketelhohn et al., 1994). The final treatment applied was soaking the seeds for 22 h in either: a control of deionised water; 0.5, 5.0, or 10.0% hydrogen peroxide (H_2O_2); or 200, 350, or 500 ppm gibberellic acid (GA_3). The chemicals had been filter sterilised and the deionised water sterilised in an autoclave prior to soaking the seeds. The seeds were then cultured aseptically following the process outlined for *P. sericea* seed (Ketelhohn et al., 1994).

The experiment was a 3 × 3 × 7 factorial, with 21 replications per treatment. A completely randomised design was used. Visible protrusion of the radicle or cotyledons was used as the parameter to determine germination.

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[1]Lynda Ketelhohn was the winner of the Rod Tallis Award in 1995.

Results and Discussion. No germination was recorded for seeds where either the mesocarp was treated with HCl, or none of the endocarp was removed. These results were consistent with that found for *P. sericea* seed (Ketelhohn et al., 1994). The results also showed that the chemicals had no significant effect on the mean germination response, with seeds that received no chemicals producing similar germination percentages to those treated with the chemicals. This result may have been due to the cool storage of the seed, as stratification has been attributed to increasing oxygen diffusion to the embryo (Come and Tissaoui, 1973), and GA_3 can be substituted for the chilling requirements of certain seeds (Frankland and Wareing, 1966). Fruit that were fermented and then had the majority of the endocarp removed produced a significantly higher germination result of 54.3%, when compared to all other mesocarp and endocarp treatment combinations that germinated (Fig. 1). This result could have been due to the intact fruit containing a chemical inhibitor to germination, or because the presence of an extra layer of seed covering may have increased the damage to the seed when the endocarp was removed. The endocarp appears to play a major role in regulating germination, possibly by restricting the physical expansion of the developing embryo. Further investigations are being conducted to determine if the cool storage period had a significant effect on germination.

CUTTING EXPERIMENT

A preliminary trial investigating the effect of blanching stock plants of *P. virgata* (Fig. 2) which had been maintained at the UQG nursery was conducted in June 1994. The blanching technique used was described by Maynard and Bassuk (1987). A

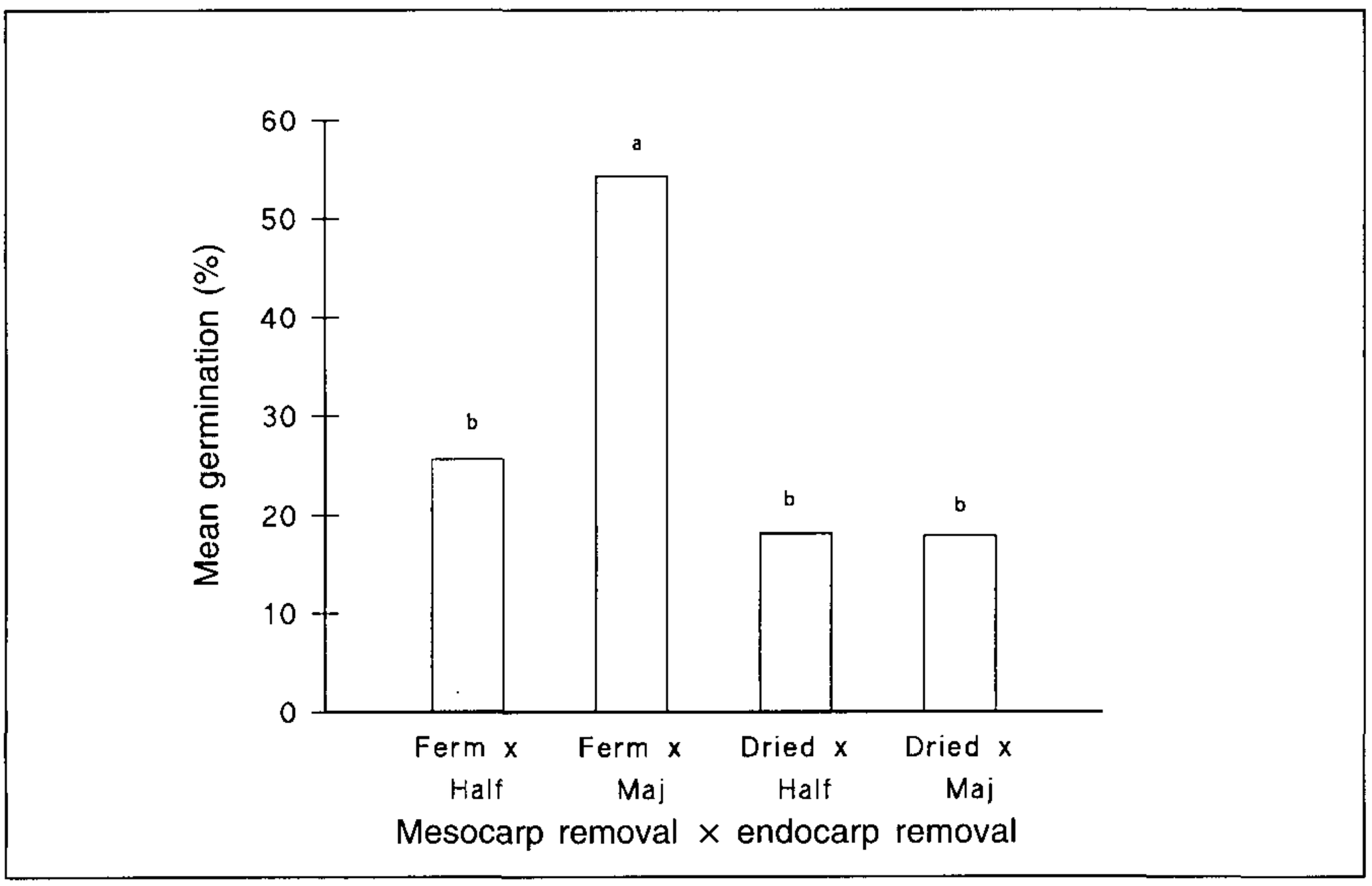

Figure 1. Effect of mesocarp treatment and endocarp removal interaction on the mean germination percentage of *Persoonia virgata* seed, averaged over chemical treatments. (Bars with different letters are significantly different at 1% level).

Figure 2. The application of velcro bands to a stock plant of *Persoonia virgata* to investigate the effects of blanching.

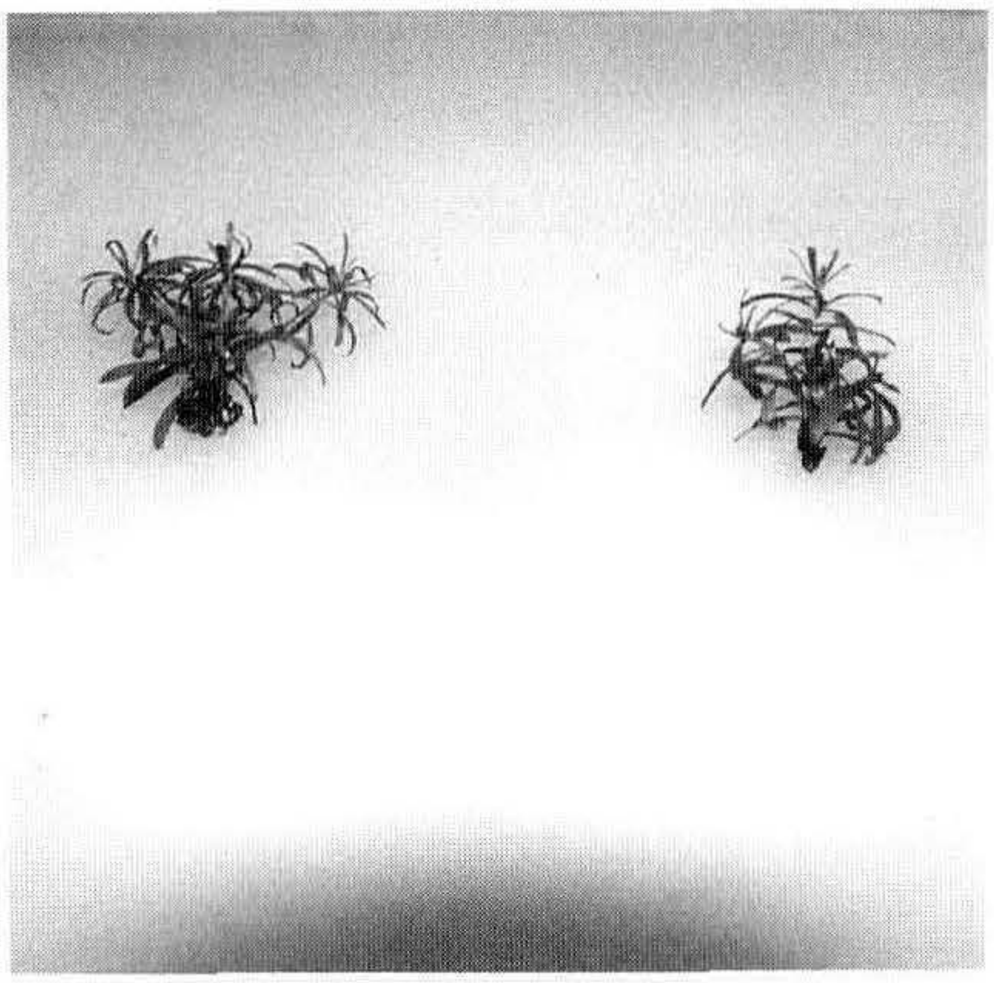

Figure 3. Multiplication of excised shoots from seedlings of *Persoonia virgata* germinated aseptically, and then cultured on de Fossard's (1981) holding medium (applied at half strength) containing 2 μM BAP.

plant-growth-regulator treatment of 4000 ppm indolebutyric acid (IBA) was applied on velcro bands, which were then attached to the shoots approximately 5 cm from the tips. The cuttings were harvested 5 weeks later, and 4000 ppm IBA was applied to the cuttings. These were then placed in Growool blocks, being considered a suitable medium for *P. virgata* tip cuttings (Ketelhohn et al., 1994). The cuttings were placed in the propagation house on heated benches (25C) with humidity maintained at above 86% by a fogging system. A total of 62.5% rooting was achieved after a period of 10 weeks in the propagation house.

This experiment was later repeated in August 1994 on a larger scale, with no rooting success. The only noticeable differences between the two experiments were that: (1) the preliminary experiment was conducted on one plant only, and genotype may be playing a role in regulating a rooting response; or (2) the preliminary stock plant used was juvenile, and the larger experiment was conducted on mature plants, suggesting that juvenile plant material may provide better rooting results. These areas are currently being investigated.

TISSUE CULTURE

There are no published reports available on propagating *P. virgata* by tissue culture. Success has been achieved in stimulating shoot multiplication from seedlings that were germinated aseptically (Fig. 3). These tip and nodal segments were transferred from de Fossard's (1981) holding medium (applied at half strength) to the same medium containing 2 μM benzylaminopurine (BAP). Growth and multiplication rates were slower on medium containing 3 μM BAP. Callus and root development have been promoted using excised shoots from seed-

lings, on the basal medium containing 5 μM naphthaleneacetic acid (NAA) and 5 μM IBA. However, the roots produced were thick, and so lower concentrations of these plant growth regulators in the medium are currently being investigated.

CONCLUSION

The propagation methods reported in this paper show potential for the commercial propagation of *P. virgata*. Seed germination results of greater than 50% have been obtained on several occasions. The incorporation of a mechanical scarifier to successfully remove the endocarp will allow for more detailed experiments in the future.

It appears that the limited success in vegetative propagation attempts may have been due to the maturity of the stock plants used. The promising multiplication and rooting results from the tissue culture work may lead to a rapid method of producing many *P. virgata* shrubs. Commercial cultivation of shrubs will then allow for a reduction in the bush harvesting of this species.

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The Use Of Hot Pipe Callusing For Bench Grafting

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The use of hot pipe callusing of subjects usually difficult to bench graft is described. The technique allows the use of bareroot rootstocks for ease of handling and the subsequent economic raising of the trees in line with the majority of bench grafting of fruit and ornamental trees on the author's nursery. The application of the technique to *Aesculus, Betula, Carpinus, Corylus, Fagus, Juglans*, and *Quercus* is described.

INTRODUCTION

Two papers in previous *I.P.P.S. Proceedings* have dealt with this subject very well with references dating back to the 1930s. The principles described in these papers have changed little in our application of the technique.

MATERIALS AND METHODS

Principle. Most grafted subjects of deciduous fruit and ornamental trees survive the initial critical growth phase well enough not to need hot pipe callusing. However, certain subjects, even with special attention, such as the use of pot-grown rootstocks and protected growing environments fail to survive in economic numbers. This is because the grafted tree cannot meet initial demands to make root, callus, and begin scion growth all at the same time. The precallusing of the graft union, using the hot-pipe technique—in advance of root and shoot activity, is a logical step to increase the survival rate.

Seasonal Timing. Our experiences show that this technique can be used at any time from mid-December to April, enabling a succession of batches to make full use of a limited facility. The use of a coldstore for extending dormancy of rootstock and scion wood, and of the grafts themselves during and after the callusing period, extends this window of opportunity to 5 months.

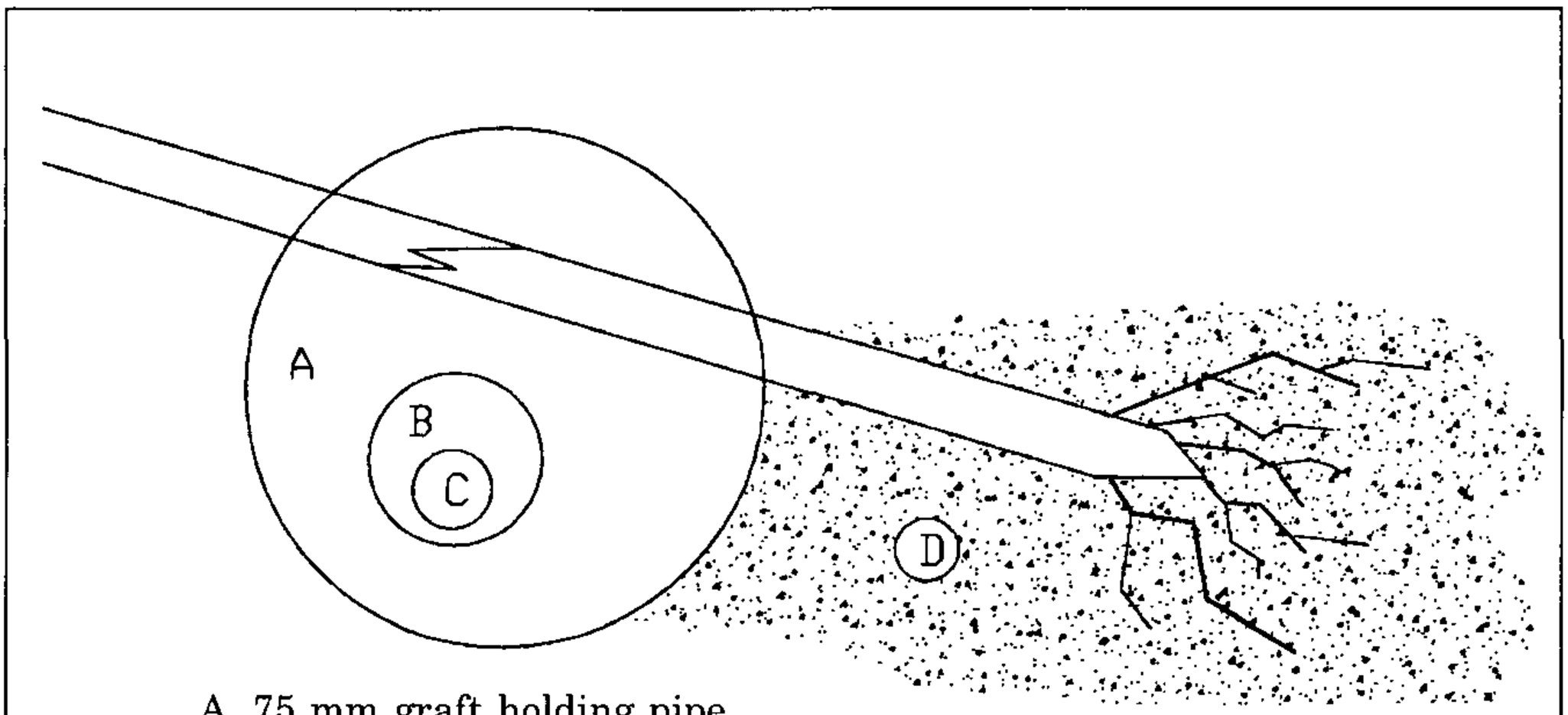
Grafting. Most forms of grafting would be suitable and we have used whip, whip and tongue, and side veneer with varying success including use with various grafting machines. Whip and tongue is our preferred method because it enables the matching of unequal sizes of rootstock and scion. This is an especially significant consideration with *Betula* and *Fagus* as it is preferential to use large well rooted (often transplanted) rootstocks whose reserves are critical to the successful promotion of callus.

Tying materials include polythene and degradable materials such as rubber and masking tape. All grafts are dipped in a specially prepared low melting point wax, essential to avoid loss of moisture during and after hot pipe callusing.

Construction of Hot Pipes. The Mark One model used self-regulating heating cable immersed in a static water pipe. This resulted in reasonable but often unreliable results because undesirable fluctuations of temperature led to variable callus

formation. The Mark Two has been designed to prevent such problems (Fig 1).

The unit consists of three different diameter pipes. The 75-mm pipe has 25-mm slots cut to hold individual grafts in place to allow heated air to completely circulate the graft union. The 35-mm pipe contains static water to act as a radiator. The 16-mm pipe circulates hot water. The 75-mm pipe is wrapped on the lower half with 25-mm Armaflex insulation (not shown in Fig. 1).



A. 75 mm graft holding pipe
B. 35 mm static water pipe
C. 16 mm circulating hot water pipe.
D. Moist peat for roots

Figure 1. Hot pipe profile.

The heating system provides circulating hot water the temperature of which is controlled precisely using a mixing valve. The water temperature on leaving the oil fired boiler is 75C. This is reduced by the port mixing valve to 10C above the required air temperature at the time, being the estimated heat loss of the system. A return valve sensor monitors the returning water temperature allowing for fluctuations in the ambient temperature of the building.

A 40,000 BTU boiler operates a 160-m pipe run allowing 3800 grafts per batch. Heating cost is low at an estimated 75 gal of oil per season for four batches.

Batch Timing. The use of a coldstore allows batches to be callused irrespective of seasonal restrictions and the pipe itself is housed in an old coldstore to reduce ambient temperatures to approximately 5C when necessary to cool the rootstock and scion. However, in keeping with the natural order of leaf emergence the earlier bud developers are callused first. We run our batches in the following order:*Corylus, Betula, Carpinus, Aesculus, Quercus, Fagus,* and *Juglans*.

Temperatures and Duration. It has taken various experiments to determine the correct temperature and length of time that certain species prefer. The following general observations have been made.

- Maximum temperature thresholds are critical and variable according to subject.
- If callus is not produced within 3 weeks grafts deteriorate quickly.

- Roots must be kept moist with a suitable mulch at all times.
- Minimum 8-mm preferably 10-mm calibre rootstocks should be used. No pretreatment, such as drying off, is necessary.
- Some development of suckers or lower buds of grafts during the latter part of callusing is not harmful provided grafts are potted and retained in a frost-free growing area.
- Early batches of grafts, i.e. *Corylus* and *Betula*, can be safely cold-stored prior to potting or after callusing.
- Whip and tongue grafting has been the most successful with equal success using side veneer on *Betula* but not on other subjects.
- Experience will determine the minimum amount of callus necessary, however, some subjects naturally produce more than others.

The list below gives the optimum times and temperatures for each subject. Degrees of callus do not necessarily reflect the best results.

	Days	Temperature	Take (%)	Callus
Aesculus	21	80	95-99	Average
Betula	18	75	85-95	Average
Carpinus	16	70	95-99	High
Corylus	14	65	95-99	High
Fagus	21	75	75-85	Average
Juglans	21	75	55-75	Low
Quercus	17	75	95-99	Average

AFTER-CARE

Batches that are callused before 1 February are coldstored after callusing to delay growth. After this date all batches are immediately potted up and held in a frost-free structure to develop slowly. The first 3 to 4 weeks growth is the most critical after which they generally grow rapidly with little problem.

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Top Worked Larch Production

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INTRODUCTION

The paper covers production of the following cultivars as undertaken at Yorkshire Plants:

- *Larix decidua* 'Karstern'—Green foliage with light tips, produces a round ball of green.
- *Larix kaempferi* 'Diana'—Contorted growth with a long leaf, curious but attractive.
- *Larix kaempferi* 'Dwarf Blue'—A tight round ball shape, with steel blue foliage.
- *Larix kaempferi* 'Pendula'—Graceful weeping form with light blue foliage.

All are showy plants in spring and summer, and have very attractive autumn colours. They make attractive plants for the patio or small feature trees with spring, summer, and autumn interest.

GRAFTING PROCEDURE

Understock Production. We grow, and also buy in, 2-year pot-grown seedlings of *L. decidua* or *L. kaempferi*, in 9-cm pots. The grade is straight stems 45 to 60 cm tall. Understock side growth is trimmed prior to potting into 1.5-litre pots during March and grown on outside. A 90-cm cane is used to maintain straight growth; side feather growth is reduced during early July when caning. Our aim is to produce a straight stem of 7- to 10-mm girth at a height of 75 cm.

Grafting Environment. After needle drop in November, stems that make grade have all side shoots removed, are trimmed to 80 cm, and are placed in a double-skin polytunnel. This is our grafting environment. Understocks that do not make the girth, but are tall enough, are potted the following March into 3-litre pots and used the following year for grafting *L. kaempferi* 'Pendula' at a height of 120 cm. This cultivar requires at least this height to obtain the full effect of its weeping habit.

The double-skin polytunnel has roll-up side curtains with side netting, double louvers, and single doors at each end for ventilation. The structures are 56 ft × 21 ft and the double skin is air inflated by a single air fan. This maintains a warm, even temperature for the stocks to start showing root growth by mid-February. Ventilation is adequate for cooling during April and May when temperatures can warm up rapidly. We use no heating within the tunnel for the grafting or growing on process.

Grafting. Grafting takes place in late February. Scions are collected from stock plants growing in the open ground. Stock plants are maintained by hard pruning and fertilizing each March. The scions are trimmed to a 10 to 15 cm length. I believe it is good practice to collect scion wood the same day as you will be grafting or the day prior to grafting and store damp overnight in a cold store or fridge. We use a side veneer graft tied with an elastic rubber strip. Grafting knives are sterilised

regularly with isopropyl alcohol to reduce the risk of transferring infection.

We put two scions on all our top worked plants, one above the other on opposite sides of the stem. The height for grafting 'Karstern', 'Dwarf Blue', and 'Diana' is 75 cm. A sap drawer of around 5 cm is retained at the top of the grafted plant. Both scions are dipped into melted paraffin wax to just below the union level, care must be taken not to over-heat or boil the wax as this will damage the scion.

Dipping the graft area in wax is quicker and less messy than painting the wax and does not seem to have any adverse effect on take or scion development. In addition, red spider mite (two-spotted mite) or aphids, that may over-winter on the scion wood, will be covered in wax and so do not cause trouble in the early spring when grafting house temperatures are allowed to build up.

When the wax has set, a 200-g 8 cm × 25 cm clear polythene bag is placed over the scions and sealed with a staple from an office staple gun. This bag creates a humid micro-climate around the graft, aiding cell division and reducing moisture loss as buds break.

More than 80% of grafted plants end up being of saleable quality using this method under our conditions. The take is higher but wastage is bound to occur during aftercare, potting, and grading at sale.

Economics of Using Two Scions. *This technique allows us to get plants to* market sooner. Two scions will produce a saleable plant by the following July or August after grafting. Should only one scion live we will still have a plant ready for sale by the following spring. Two scions give a quality marketing advantage over growers who use only one scion on their topworked larch.

Aftercare. Root growth, compost moisture, and scion development are checked daily in the grafting house. It is easy to make the mistake of over watering at this stage, as larches do not make rapid root growth during the spring months. There is no better way than hand watering the grafts each morning as required. During the 6 weeks after grafting, no ventilation should be necessary. After 6 weeks, we release the staple at the base of the polythene bag to allow air to the union area. The tunnels are then aired as required by dropping the side curtains and opening louvers during the day—always closing them up at night.

The bags are removed within 2 weeks of releasing the staple. This should be done on a dull, overcast day to reduce the risk of scorching or stressing the scions through drying out. Removing the bags later than this will only result in disease on the establishing scions and cause failure or unnecessary spraying. It is essential to remove all suckering below the union area as these shoots are competitors for the scions and reduce scion growth.

The sap drawer is removed in late April or early May. Two weeks prior to potting, the tunnels are aired day and night to allow the plants to acclimatise to outside conditions. *Larix kaempferi* 'Diana' and 'Dwarf Blue' and *L. decidua* 'Karstern' are potted into 5-litre pots and placed outside after the last of the spring frosts—usually early June in Yorkshire. I recommend tying the cane to a support structure of post and wire with drip irrigation.

Larix kaempferi 'Pendula' grafted at 120 cm are potted into 7.5-litre pots and placed in the same environment, again in early June. We start sending out plants for retail sales in garden centres by July of the grafting year.

Propagation of Hibiscus by Grafting

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INTRODUCTION

This paper covers grafting of *Hibiscus syriacus* cultivars 'Oiseau Bleu' (syn. *H. syriacus* 'Blue Bird'), 'Hamabo', 'Meehanii' (a variegated cultivar), 'Monstrosus', 'Red Heart', 'Woodbridge', and 'William R. Smith'. Grafting allows the production of a saleable hibiscus plant in full flower in less than a year, whereas, production from cuttings can take two to three times longer. The method described might be applied to other species such as *Lilac* and *Viburnum*.

METHOD AND MATERIALS

The scion wood is collected in December from our own stock plants. 'Meehanii' stock plants are grown under polythene to provide enough scion wood for the large numbers grafted.

At New Place some 20,000 English-grown *Hibiscus* root stocks are bought in as 2-year-old seedlings and cold stored until required for grafting in January.

Graft Preparation. The rootstocks are topped and tailed—with the stems cut off through the hypocotyl—so that the whole of the root fits in the pot it will eventually end up in.

The top of the rootstock is then prepared by taking a thin sliver off the top of the stock to leave a clean and smooth surface. A grafting knife is then driven vertically down through the centre of the top of the stock for approximately 2 to 3 cm to give a clean split to receive the scion.

Scion material should have four buds with enough room at the base to make a wedge. Two cuts are needed, one on each side of the scion to create a wedge of about 2 cm. This wedge is then inserted into the top of the prepared root. If the scion is similar in size to the rootstock, it is put in the middle, if it is smaller, it is put to one side so that it gets maximum cambium contact. The graft is tied with a Rapidex tie (blue 0.5 mm thick, 140 mm long, 3.5 mm wide). The graft union and scion is then dipped in wax (paraffin wax with a melting point of 46C kept at 70C) and wrapped in a damp hessian on a trolley for transport to the heated heeling-in bed.

Heated Bed. The heated bed is a simply construction using the heated floor of a propagation glasshouse, Mypex is laid down to keep the sand that covers the floor of the propagation house clean. A 45-cm-high frame is then constructed. The grafts are laid into it in rows with damp peat covering roots and graft unions. Depending on their development grafts will stay here for 4 to 5 weeks. The under-bed heating is run at between 12 to 14C to induce rooting and callusing around the graft union. When new white roots appear, and a good light green line of callusing is visible around the graft union, they are ready for potting.

Potting and Aftercare. Compost mix per 450 litres of peat:

Ficote 140 16:10:10	1.0 kg
Single super phosphate	0.25 kg
Magnesium limestone	0.7 kg
Frit trace elements	0.15 kg
Suscon green	0.3 kg

Hibiscus prefers an open peat with a high AFP.

The *Hibiscus* grafts are potted into 1-litre "long-tom" pots, and then stood down in polythene tunnels.

Correct watering is essential. Grafts must be kept reasonably dry at the start until the roots grow to the side of the pot. At this stage, watering is slowly increased and by midsummer the grafts will need a considerable amount of water. Early watering can result in roots rotting, an increase in liverwort and mosses, and possible graft flooding.

FINISHED CROP

The first orders are despatched in the beginning of August when they are fully in flower. It is at this point that the Rapidex ties can be removed. Ties stay on this long because they are under compost. Any plants not sold at this stage (midsummer - autumn) will be graded, pruned, and over-wintered. In the spring they will have better branching and become a very saleable first grade plant.

Aphid and white fly have been the only real pests but are easily controlled—the aphid with Ambush C and Pirimor; whitefly with the biological control agent, *Encarsia formosa*.

Winter Bench Grafting of Walnut Varieties

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Walnut (*Juglans regia*) is regarded as difficult to propagate, needing more heat for callus formation and healing than easier species. In Hungary it cannot be propagated by chip- or T-budding, or by outdoor whip or cleft grafting in the spring. This paper describes trials using bench grafting. One- and two-year old seedlings of *J. regia* were used as rootstocks. They were lifted in late autumn and cold stored until grafting time. Scions of the local clones 'Alsoszentivani 117', 'Milotai 10', and 'Tiszacsecsi 83' were collected before grafting and were cut to one-bud sections. Whip grafts were made by hand in February and March 1994. The grafts were forced for 2 to 3 weeks, until an unbroken ring of callus was formed at the point of graft union then moved to cold storage and planted into the open ground at the end of April. Success rate was 70.5% for 'Alsoszentivani 117' and 91.5 % of the trees of this clone were in size category 1.5 m+.

INTRODUCTION

Walnut (*Juglans regia* L.) is one of the difficult-to-propagate plants. In the Hungarian climate it cannot be propagated by such common methods as chip- or T-budding in summer, or outdoor whip or cleft grafting in the spring. It needs extra heat for callus formation and healing. The high level of phenolic compounds in the tissue may also prevent healing of graft or bud unions in some periods (Karadeniz et al., 1995).

In Hungary, the propagation of selected walnut cultivars was started in the 1950s. Porpaczy enhanced the method of greenhouse grafting which was originally developed by German nurserymen. He grafted potted seedlings in early spring after the plants had started into leaf. The grafted plants were kept at 26 to 30C and at high humidity and were transplanted to the open ground in May.

In the 1960s and 1970s, Szentivanyi adapted the method of patch budding, using a bud with a 1 cm × 2 cm bark piece budded onto the rootstock (Szentivanyi, 1974). Optimum time for patch budding is end of July to early August. This method remained the principal method of walnut propagation for some time but since cold and rainy weather after budding reduce the success rate (the rate varies between 10% and 70%, depending on the year) few nurseries use the method today.

An alternative is by woody ring graft in May. A dormant bud with a ring of bark is removed from the lower part of a leafing shoot. The bark of the rootstock is removed and the scion bud with the bark ring is pulled on until it fits tight. It gives good results for small quantities but is fairly slow to do. Green grafts in any season and stage of woodiness give poor results.

To find a more effective method we tried winter bench grafting which was developed by Duhan (1958, 1960) in Austria and Curkan (1975) in Moldavia. We adapted and somewhat modified their method and we have been using it for years.

MATERIAL AND METHODS

One- and two-year-old seedlings of *J. regia* were used as rootstocks. Optimum diameter is 12 to 22 mm. They were lifted in late autumn and cold stored until grafting time. The tap root was cut to 20 cm, the side roots to 2 cm. Scionwood, collected from a stock plantation, was cut into one-bud sections. Scions were the main Hungarian clones, 'Alsoszentivani 117', 'Milotai 10', and 'Tiszacsecsi 83'.

Whip grafts were made by hand in February and March 1994. The tip of the scion was dipped into wax and the cut part of the roots into 1 : 10 v/v mixture of the fungicide Kaptan and talc. Completed grafts were put into wooden boxes and covered completely by damp sawdust. No tying was applied. The boxes were moved to a forcing room with 26 to 28C temperature and 80% to 90% humidity. The grafts were kept there until an unbroken ring of callus was formed at the point of graft union. After callusing, grafts were moved to cold storage and stored at 1 to 3C. Altogether 9821 grafts were made—1592 to 4237 pieces of each cultivar.

Grafts were planted to the open ground at the end of April. Spacing was 1.5 m × 0.3 m. Before transplanting, etiolated rootstock sprouts were removed. Only grafts with strong callus formation were planted out. Grafts were completely molded up with earth to protect them against drying out and late frosts. Weed control, spraying, elimination of rootstock sprouts, and irrigation were done as necessary. In the second year bamboo stakes were needed to prevent wind damage.

Trees were graded to less than 1 m, 1.0 to 1.5 m, and 1.5 m+ size categories. Trees under 1 m were considered unmarketable. The data were collected in the commercial nursery of the Fruit Research Institute in Erd, Central Hungary, and this technology has been applied for 8 years.

RESULTS AND DISCUSSION

During callusing, the newly formed callus appeared after 7 to 10 days. After 3 weeks a complete ring was formed at the graft union. An even 26 to 28C is important for callus formation—lower or higher temperatures inhibit healing. Plants grew 0.2 to 0.6 m in the first year and reached 0.8 to 2.2 m tall in the second year.

Table 1. Results of winter bench grafting of three walnut cultivars.

Scion cultivar	Success rate (%)	Percentage of trees in size category	
		100-150 cm	150 cm+
Alsoszentivani 117	70.5	8.5	91.5
Milotai 10	59.9	34.2	65.8
Tiszacsecsi 83	65.8	26.4	73.6
Average	65.4	21.0	79.0

Table 1 shows the results of propagation season 1994/95. The success rate is derived from the number of trees larger than 1 m compared to the number of grafts made. These data are similar to the previous years' results and confirm our earlier

experience that 'Alsoszentivani 117' is the most, and 'Milotai 10' the least, vigorous clone both in the nursery and orchard.

All the trees make a fibrous root system as they were transplanted once. The grafts can alternatively be planted into 10- or 12-litre containers when, with good care, they reach the same size as in the open ground. Black walnut (*J. nigra*) can be used as an alternative rootstock, but the success rate is about 20% lower than when *J. regia* is used.

Other hardwood species such as *Aesculus, Carpinus, Castanea, Corylus, Fagus, Quercus*, etc. can also be grafted by winter bench grafting and callusing. *Castanea* and *Corylus* seem to have less demand for heat for good callus formation.

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Propagation and Production of *Hamamelis* Cultivars in the Field by Chip Budding

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INTRODUCTION

The conventional propagation method for *Hamamelis* cultivars in Europe is a summer side graft onto pot-grown rootstocks of *H. virginiana*. Having seen the type of plant produced by nurseries in New Zealand, where they chip-bud onto field-grown rootstocks, I decided to try this method myself. Over the last few years I have budded between 1000 and 2000 plants per year with varying success.

LAND PREPARATION

This consists of setting up a production rotation. Currently the nursery has sufficient land that on each site 8 to 10 years can be left between crops. The land not in use is down to a grass ley. A crop of hay is taken from this grass sward until 2 years before being needed. During these 2 years the grass is mown frequently and allowed to rot back into the soil to improve humus content. It is basically free of perennial weed but if nettle, dock, etc are present these are taken out with Triclopyr.

In the August before planting the sward is sprayed off with Glyphosate to kill the grass and any remaining perennial weeds. During the winter the land is ploughed and left until planting takes place in the spring. Just prior to planting the land is finished with a spring tine cultivator.

ROOTSTOCKS AND PLANTING

Two-year-old seedlings of 6- to 8-mm diameter are planted by line and spade. Rootstock preparation consists of the removal of any low side shoots and just tipping any wayward or lengthy roots. It is important not to trim the roots or tops too hard. Planting distances are 40 cm apart in rows 100 cm apart.

SOURCE OF PROPAGATION MATERIAL

Stock plants are maintained at 1.5 m apart in rows 4 m apart to allow access for tractor mowing. A herbicide strip is maintained under the plants in the row. Maintenance includes an annual prune of the previous seasons growth back to one bud. Fertilizing consists of a nitrogen fertilizer in March of 80 units of sulphate of ammonia per acre and 80 units of sulphate of potash in July to help ripen the growth. Irrigation is given as necessary.

BUDDING OPERATION

The chip budding process is carried out around the second week in August. This seems to be the optimum time to get the budwood as ripe as possible but still have good growth on the rootstocks. I only use the two basal buds on a shoot, the four or five further up not being ripe enough. The buds are tied in with 25-mm-wide

polythene tape taking care to go round the long bud and not damage it. The ties are removed after 6 to 8 weeks when they have taken. They do not produce large amounts of callus so the buds must be carefully checked before untying.

HEADING BACK AND GROWING ON

In October the rootstocks are shortened back to 45 cm in height to prevent wind rock. In January they are further headed back to leave a 15-cm snag above the bud. At this time a bud guide is applied to the chips, this saves time in the spring and also affords some protection to the bud.

In March a nitrogen fertilizer is given as for the rootstocks and this is followed up again with another in June. Sucker growth is removed as it appears during April/May. At the end of May the 15-cm snag is cut back to the growing bud. If any bud has failed the rootstock can be left for rebudding the following August. At least three shoots, sometimes as many as five, will arise from the bud giving a really bushy plant suitable for lifting at the end of the year.

WEED CONTROL

This is carried out by using Simazine + Isoxaben after planting in the spring and Simazine + Propyzamide the following December and again 1 year after that.

HARVESTING

After leaf fall the plants are dug by hand, the shoots are tied together with a hand tying machine to prevent damage. They can then be lifted bareroot for containerising for later sales or can be rootballed for immediate sales. These 1-year plants will not have flower buds but if containerised will produce a mass of flowers the following year.

CONCLUSION

The largest problem I have experienced with chip budding *Hamamelis* is getting ripe budwood to coincide with optimum growth of the rootstock. Budwood taken at the end of August would be much riper but rootstock growth could not be maintained effectively even with fertilizing and watering at that time of year. Less activity in the rootstocks would lead to a reduced bud take even though the quality of budwood is better. To this end I have planted some stock plants into a polythene tunnel to achieve good ripe budwood 2 to 3 weeks earlier which will coincide with good rootstock activity.

Bud-take over the last 3 years (this is plants reaching a saleable size) is as follows: 1992, 75%; 1993, 40%; 1994, 70%.

The results can, I believe, be improved by early August budding with properly ripe budwood and actively growing rootstocks. Adverse cool, damp weather after budding may also still reduce bud-take but hopefully not as low as 1993 levels.

Effectively Using Tissue Culture for Ericaceous Plants

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INTRODUCTION

Briggs Nursery is a pioneer in the field of plant tissue culture. Nearly 25 years ago Bruce Briggs cooperated closely with Dr. Wilbur Anderson on research focused to develop a micropropagation system for rhododendron. At that time progress was slow and sometimes disappointing—but a system was developed to effectively micropropagate rhododendron. In 1976, Dr. Anderson (Anderson, 1976) published an outstanding paper presenting a new medium that could be used to micropropagate rhododendron.

Currently Briggs Nursery produces yearly over 3 million ericaceous plants, including rhododendron, using tissue-culture methods. Over the past 25 years, we have built and used three different laboratories, and grown on over 20 million tissue-cultured rhododendrons.

The heath family or ericaceae is comprised of nearly 70 genera with over 1900 species (Bailey, 1976). This family is composed of mostly shrubs, perennial herbs, small trees, or occasionally vines. Many genera in the ericaceae are important ornamental and fruit crops, being widely grown throughout the world. Several members of the ericaceae have been successfully micropropagated (Table 1). We have yet to discover an ericaceous genus that is recalcitrant to tissue culture.

Table 1. Genera in the Ericaceae that have been micropropagated.

Andromeda	×*Gaulnettya*
Arbutus	Kalmia
Arctostaphylos	Kalmiopsis
Calluna	Leucothoe
Daboecia	Oxydendrum
Enkianthus	×*Phylliopsis*
Erica	Pieris
Gaultheria	*Rhododendron*

Nearly all genera in the Ericaceae can be micropropagated using the following protocol.

INITIATION

Cultures can be initiated from a variety of explants. Tissues including: vegetative buds, meristems, and shoots at a variety of stages of development can be used. Floral pedicels and ovary bases have also been reported to be successful as explants to initiate cultures of *Rhododendron* cultivars (Meyer, 1982).

At Briggs Nursery, shoots are the preferred explant to initiate cultures with ericaceous plants. Shoots that are somewhat stiff and mature are removed and the

foliage is stripped off. These leafless stems are then placed into a soap (Tween 20) water rinse. This solution is agitated for 3 to 5 min at 60 to 80 rpm on a rotary shaker. This process may be repeated if the stems are particularly dirty. Once rinsed thoroughly with tap water, the washed stems are placed into 10% laundry bleach (0.5% NaOCl) for 15 to 60 min, at 60 to 80 rpm on a rotary shaker. The exposure time to the sodium hypochlorite solution is dependent upon the number of shoots, maturity of the stems, and the concentration of the bleach solution.

After sterilization or disinfection of the explants is complete, shoots are transferred into sterile water to free the stem tissue of bleach. Sterilized shoots or shoot pieces may be transferred to a liquid or semisolid medium.

Sterile vegetative buds or meristems may also be used as a explant. Using a binocular microscope, scalpel, and fine-tipped forceps, vegetative buds are dissected to remove the outer bud scales. These dissected buds are then either used as an explant or dissected further to remove the meristem. The terminal meristem can be quite small, approximately 0.2 to 0.4 mm in diameter in several different *Rhododendron*. Growth of the dissected buds or meristems is quite rapid, with green primordial leaves appearing within 2 to 4 weeks.

SHOOT MULTIPLICATION

When shoot cultures have stabilized, a typical multiplication rate of 2.0 to 4.0× is sought. Higher multiplication rates can be achieved, but at the expense of adventitious shoot formation. Shoot quality is critical. Shoots should have good caliper with expanded leaves and no hyperhydricity.

Ericaceous shoots are proliferated on a low-salt medium, such as those proposed by Anderson (1976) or McCown and Lloyd (1983). Shoots respond to cytokinins: 2iP, [N^6-(-2-isopentenyl)-adenine]; zeatin, 4-CPPU, [N-(-2-chloro-4-pyridyl(-N-phenylurea)]; and thidiazuron. The optimum 2iP concentration for shoot multiplication with ericaceous plants varies from 0.4 to 16.0 μM.

ROOTING

Microshoots may be rooted in vitro as suggested by Anderson (1978) or rooted out of culture. Microshoots are rooted ex vitro using microcuttings approximately 1.0 cm in length that are stuck into a peat : perlite (1 : 1, v/v) soil mix. No rooting hormones are required. Microcuttings are placed in a humid, warm environment such as: under open mist with bottom heat or in a closed plastic tent. Rooting occurs within 10 to 14 days.

Rooted microcuttings are later transplanted into a porous but moisture-retentive, acidic soil mix. Ericaceous shrubs are sheared from one to four times during the growing season to enhance quality producing a multi-branched liner. Ericaceous trees are normally raised to a single- or few-stemmed liner.

CONCLUSION

The Ericaceae is a family rich with important ornamental and fruit crops. Micropropagation has revolutionized the propagation and introduction of superior and often difficult-to-root new selections. With further research we should expect to see many more new and exciting members of the ericaceae available in the near future.

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The Motives for Using Micropropagated Plants and Their Management by the Nursery Stock Producer

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The reasons for using micropropagated plants are explored from a nursery stock producer's point of view. Comments on the suitability of micropropagated material to achieve specific management objectives are made from practical experience of using micropropagated plants. The relationship between the supplier of micropropagated plants and the client nursery is discussed.

MOTIVES FOR USING MICROPROPAGATED PLANTS

1) To have available a supply of difficult-to-root plants for production, e.g., *Lithospermum*, *Erigeron aureus* 'Canary Bird'.
2) To improve stock health with disease-free or virus-free plants.
3) To obtain plants better suited to production. For example: to ensure trueness to name of clones such as*Heuchera micranthav*ar. *diversifolia* 'Palace Purple' which is variable from seed; to obtain plants with more bud breaks; or to select specific colour strains, as has been achieved in hellebores.
4) To mass-produce new cultivars.
5) To obtain better crop schedule management, e.g., *H. micrantha* var. *diversifolia* 'Palace Purple' on week 16, 24, 32, etc.
6) To make high value plants, which are expensive because other methods of propagation are slow, more widely available. This can be a disadvantage when trying to maintain good prices.

These are all desirable qualities and justifiable reasons for using micropropagation, and will continue to be so as long as prices are maintained and no variables are introduced to change this.

MANAGEMENT OF MICROPROPAGATED PLANTS

The way micropropagated plants are managed on the nursery depends on whether they are standard stock items produced "off the shelf" by a laboratory or new introductions, perhaps exclusive to an individual nursery.

Standard Stock Items. The price of the propagule is an important consideration. How does the price affect the finished product? For example,*Heuchera* 'Snowstorm' costs 75p as a micropropagule. Finished plants in a 1.5-litre pot fetch £1.75. It costs £1 to produce the plant to liner stage using a micropropagule; 36p to take it on to 1.5 litres. Therefore profit, overheads, delivery, label, despatch, etc. all have to come out of 39p.

The next consideration is availability. When are the plants available to the nursery and does that fit in with the existing production programme? It is no good having the plant offered in December when the nursery needs it in July. Micropropagation is a good tool for batch cropping and suppliers should be able to

offer plants for batch cropping of subjects like *Heuchera*, *Sisyrinchium*, *Scrophularia*, and so on. Reliability of supply allows the grower to forward-plan space requirements, pot deliveries, etc. and releases propagation space for other plants.

Reliability depends entirely on the individual supplier so it pays to obtain evidence of good previous performance. Crop failure through contamination, delays in supply, or sudden decisions to drop particular product lines all make a nursery vulnerable to the possibility of not being able to supply the final customer.

It is important to establish regular communication with the supplying laboratory to check that deadlines are being met and that regular lines are going to continue to be produced. In return the nursery should inform the laboratory if its future plans are likely to affect the laboratory's production levels of particular lines.

Orders should be confirmed in writing with details of price, quantity, delivery schedules, and so on.

New Introductions. My own experience varies from the production of 120,000 plants per year of a single cultivar, such as *Heuchera* 'Snowstorm', to runs of only a few thousand for trials of plants.

One of the most important things is for the nursery to establish it has a cultivar worthy of introducing and of producing by micropropagation. Establish that it does not already exist from another source to avoid losing time and money spent on research.

An exclusive agreement should be made between the nursery and the owners of the plant, between the nursery and the micropropagation laboratory, and between the nursery and any sublicensees. There should be a joint commitment to undertake trials to ensure that the lab can initiate and produce true-to-type stock and that the grower can reliably produce finished plants that will flower if necessary.

The laboratory trials should reveal whether or not the plant is capable of being produced in consistent quantities without deterioration at weaning stage; that they are produced true to type, especially variegated forms; and that good multiplication rates are maintained.

The nursery trials should reveal the success rate of growing on the propagules; the optimum pot size for the finished plants and whether the propagule can be direct-stuck in it; suitable composts and which growing areas on the nursery should be used.

As with standard stock items, communications between grower and laboratory are important. Not only does this help maintain enthusiasm on both sides but allows the grower to obtain regular updates on progress and to discuss a reliable launch date and realistic numbers for a programmed schedule.

Handling and Growing On of Young Plants. The timing of delivery is crucial to achieving saleable plants to schedule but a nursery also needs to ensure availability of its own facilities after delivery. For example, will the plants require heat, shade, or supplementary lighting?

It is now that the attention to detail in pre-production trials pays off. For example, the appropriate choice of compost is crucial—some nurseries had some very bad experiences with *Heuchera* 'Snowstorm', but the high losses were probably a result of using the wrong compost. Micropropagules cannot be treated in the way some nurseries treat liners. They need more careful handling and close attention to watering.

It is important to watch for botrytis in the early stages and pre-potting fungicidal drenches may be needed. The high numbers of plants involved mean potentially high losses if disease goes unchecked.

IMPLICATIONS FOR THE FUTURE OF MICROPROPAGATION

Micropropagation can speed up breeding programmes and make new introductions much more quickly. Conventional breeding programmes take so long that by the time a plant is ready for introduction the market's requirements may have changed. Many excellent cultivars never achieve commercial potential.

The increased use of micropropagated plants for nursery stock production will depend on a number of factors:

- The cost must be competitive with conventional methods of propagation, although some plants may withstand a small premium.
- The finished plants must be adaptable to the cultural practices of the consumer.
- The plants must be genetically stable and identical to the original stock plants.
- Plants must be produced at the proper time and in the correct quantities for the customer.

A number of specific trends may be identified:

- *Micropropagation is becoming more integrated with normal* production. For example, it is being used for the production of stock plants from which cuttings or budwood are taken for conventional propagation.
- Smaller micropropagation firms are consolidating into larger, more efficient suppliers, linked to geographical areas.
- Laboratories are becoming more specialised, some in research, others in production. This may be linked to differential labour expertise and cost, for example Western European laboratories may offer to research a new product line which could then be produced in Eastern Europe or other low labour-cost countries.
- *Automation of handling and use of new techniques, such as* somatic embryogenesis and autotrophic micropropagation, will affect the range and prices of plants offered.

Hardwood and Softwood Cuttings: Factors Affecting Rootability

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Although propagation of nursery stock by cuttings has become far more efficient there are still problems. The most striking questions relate to the factors that determine rootability in individual cuttings, which lead to variable results even when cuttings are taken from a single source and treated identically. Attempts to find easily identifiable characteristics that would enable propagators to grade out non-rootable cuttings before striking are described.

INTRODUCTION

Research has solved many problems associated with rooting cuttings. The number of taxa which can be rooted and the success rate have both increased, thanks to improved understanding of the environmental requirements for rooting and attention of plant breeders to propagation efficiency. Our increased knowledge of the effects of juvenility have been one of the most important factors in recent improvements in performance as more attention is paid to the effect of age and pruning of stockplants on the rooting capacity of the cuttings. Tissue culture is now used to rejuvenate stockplants and improves the rooting of many taxa.

One of the most significant of remaining problems is the variability of results depending on season, year, mother-stock, growing conditions, cultivars, etc. We still do not know which factors determine the rootability of cuttings in many cases. In practical terms this means it is still difficult to ensure good production planning.

One of the most striking questions is: Why, in a batch of cuttings, some will root and some will not, even under controlled conditions. In our most recent experiments we tried to see if there were any visible or easily measurable characteristics of individual cuttings that would determine their rootability—this would allow growers to grade out any cuttings that would be unlikely to root before attempting propagation.

ROOTING AND CHARACTERISTICS OF CUTTINGS

The rootability of hardwood cuttings is determined mainly by characteristics of the cuttings at the time of harvest. The conditions during the rooting phase are of secondary importance. Hardwood cuttings possess few visible clues about their rootability. Characteristics, such as location on the stockplant or age of the stockplant and thickness of the cutting (Howard and Ridout 1991a, b), do affect rooting. But more endogenous characteristics are needed to predict the rooting results. It is essential to know which characteristics determine rooting and how they can be measured. The level of dormancy (Howard 1981; Kunneman and Otten

1994), the vigour, and juvenility seem to be major factors in rooting.

With softwood cuttings the provision of ideal rooting conditions is more difficult than with hardwood cuttings. Softwood cuttings need light for their development. Therefore, these cuttings are rooted in greenhouses or tunnels where sunlight is available. But with light, problems arise with heat, carbon dioxide supply, and humidity control. Even in climate rooms it is sometimes hard to keep temperature and humidity under control. So the rooting conditions for softwood cuttings may vary from place to place and from time to time. Under such varying conditions it is very hard to ascertain the effect of the quality of individual cuttings on the rooting results. But in softwood cuttings more visible or easily measurable characteristics are available than in hardwood cuttings.

ROOTING OF CONIFER CULTIVARS

Relations between several visible characteristics of individual cuttings and the final rooting results were determined in *Chamaecyparis lawsoniana* 'Golden Triumph', *C. nootkatensis* 'Glauca', ×*Cupressocyparis leylandii*, *Juniperus* ×*media* 'Plumosa Aurea', and *J. virginiana*. The cuttings were rooted under standardised rooting conditions in a mist unit in multicell pots.

The basal 2 cm of each conifer cutting was treated with a solution of 50 or 100 mg litre^{-1} IBA for 8 h. The cuttings were shaded with a 40% daylight screen when natural radiation outside exceeded 120 J m^{-2} s^{-1} and with a 76% screen when the radiation exceeded 170 J m^{-1} s^{-1}. The minimum night temperature was 18C, the minimum day temperature 21C. In all rooting experiments the minimum CO_2 concentration in the air was 800 μl litre^{-1}.

After 8 to 10 weeks the rooting percentage, the number of roots per rooted cutting, the fresh weight, and the dry weight of the cuttings were determined.

Any relationships between rooting percentage, root number, and fresh and dry weight of the rooted cuttings with characteristics of individual unrooted cuttings were analyzed by multiple regression analyses. Characteristics of unrooted cuttings were fresh weight, diameter of the cutting, fresh and dry weight of the basal 1 cm of the cutting, the dry matter content of the basal 1 cm of the cutting, the colour of the cutting, and the presence of a visible woody base.

The rooting percentages were: *C. lawsoniana* 'Golden Triumph', 57%; *C. nootkatensis* 'Glauca', 86%; ×*C. leylandii*, 89%; *J.* ×media 'Plumosa Aurea', 68%; and of two batches of *J. scopulorum* 'Skyrocket' 51% and 54%. The rooting percentages for *C. nootkatensis* 'Glauca' and ×*C. leylandii* were rather high and this complicated the search for correlations of rooting with characteristics of individual cuttings. The relations of characteristics with rooting percentage and mean number of roots were limited and cultivar specific. The most general correlations were found between fresh and dry weight after rooting and initial fresh weight of the unrooted cuttings. The initial fresh weight had a strong effect on the fresh and dry weight of the rooted cuttings, except for ×*C. leylandii*. In two conifers there was a negative relation between diameter of the cuttings and characteristics of rooted cuttings.

In related experiments, the number of characteristics with significant effects was limited also for rooted and unrooted cuttings of *C. nootkatensis* 'Glauca' and *J. scopulorum* 'Skyrocket'. Characteristics of unrooted cuttings as fresh weight and fresh and dry weight of the bases of the cutting had high correlation coefficients. In this experiment, too, there was a high correlation between initial fresh weight and

fresh and dry weight of rooted cuttings. Also, there was a rather good correlation between rooting percentage and number of roots. Hardly any (very small) correlations existed between rooting percentage and number of roots and characteristics of the unrooted cuttings.

ROOTING OF ENGLISH OAK

In several experiments the regular rooting percentage of English oak (*Quercus robur* 'Gamma') varied from 40% to 60%. This percentage was ideal to determine the correlation of specified characteristics with rooting. Cuttings were taken from stockplants grown in a greenhouse. These cuttings were individually characterized by individual stockplant number, type of twig (short vs. long), type of cutting (nodal cutting vs. top cutting), position of twig on stockplant (base vs. top), number of leaves, diameter of the basal part of cutting, fresh weight, dry weight, and dry matter content (hardness) of basal 1 cm of the cutting.

The cuttings were treated with 0.5% IBA (in talc) and rooted under standard rooting conditions as described above for conifers. The mean rooting percentage of this group of cuttings was 49.6%. The number of the stockplant and the initial fresh weight of the cuttings ($p<0.05$), distance to shoot tip, diameter, and length of the shoot ($p<0.01$) affected rooting percentage significantly. The best rooting was obtained with short thin shoots from the basal part of the stockplant. However, there was no single measured characteristic which determines rooting to a great extend.

Table 1. Effect of shoot position (base-top), shoot type (short-long), and type of cutting (nodal-tip) on rooting percentage of *Quercus robur* 'Gamma' cuttings.

		Nodal	Tip	Mean	Gr. mean
Base	Short	86	62	67	63
	Long	47	68	60	
Top	Short	56	52	53	44
	Long	33	48	35	
Mean	Short	65	57	59	
	Long	38	53	45	
Gr. mean		43	55		49

[1]Unequal numbers of cuttings per treatment.

Correlation of characteristics with rooting was moderate. Only combinations of more than one characteristics had strong relations with the rooting percentage. Rooting of 86% could be obtained when selection of the cuttings was based on position, type of twig, and length of the twigs. Table 1 shows the combined effect of these three characteristics.

CONCLUSIONS

It was difficult to relate visible or easily measurable general characteristics of unrooted cuttings to rooting results. In winter cuttings the level of dormancy is

related to rooting. In softwood cuttings relations between characteristics and rooting percentage and root number are limited. Characteristics seem to be cultivar specific.

To relate rooting to previous measured visible characteristics was difficult. The first problem was to determine which visible or measurable characteristics could be used. There was no general relation with rooting percentage and root number. Relations of weight before rooting and weight after rooting were general. This means that the quality of the cuttings and the regrowth can be improved by increased initial fresh weight. Initial fresh weight can also be used to sort the cuttings to improve the uniformity after rooting.

The second problem was the effect of rooting conditions on the relationship between characteristics and rooting. The relationships varied depending on whether cuttings were rooted under mist, fog, or polyethylene (data not shown).

The third problem was that several characteristics were not independent. This influenced the analysis of the relationships. For example all characteristics based on weight correlate with each other. However, thicker cuttings generally have a higher weight than thin cuttings, and the weight of cuttings with more branches is higher. This means that all relationships between rooting and every single characteristic have to be analyzed to see which have the best correlation.

The fourth problem was that certain combinations of characteristics, which individually have only a minor correlation with rooting, work synergistically—they have a greater effect when working together than you would expect.

In hardwood and softwood cuttings the endogenous levels of enzymes, growth substances, and/or carbohydrates (Veierskov, 1988) might have a more significant relationship with rooting than visible characteristics. Searching for such characteristics is one of the major tasks for future research.

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Methods for Difficult Hardwood Cuttings With Bottom Heat in Hungary

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INTRODUCTION

The use of leafless hardwood cuttings is a traditional propagation method for easy-to-root woody plants. Hardwood cuttings of some "problematic" species root as well as or even better, than leafy softwood cuttings if special techniques, such as the heated-bin treatment developed at the East Malling Research Station in England (Howard, 1968; Howard and Harrison-Murray, 1988; etc.), are used. Another way is to root the cuttings indoors instead of outdoors, usually under a plastic tunnel in a heated greenhouse (De Boer and Van Elk, 1983; Joustra and Verhoeven, 1984; Macdonald, 1989).

In Hungary, the heated bin technique was tried in the late 1970s and early 1980s. Good initial rooting (or callusing) was usually obtained in the bin, but, owing probably to poor weather during winter and spring, survival in the field was so poor that the method was finally abandoned (Schmidt and Tusnádi, 1979; Horváth et al, 1984).

The aim of the present study was to explore the possibilities for propagating difficult species and cultivars by leafless hardwood cuttings which are usually propagated by other techniques.

MATERIALS AND METHODS

The experiments were carried out during 1992 to 1995 at the experimental field of UHFI Department of Floriculture and Dendrology in Soroksár (near Budapest) and fall into two categories: simple rooting of hardwood cuttings and the method of "nurse hardwood cuttings."

Simple Rooting of Hardwood Cuttings. One-year-old leafless shoots were collected between 24 February and 10 March; immediately prepared into hardwood cuttings 10, 20, or 40 cm long, dipped for 5 sec in 0.2% w/v alcoholic solution of indole-3-butyric acid, and planted in flats or boxes (according to their size) in a coarse sand and perlite (1:1, v/v) mix. The flats and the boxes were placed on elevated benches in a greenhouse with l8C bottom heat provided by electric cables and covered with a 0.04-mm-thick transparent polyethylene sheet to retain heat and moisture. The greenhouse received no additional heating.

For experimental controls, hardwood cuttings were prepared of the same species and in the same way, but planted in the open field instead of the greenhouse.

The experiments were laid out in the randomized block system, in four replicates, and with 15 cuttings per plot. Rooting was assessed in late August of the same year.

Nurse Hardwood Cuttings. Cuttings of easy-to-root shrubs and semi-shrubs were prepared and planted at the same time and in the same way in the greenhouse as described above, but 6 weeks after planting, when they started to root and

Table 1. Rooting of selected woody ornamentals propagated by hardwood cuttings at the end of winter and stuck in a glasshouse with 18C bottom heat or in the open ground (control) respectively.

Plant	1992		1993		1994	
	Glasshouse ground	Open ground	Glasshouse	Open ground	Glasshouse	Open ground
Ailanthus altissima 'Purple Dragon'	-	-	14	0	8	2
Betula mandschurica	10	0	6	0	-	-
Buddleja davidii 'Royal Red'	98	82	91	80	94	64
B. davidii 'Nanho Blue'	92	76	98	74	86	70
Calycanthus occidentalis	28	0	24	4	-	-
Campsis ×tagliabuana 'Madame Galen'	-	-	56	12	62	4
Caryopteris×landonensis 'Heavenly Blue	98	21	87	14	96	18
Cercidiphyllum japonicum	12	0	16	0	-	-
Cotinus coggygria 'Royal Purple'	0	0	0	0	-	-
Ficus carica	84	11	72	24	82	-
Hibiscus syriacus 'Lady Stanley'	48	12	56	10	52	-
H. syriacus 'Puniceus Plenus'	54	14	49	11	53	-
Hydrangea arborescens 'Grandiflora'	-	-	82	44	64	24
Jasminum nudiflorum	100	78	98	82	-	-
Metasequoia glyptostroboides	10	-	12	-	-	-
Parrotia persica 'Firebird'	4	-	6	0	-	-
Potentilla fruticosa 'Elizabeth'	-	-	64	11	81	22
P. fruticosa 'Herbstfreunde'	-	-	68	21	62	8
Prunus cerasifera 'Nigra'	-	-	14	0	8	0
P. tenella 'Pink Carpet'	-	-	2	0	4	0
Punica granatum 'Legrelle'	98	31	84	24	86	-
Rosa rugosa	2	-	4	-	-	-
Rubus thibetanus 'Silver Fern'	-	-	14	0	-	-
R. 'Benenden'	44	22	47	-	-	-
Syringa josikaea 'Emerald'	10	0	8	0	-	-
S. ×chinensis 'Saugeana'	0	0	0	0	0	0
S. vulgaris 'Andenken an Ludwig Spath'	0	0	0	0	0	0
Tilia tomentosa	0	0	0	0	0	0
Ulmus ×hollandica 'Jacqueline Hillier'	48	21	52	10	-	-

produced viable new shoots, they were pruned back and their upper shoots were prepared as softwood cuttings, dipped in 0.2% NAA in talc and rooted under a low polyethylene tunnel with 22C bottom heat in the same greenhouse and in the same rooting mixtures.

RESULTS AND DISCUSSION

Simple Rooting of Hardwood Cuttings. *Buddleja, Campsis, Caryopteris, Ficus, Hibiscus, Hydrangea, Jasminum, Potentilla, Punica, Rubus* 'Benenden', and *Ulmus ×hollandica* 'Elegantissima' rooted fairly well (Table 1) in the greenhouse with bottom heat, although the traditional method of vegetative propagation for most of them is softwood cuttings (Krüssmann, 1978; Macdonald, 1989). A similar method of propagation is mentioned only for *Hibiscus syriacus* by M.A.D. (1988) and for *Corylus* and *Laburnum* by De Boer and van Elk (1983). Krüssmann (1978) notes for *Ficus carica*, that it is sometimes propagated by hardwood cuttings in the open field in countries with warmer climates.

Poor rooting (below 20%) was achieved in the greenhouse with *Ailanthus, Betula, Cercidiphyllum, Cotinus, Metasequoia, Parrotia, Prunus, Rosa rugosa, Syringa,* and *Tilia*. Most of the poor rooters showed a good initial growth or even callusing in the greenhouse but later (usually in the second or third week after planting) their new shoots suddenly wilted and the cuttings died, in spite of the regular fungicide drenches and sprayings. *Ulmus ×hollandica* 'Elegantissima' cuttings usually rooted first and only later died.

In the open field, most of the species and cultivars rooted poorly (under 30%); only the very easy-to-root *Buddleja* and *J. nudiflorum* gave 78% to 82%.

Table 2. Rooting of nurse hardwood cuttings and of the softwood cuttings taken from them (glasshouse with 18C and 22C bottom heat) from February through April.

	Cuttings rooted			
	Nurse hardwood cuttings		Softwood cuttings	
Plant	Cuttings per box	Number rooted	Cuttings per box	Number rooted
Caryopteris ×clandonensis 'Kew Blue'	200	196	324	266
C. ×clandonensis 'Heavenly Blue'	200	192	310	229
Hydrangea arborescens 'Grandiflora'	80	54	140	123
Jasminum nudiflorum	200	200	382	357
Potentilla futicosa 'Elizabeth'	100	81	168	136
P. fruticosa 'Goldfinger'	100	71	149	136
P. fruticosa 'Gronland'	100	62	182	157
P. fruticosa 'Herbetfreunde'	100	62	152	116
P. fruticosa 'Ochroleuca'	100	80	164	144
P. fruticosa 'Primrose'	100	58	121	87

Nurse Hardwood Cuttings. The results in Table 2 show that the system worked very well with the species and cultivars tried. The leafless hardwood cuttings rooted with 60% to 96% success after 3 weeks, and produced new, readily rooting leafy softwood cuttings. As a result of this "double yield" each hardwood cutting gave altogether 1.5 to 2.3 rooted cuttings within 4 months.

The above methods described have practical advantages as follows: extension of the range of cutting-propagated plants; extension of propagation season, by utilising the relatively "free" months of late winter; shortening the production time, by giving the plants an earlier start into growth; the "nurse hardwood cutting" system gives higher yields of rooted cuttings per stockplant then the simple rooting of hardwood cuttings.

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Liriope muscari Production and Use in the Southeastern United States

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INTRODUCTION

Liriope muscari is an evergreen, basal-leafed, herbaceous, lily-like, monocotyledonous perennial. It is commonly called lilyturf, monkey grass, border grass, or big blue lilyturf. A closely related genus, *Ophiopogon*, is also commonly called monkey grass. *Liriope muscari* is in the Liliaceae and is native to China and Japan. The species is cold hardy to U.S.D.A. Zones 6 to 10. There are four other species in the genus. *Liriope spicata* and *L. gigantea* are also commonly used as ornamental landscape plants. Lilyturf is a clumping lily. The clump enlarges by rhizomes and possesses tubers. These tubers seem to store water and have no vegetative reproductive features. The species varies in height from 7 to 70 cm.

Liriope muscari has foliage that is evergreen, basal, linear, straplike, sometimes revolute, entire, ciliate, prominently parallel veined, midrib protruding below, glabrous and glandular dotted on both sides, dark green to light green to variegated, and to 60 cm (2 ft) long by up to 20 mm (3/4 in.) across.

The plant is landscape hardy for heat, humidity, and drought and is tolerant of many pests. The inflorescence is ornamental. Racemes are up to 20 cm long. Many cultivars elevate the racemes on scapes up to 30 cm above the foliage. Flower color ranges from dark purple to shades of lavender and pink to white. The species blooms mid to late summer and persists for 8 weeks. The fruits are 1 or 2 seeded, dark black, shiny, globose capsules to about 1 cm across. Germinating seed in established landscapes and production nurseries will contaminate pure genotypes.

Liriope spicata is a creeping species and cold hardy to Zone 4. It is used as a spreading groundcover. It has narrower leaves and is shorter than *L. muscari*. The flowers are pale lavender and not as showy.

Liriope gigantea has the largest leaf of all liriopes. Commonly called evergreen giant liriope, *L. gigantea* grows up to 75 cm tall. The slender scape is dark purplish brown and flowers are light violet. The scapes are hidden beneath the canopy.

LANDSCAPE USES

Liriope muscari is one of the most useful and versatile groundcover plants for a large part of the United States. The liriope species that are commercially important can be planted from Zone 4 to Zone 10. *Liriope spicata* is useful as a mass planted groundcover in Zones 4 through 8. Chicago, Illinois; Dallas, Texas; Philadelphia, Pennsylvania; and Atlanta, Georgia; are cities within that range. *Liriope muscari* is less cold-hardy but thrives in Zones 6 through 10. It is less invasive and is the predominant species used ornamentally. *Liriope gigantea* is the least cold hardy, reliably used in Zones 8 through 10.

Lily turf can survive under a wide range of environmental conditions. They tolerate hot, dry locations such as Dallas, Texas, but they equally like hot and humid areas, such as the Gulf Coast of the Southeastern United States. They are not particular

to soil type although some organic addition to sandy soils is preferable. Liriope can be used on steep banks and slopes as erosion control or in areas where other plants are difficult to establish, such as under trees. It is used in border plantings along sidewalks, driveways or along landscape beds and is popular as a mass planting. Because of its tolerance to drought, it is used in planter boxes, patio urns, and as specimens in rock gardens. Liriope tolerates heavy shade but is slower growing and the flower stems are more elongated under shade conditions.

Plantings should be mowed to the ground to eliminate old foliage and to allow a new flush of growth in the spring. *Liriope gigantea* should not be mowed to the ground in late winter because the foliage remains upright and clean from year to year. *Liriope muscari* foliage deteriorates from the autumn through the winter months, becoming spotted, tattered, and prostrate. As spring approaches and the new flush of growth appears, the older foliage turns brown and unsightly.

CULTIVARS OF COMMERCIAL VALUE

Liriope spicata (creeping liriope) is sold as the species and is green. 'Silver Dragon' is the only *L. spicata* cultivar that has dark green leaves with silvery-white longitudinal variegation. The height is 16 to 20 cm and the variegation makes a very cool appearance in the garden. *Liriope gigantea* 'Evergreen Giant' is the tallest ornamental lilyturf growing up to 75 cm. Adapted especially well in Zones 8b through 10, it is a major landscape ornamental in Florida and is gaining popularity along the Gulf Coast of the Southeastern United States from South Carolina, to Louisiana, to San Antonio, Texas.

I have made two selections from a seedling population that are darker green, and more vigorous and robust than 'Evergreen Giant'. My hope is to determine whether or not one is more cold tolerant, moving the range of adaptability north. Currently, we are moving some of the selections to tissue culture for rapid multiplication but still need 2 or 3 years more for observation of these selections before we can confidently name and release them as cultivars.

Liriope muscari 'Big Blue' and 'Variegata' cultivars are the most commercially successful and desired cultivars of this species. 'Big Blue', introduced by Tidwell Nursery of Georgia more than 40 years ago, has broader and longer leaves and larger flower spikes than the common lilyturf. 'Big Blue' has tapered spikes and is considered typical of the species.

Liriope muscari 'Variegata' is produced in similar numbers to 'Big Blue'. 'Variegata' is gold variegated with dark violet-blue flowers and is an established garden favorite. Height is 30 to 45 cm tall. It was introduced to the United States by the U.S. Department of Agriculture in 1956. This form shows close affinities with *Liriope platyphylla*.

Commercial cultivars of secondary importance include:

- 'Christmas Tree'—spikes of non-opening flowers are shaped like a blue Christmas tree, green foliage (also called Munroe's No.2.)
- 'John Burch'—Very large variegated form, wide leaves, upright, young leaves edged with white. Cock's comb blooms, standing well above the foliage. Flowers are lavender, showy and prominent.
- 'Monroe's White'—The only large, white-flowering liriope. The long stiff spikes stand out well above the foliage. This cultivar does best in partial shade. It is also known as 'Monroe's No.1'.

- 'Majestic'—Grows 30 to 40 cm tall, producing lavender flower spikes in July and August that stand above the wide, dark green foliage. The spikes are compact. The flowers are more showy in shade than in sun.

Many cultivars have been designated by gardeners and nurserymen over the years. Some of their names are: *L. muscari*: 'Samantha', 'Silvery Midget', 'Gold-banded', 'Purple Bouquet', 'Lilac Beauty', 'Blue Spire', 'Curly Twist', 'Silver Banded', 'Border Gem', 'Crested White', 'Densiflora', 'Exiliflora', 'Franklin Mint', 'Gilner White', 'Graminifolia', 'Graminifolia alba', 'Graminifolia minor', 'Green Midget', 'Hawk's Feather', 'Peedee Ingot', 'Rocket', 'Royal Purple', and 'Sheffield'; *L. spicata*: 'Alba', 'Webster's Wide Leaf', 'Yellow Leaf', and 'Superba'; and *Liriope exliflora* 'Silvery Sunproof' (syn. *L. muscari* 'Silvery Sunproof').

The 'Superba' cultivar shows great promise as a commercial cultivar, more robust than 'Big Blue' and the leaves are very long. Observing 'Superba' in a nearby collection, the cultivar thrives and grows well all year round on poor soils, given care. The flowers are tall, profuse and silvery metallic pink.

PROPAGATION OF LILYTURF

Seed propagation of *Liriope muscari* is not commercially acceptable. Seedling variation is great even from seed lots that are collected from a cultivar stock source. The great variation reduces the desirability of plants produced for ornamental uses. The seed matures in the autumn and should be sown as soon as ripe. Under greenhouse conditions, germination is rapid. The seedlings require 1 to 2 years after germination to develop sufficiently to be transplanted into the garden. Seed sown directly outdoors in the autumn and mulched with organic matter will germinate in the spring.

The variegated forms of *Liriope* have been difficult to tissue culture. Many attempts to do so have been difficult because of the great variability in variegation of the resulting plantlets. Only the green-leaved cultivars have been commercially produced in tissue culture laboratories. *Liriope gigantea* 'Evergreen Giant' is readily available commercially, produced by tissue culture.

Division is the primary method of *Liriope* propagation. Propagules are called pips or bibs. A bib of *L. muscari* 'Variegata' given optimum conditions will multiply to a clump of five bibs in one year. *Liriope muscari* 'Big Blue', under similar conditions, will multiply to eight bibs in one year.

Our nursery is located in U.S.D.A. Zone 8b. The traditional start date for propagation is February 15 each year. At that time the liriope is dormant and the danger of extreme cold (below -9C) is past. Clumps are cropped of foliage to 10 cm. Raised-bed, field-grown, or containerized liriope can be used for division. We prefer growing containerized stock for propagation. We are able to maintain genetic uniformity with containers more easily than those from raised beds or in the ground.

The optimum time for division is 15 March to 15 April, prior to the first flush. The soil is removed and the roots are cropped. The clump is divided into single plant propagules. The top is further cropped to 5 cm and the roots are cropped to 2.5 cm.

The bibs are transplanted into 8- cm or 10-cm diameter plastic containers. The 8-cm liner, when matured, will be transplanted into 2-litre, 3-litre, or 4-litre containers for growing on. The 10 cm is sold at maturity in a tray of 16 units. *Liriope muscari* 'Big Blue' will produce a saleable 10 cm in 6 months maximum. The

'Variegata' requires 10 months. The 10-cm trays are boxed, three trays per box to our customers.

Our company produces 1.4 million units per year, so we have to divide all year round. Division after 15 September is hazardous. The new division will have little time to reestablish prior to the winter. Liriope responds quickly to regenerate root growth in the spring and summer heat. During the heavy spring growth (15 April to 15 May) we stop propagation because the new divisions are easily killed by dividing the soft new tissue.

PRODUCTION

Bibs planted after 1 October are put in cold frames to protect against frost. Liriope exhibits two primary growth cycles: a very heavy flush in the spring and another flush in September. The September cycle is half that of the spring cycle. 'Variegata' requires the spring and autumn growth to become saleable. 'Big Blue' can be saleable as a 10-cm container on the spring growth alone. Half of the plants produced after this will be saleable following the autumn cycle. All of our production is at a full sun site.

The growing medium is mostly 1-cm milled pine bark, with some Canadian peat moss (25 : 3.5, v/v). *Liriope* is a heavy feeder. The medium is amended with approx. 6 kg per m^3 of 6N : 6P : 6K fertiliser with micronutrients; 3 kg of dolomitic lime, 2.4 kg of calcitic lime, and 12 kg. of 16N : 10P : 10K slow-release fertiliser. *Liriope* grows well with NO_3 levels of 30 ppm in the soil solution, however, 0.9 kg per 10 m^2 of 12N : 6P : 6K fertiliser can be used to boost NO_3 levels if needed.

Because of the high fertility levels and liriope's nature, we water heavily throughout the growing season. Too little water encourages spider mite problems and leaf spotting. These problems do not occur with vigorous, well-watered plants. As in the landscape, old foliage is removed in production prior to the spring growth. Liriope held more than 12 months in a container becomes unsightly, diseased, and unsalable. Production and marketing should be timed to avoid having old *Liriope* left on the nursery.

Our crops receive a general fungicide application every 14 to 21 days. Scouting for red spider infestation should be done every 7 days and a preventative miticide application should be on a 14- to 21-day schedule. Hot spots of mite infection should be acted upon aggressively. We have had total success using predatory mites to control red spider mite populations and eliminate both fungicide and miticide application.

Our company produces over 1.4 million liriope per year. Sixty percent is marketed as 10 cm and the remainder as 2-litre, 3-litre, or 4-litre containers. 'Big Blue' and 'Variegata' are the primary cultivars. 'Evergreen Giant' currently sells in 3-litre and 4-litre containers. We sell 300,000 per year of that cultivar. We also think we could sell more than 500,000 'Evergreen Giant' in 10-cm pots. *Liriope spicata* 'Silver Dragon' is produced but is only 3% of our total. *Liriope muscari* is a rewarding crop to grow. Homeowners use it in large quantities and the total demand is more than we currently produce.

Natural Regeneration and Propagation of Bamboos and Grasses

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INTRODUCTION

Interest in grasses has clearly been on the increase over the last few years and at Bransford Garden Plants we have attempted to build on this tide with our involvement in various projects and gardens which have helped to show the potential of these plants.

Grasses and bamboos belong to the largest botanical family in the world, Gramineae. However, sedges—which belong to a different family, Cyperaceae—can be used in horticulture in a similar way to true grasses and many of the remarks in this paper refer to sedges as well as grasses.

NATURAL REGENERATION

Grasses regenerate in numerous ways, most relying on a combination of the following to maintain and increase their populations: seeds, stolons, rhizomes (sympodial or monopodial), runners, nodal bulbs, and miniature plantlets.

Seed. Evolution has reduced the floral parts of grasses and bamboos to a bare minimum. They rely on the wind for cross pollination and many species have specific flowering habits. For instance most species of grass flower at a particular hour of the day, with one or two flowering twice in the same day. Some annuals are self-fertile—or can be, if cross fertilisation has not taken place. Most perennials, on the other hand, are self sterile and can wait for another year if they have not successfully cross-pollinated.

The flowering of bamboos is a considerable mystery, some varieties flower almost continuously, some annually, and some at regular intervals of up to 120 years. Some species die after flowering, others look dead because all the culms are flowering culms which tend to die off after flowering. However, the following year new vegetative culms may well appear.

There are also records of simultaneous flowering of certain species of bamboo, where a species has flowered at similar times in different parts of the world.

This erratic flowering has, as you can imagine, made the taxonomy and nomenclature of bamboos very difficult. For example, *Sinarundinaria murieliae* flowered for the first time in cultivation in Denmark in 1984; investigation of the flowers showed it should have been classified as *Thammocalomus spathaceus* and so the seedlings raised were renamed. However, plants raised in the rest of Europe did not flower at the same time and we now have two names for one type of plant. (Botanical editor's note: *Sinarundinaria murieliae* and *Thammocalomus spathacus* are considered names for the same plant, *Fargesia murieliae*.)

Selection, breeding, and crossing has been successful for many years for raising new strains of the members of the Gramineae we grow as cereal crops but as yet has not been explored much with ornamental grasses. It could no doubt yield some very worthwhile results.

Stolons. A stolon is simply an overground creeping stem which roots at the nodes, this node will then shoot to produce a new plant which can then be detached from the parent.

Sympodial Rhizomes. Here the rhizome turns upward towards its tip producing a culm, new rhizomes then form from the dormant buds on the original rhizome. Such grasses and bamboos form tight and dense clumps.

Monopodial Rhizomes. These are longer, running rhizomes where growth continues to be made from the same growing point year after year. Many noxious invasive grasses regenerate in this way. However, not all monopodials are invasive and some of them only spread very slowly. Some grasses have both monopodial and sympodial rhizomes, such as the bamboo genus *Chusquea*.

Runners. A runner is simply a horizontal culm that produces upright culms at its nodes. It is neither a stolon nor a rhizome, but in practice is very similar to a stolon.

Nodal Bulbs. A bulb-like organ, from which a new plant can grow, is produced at the nodes.

Miniature Plantlets. The tip of the flowering spickelet continues to grow forming a miniature plant. This either falls to the ground, or because of its weight bends the culm down until it touches the ground, where it takes root.

COMMERCIAL PROPAGATION OF BAMBOOS AND GRASSES

The majority of types of ornamental grasses, bamboos, and sedges are most usually propagated through division.

However, the following types of grasses can satisfactorily be grown from seed: *Bouteloua* species, *Briza maxima, B. media, Carex* species, *Deschampsia cespitosa, Eragrotis trichodes, Festuca mairei, Helictotrichon sempervirens, Hordeum jubatum, Hystrix patula, Juncus effusus, Luzula* species, *Molinia* species, *Pennisetum orientale, P. setaceum, Poa chiaxii, Schizachyrium scoparium* (syn. *Andropogon scoparius), Stipa* species, and *Uniola latifolia.*

Variegated grasses will tend not to come true from seed, reverting to their green ancestors.

Division of Grasses and Sedges. Here I will describe a simple system that we have developed at Bransford Garden Plants to meet our particular needs.

As with most propagation, healthy juvenile material is the key to success. We achieve this by lining out small plants in our stock area in May, this can also be done in pots. Provided the material is watered well (and shaded in the case of *Milium effusum* 'Aureum') the plants will grow away satisfactorily and be suitable for dividing the following April. In February, the evergreen types are cut back to about 15 cm tall and herbaceous types are tidied back to the ground.

All kinds come into growth quite early in the spring. We prefer to lift them at this stage when they are still actively growing, usually at the end of April or early May. Plants are simply lifted with a spade and divided using a sharp knife or hedge-bill. Each plant will produce between seven and 12 divisions which are boxed up and kept cool and moist, before potting into 9-cm pots under protection.

Provided they are kept moist, the young divisions soon establish themselves in 9-cm pots and can be potted on into finals in August of the same year, or held over for potting the following spring, depending on when they are wanted for sale.

A proportion of divisions are kept back to re-plant in the stock area and so keep the cycle going. However, one must be careful with grasses which run, because fragments of rhizomes will be left in the ground. The solution is either plant a particular variety back into the same ground, or opt for clear rotation and go into clean ground.

Throughout the process, weed control is very important. We rely on both broadleaf herbicides and manual weed control.

Division of Bamboo. The clump-forming or sympodial types are the easiest to propagate and follow a similar but longer cycle to the grasses. We aim to divide them in the early spring once root movement has started but before they start producing new culms. Plants are lifted by hand and divided with a hedgebill or spade. These divisions are then potted straight into larger pots and should become saleable within about 12 months. Divisions are also lined back into the field for 2 years before being lifted and split, again it is essential that they are kept moist during their establishment.

The running bamboos or monopodials can be more difficult to propagate but juvenility is once again the key. One way to help achieve this is to take rhizomes from the field and cut these into about 30-cm lengths and pot these into larger containers in the nursery. They can be left in these containers for up to 2 years depending on the number of culms produced and the growth within the container.

After 2 years you should have a container absolutely full of rhizomes which can then be knocked out in the early spring just as the roots are beginning to grow. The rhizomes can simply be cut up into about 15-cm lengths, providing there's a good bud on each piece, and potted up into small pots to produce young plants. For more difficult types, all I can stress is go for smaller rhizomes with greater juvenility.

Other Techniques. If ever you have bamboos around that are flowering, it's perfectly satisfactory to save mature seeds and sow this although you will get a certain amount of seedling variation.

Beyond division and seed, some researchers are experimenting with tissue culture and cuttings of bamboo but I gather with limited success and as yet no proven track records.

FURTHER READING SUGGESTIONS

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Using the Opportunities for Geranium Propagation

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A range of techniques, both modern and traditional, for the propagation of *Geranium* species and cultivars are considered. The assessments are set in the context of a growing market for herbaceous perennials with customers demanding both new introductions and a continuous supply of established cultivars.

INTRODUCTION

A successful herbaceous producer must be able to supply plants suitable for a variety of purposes and markets. Geraniums are currently very fashionable in Great Britain with many exciting new cultivars like *Geranium* ×*riversleaianum* 'Mavis Simpson' helping to stimulate a market also boosted by media coverage. Among the 400 or so species and cultivars of *Geranium* available in Great Britain there are plants for nearly all market niches.

Various factors will determine the production technique to be used on any particular nursery. Some techniques will be preferred for convenience or necessity to make the operation work but may not initially appear to be the cheapest and simplest method. This paper details the solutions evolved by Howard & Kooij's Nurseries to produce 173,000 geraniums of approximately 40 cultivars, while spreading the work-load throughout the year and fitting in with demands of propagating many other genera.

OPTIONS FOR GERANIUM PROPAGATION

The geraniums considered in this paper are the perennial species that essentially consist of a rootstock which can produce vegetative and flowering stems. Within the basic structure the species vary widely, creating a range of opportunities for propagation.

The rootstock is made up of a permanent stem and the root arising from it. This root can be thick and form buds readily, as in *G. sanguineum,* offering the chance of root propagation.

Division is often the first choice for propagation. *Geranium endressii* and its hybrids are typical of the clump-forming plants that lend themselves to division. The rooted stem usually has short internodes but some species have longer internodes to become a stout rhizome, tuber, or even creeping stolons, again providing potential propagation pieces. *Geranium macrorrhizum* is typical of rhizome-forming species while *G. orientalitibeticum* produces tuberous roots.

Some rootstocks can become woody or the stock remains small producing trailing stems, making them difficult, if not impossible, to divide. Then cuttings have to be considered—either heeled cuttings taken early in the spring or stem cuttings in early summer. Heeled material can readily be obtained from plants, such *as G.* ×*riversleaianum* 'Russell Prichard'. The branching, short-lived aerial stems of many species are really inflorescences and will not root readily. In other species,

nearly all the foliage leaves are borne on flowering stems and are more persistent, e.g. *G. wallichianum,* so stem cuttings are possible.

Geranium procurrens is unusual because its flowering stems run along the ground and take root so stem cuttings can definitely be considered, but its hybrid, 'Ann Folkard', does not root itself readily so tissue culture has to be considered.

Choice of propagation technique is also determined by the intended market. At Howard & Kooij's Nurseries the aim is to grow field-grown material on a 1-year system to produce strong, young rootstocks that a customer could divide into 3 or 4 divisions for planting or potting should they wish.

The plants can be grown in a single batch for sale during the dormant period, typically October to April. Division at a suitable time of year is ideal for this production.

For container production, it becomes necessary to produce plants in batches for sale in flower if possible. Here cuttings, and ultimately tissue culture, allow more accurate programming. The control offered by propagating in modules also comes into play here.

PROPAGATION BY DIVISION

Traditionally gardeners carry out division while plants are dormant but commercially this is often impractical as this clashes with the main sales period for field-grown stock. Geraniums, however, can be divided successfully over a surprisingly long period. The principal period for division at Howard & Kooij's is April to June. Typically the first species divided would include those that also provide heeled cutting material, e.g. *G.* ×*riversleaianum* 'Russell Prichard', *G. renardii, G. nodosum,* and species, such as *G. psilostemon*, which are more sensitive to cutting back of their foliage.

Next, *G. macrorrhizum* cultivars, *G.* ×*cantabrigiense* cultivars, *G. sylvaticum* cultivars, *G. pratense* 'Mrs Kendall Clark', and *G.* 'Johnson's Blue' where simple division often provides sufficient stock. Practical necessity often means *G.* ×*oxonianum* cultivars, *G. clarkei* cultivars, *G.* ×*monacense*, and *G.* ×*magnificum* are divided in May and June when well into growth and even flowering, but these species readily throw up new shoots.

Another window for division exists during October and November as plants become dormant. At this time of the year the split pieces could be replanted directly but cool soil could lead to poor establishment while weeds would need to be controlled before the re-emergence of the geraniums in the spring. At Howard & Kooij's Nurseries we prefer to store these splits outdoors in boxes filled with peat, ready to be planted out in February or March. This method has been used to reduce spring division work load on *G. himalayense* 'Gravetye', *G.* ×*magnificum*, and *G.* ×*oxonianum* 'Winscombe' for example.

Some Tips to Minimise Damage and Improve Establishment. Firstly, propagation staff should be encouraged to look and feel for the natural divisions in the clump. An experienced splitter will readily pick these up, usually using their thumbs as the main guide. Plants, such as *G.* ×*oxonianum* cultivars, will readily pull down into these natural division.

The next progression is to use a sharp knife to nick the plant so that it will again pull apart with minimum wounds. The last resort is to pass the knife through the centre of the clump causing large wounds, but with compact rootstocks, such as *G.*

psilostemon, this is often unavoidable. The use of a 1-year growing system means that division is carried out on young active crowns with little wastage resulting from dead centres and damage can be minimised because forks and spades are not required to smash the plants apart.

The end product of the division process is a split plant with roots trimmed back to 8 to 10 cm for planting and with 1 to 3 strong shoots. The extent to which foliage can be trimmed depends on the species. Early in the growing season it can often be avoided but typically stems are cut back to 10 to 12 cm. It is expected that damaged stems will die back but the main function will be to protect the new leaf in the centre of the division during planting, especially if planting is mechanised as at Howard & Kooij's Nurseries. *Geranium psilostemon* is an example where success depends on doing the minimum damage to the foliage.

Use of Material from Saleable Stock. Splits and cuttings can be obtained from saleable plants during the winter if they are larger than the size required by customers. The pieces obtained can be peat stored as with other splits and planted out in the spring. This is often done with plants that are in short supply, e.g., *G. clarkei* 'Kashmir Purple' or *G.* 'Johnson's Blue'. But it is a costly procedure and one that should only be used as a last resort as the customer may receive a damaged plant and may well have been hoping to take propagating material from it themselves.

PROPAGATION BY HEELED CUTTINGS

These are young shoots removed with a nick from a knife so that a piece of old stem comes away with them from the root stock. Typical geraniums propagated by heeled cuttings include *G.* ×*riversleaianum* cultivars and *G. renardii*. Heeled material is generally taken while the plant is dormant and so can be collected from saleable plants in short supply or as plants start into growth in the spring. Therefore, the technique can be valuable for difficult cultivars, such as G. 'Ann Folkard' or *G. cinereum* cultivars.

An important part of the process is placing the cuttings in a warm, moist environment to encourage rapid growth but success declines rapidly if cuttings are already in vigorous growth when taken. At Howard & Kooij's we use 150- or 77-unit modular trays according to the size of the heel, filled with Levington F2 peat-based compost.

Cuttings are rooted in a glasshouse with cable-heated sand beds, under mist if plants are in growth. Mini Osmocote fertiliser may be added to the compost mix in the autumn to carry cuttings through to spring potting and planting.

In the past, heeled cuttings have also been inserted in open-ground nursery beds between November and March and covered by low polythene tunnels. The old system gave reasonable takes but was costly to weed and lift plants ready for lining out in the fields. The modules reduce the transplant shock associated with planting or potting, improve uniformity, and permit a longer season for taking heels as material may be rooted under the mist in April or May.

Recently we have been extending the use of modules for material that is not strictly heeled cuttings but is more like miniature splits, pieces of rootstock possessing roots and leaves but too delicate to treat directly as splits or potting pieces. The use of the modular stage under mist improves success rates when transplanted and can give 100% establishment in pots. Such material can be

obtained at nearly any time of the year, for batch production of plants, such as *G. himalayense* 'Gravetye' and *G.* ×*oxonianum* 'Wargrave Pink', for sale in flower in pots. For example, late June cutting pieces can produce plants for sale in September to October.

PROPAGATION BY STEM CUTTINGS

Once the time for heeled cuttings has passed and plants are in active growth in May or June it is possible to take cuttings from the flowering stems of a few species. The stems should be cut into pieces with the cut just below the node. The cuttings are treated with 0.5% Synergol rooting hormone and inserted in Levington F2 compost in 150-unit modular trays under mist.

The technique only works well if the resulting plants have time to form resting buds once potted. Cuttings taken from July onwards will root but only produce long trailing flowering stems and the plants frequently die with the onset of autumn.

This technique should be considered for building up new cultivars, such as *G.* ×*riversleaianum* 'Mavis Simpson', and otherwise slow cultivars, such as *G.* 'Ann Folkard', but it is problematic and I would not recommend it for general geranium propagation.

PROPAGATION FROM ROOT CUTTINGS

A traditional low-tech means of propagation is from root cuttings which can be remarkably effective when a little thought is applied to the handling of the job.

Geranium sanguineum and its cultivars are typical sources of root cuttings but sections of the rhizomes of *G. macrorrhizum, G. dalmaticum,* and *G.* ×*cantabrigiense* can be treated in a similar manner. Propagation material may be collected at any time while the plants are dormant but February to March would be usual for these species. Two-year-old stock plants provide the best root cuttings.

Ideal geranium root cuttings are 4 to 5 cm long and 6 to 8 mm thick. Maintaining correct polarity is important but rather than use the traditional slanting cut to indicate the distal end of the cutting, propagators at Howard and Kooij's are trained to store cuttings with the proximal end facing the outside of the box, saving considerably on cutting time. The root cuttings are stood up in a sand and perlite mix covered by 4 to 5 mm of the mix.

Finished boxes can be placed in glasshouses or polytunnels and kept frost free until the cuttings have well-developed shoots. They are then hardened off outside, shading if necessary. A sand and perlite (5% to 10%) mix is used because this facilitates rapid knocking out of the rooted cuttings. Crops can be timed so that they are just beginning to draw new root when potted or planted in April to May. Up to this point cuttings merely require regular watering and survive on their own nutrient reserves.

If peat, or another medium on which young roots can take a hold is used, handling of the cuttings is slowed considerably and root damage increases. The sand and perlite medium gives 90% to 100% takes and, because it is free draining, loss resulting from root rots is minimal.

PROPAGATION FROM TISSUE CULTURE

Generally geraniums propagate readily and quickly by conventional means. There are some cultivars with high merit as garden plants that are slow by division and

difficult by cuttings, for example *G.* 'Ann Folkard', that could justify the expense and effort of tissue-culture propagation. Tissue culture, like cutting production, offers the chance to produce in batches for successional sale in flower. The danger is rapid over-supply, especially if nurserymen propagate-on from their tissue-cultured plants.

PROPAGATION BY SEED

Seed is of value for raising new cultivars and propagating species—quite a few of which will come true providing there are no other compatible species near the parent. Some species, such as *G. endressii* and *G. pratense*, are notoriously cross-fertile.

Geranium seed is dispersed by the explosive break up of the rostrum as it dries out. Close attention must be paid to catching seed pods just as they ripen. Fortunately most culitvars flower and set seed over a long period. As well as species some cultivars come true from seed, e.g. *G. wallichianum* 'Buxton's Variety'.

Once collected, seed may require a period of after-ripening by storing in a paper bag in a warm place. Autumn sowing in modules is possible, provided the seedlings can be over-wintered under protection. If not, sowing can be delayed to the spring.

Germination may be prolonged, with the main flush not taking place till spring. This means it is often quicker to propagate by division and cuttings.

The Propagation and Development of Penstemons

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Penstemons have enjoyed a strong recent revival. The constant influx of new cultivars has resulted in confusion in nomenclature. The National Council for the Conservation of Plants and Gardens Penstemon Collection at Pershore College has been reviewed and, where possible, synonyms identified. At the College, softwood cuttings taken in April or May have rooted reliably under polythene tents in 10 to 14 days, may be potted on in June or July and be saleable in the following spring.

INTRODUCTION

Penstemons were grown widely in the late 19th Century and enjoyed something of a revival in the U.K. in the mid 1950s. They have again become very popular, even being dubbed "the cult plant of the 1990s". The genus is the largest in the Scrophulariaceae with around 200 species and numerous, often confusingly named, hybrids. All the types cultivated in the UK are derived from the North American species. Both hybrids and species are popular in the U.K.; there is a definite preference for the species in the U.S.A. The hybrids, on account of their showy flowers, tend to be given the general specific name *Penstemon gloxinioides*. They are usually derived from accidental or deliberate crosses of *P. cobaea, P. hartwegii*, and *P. gentianoides*.

Pershore College of Horticulture holds one of the National Penstemon Collections of the National Council for the Conservation of Plants and Gardens (NCCPG). It is based on a personal collection donated by the late Ron Sidwell, first Vice Principal of the College. Ron also raised seedlings and selected the "bird" series of penstemons: 'Blackbird', the highly popular 'Osprey', and 'Raven'. Of these 'Osprey' is a little tender but 'Blackbird' very hardy. Although new seedlings continue to be selected at Pershore the prime purpose of the collection is to help to sort out the considerable confusion that exists with the existing species and cultivars.

Penstemons have a reputation for being rather tender. For the larger leaved hybrids this is generally true. The smaller leaved ones tend to be the most hardy and can survive quite hard winters given shelter from cold winds. *Penstemon* 'Andenken an Friedrich Hahn' (syn. 'Garnet') survived the 1981 to 1982 winter when such plants as *Cotoneaster lacteus* and *Elaeagnus pungens* were cut back to ground level. Penstemons are, however, easily killed by excessive moisture, thus an ill-drained container or site is unsuitable.

PROPAGATION

There is currently a strong market for penstemons in 1- and 2-litre pots and in 9-cm pots. Named cultivars do not come true from seed and in the past were often produced by semi-ripe cuttings taken in the late summer and autumn. Traditional cold frames were used, particularly for plants produced for one season summer bedding.

Experience at Pershore has shown most penstemons to root readily from cuttings taken from April to November although there are huge differences in subsequent survival, late season cuttings proving most difficult to reliably overwinter because they tend to rot. For this reason 6- to 9-cm nodal-tip cuttings taken in April and May have given the best overall results. Container stock plants under polythene have produced early ripe material and subsequent cuttings have performed well without hormone in PG56D trays (85-cc cells, 7 cm deep) under "in tunnel" polythene tents. The propagation mix must be freely drained; a peat and fine bark (Cambark fine) (1 : 1, v/v) mix has produced good results. The addition of Osmocote Mini resin-coated fertiliser at 1.5 kg per m^3 has proved most satisfactory and ground magnesium limestone and Suscon Green (chlorpyrifos) for vine weevil control are added routinely at the College.

Rooting normally takes 10 to 14 days and a second crop of cuttings may be taken from the rooted plants within 4 weeks. The plants are potted up into the final pot in June or July, overwintered under polythene, and are ready for sale or cutting production in the following spring.

THE NATIONAL PENSTEMON COLLECTION

(Heights, where stated, are inflorescence maximum heights)

Cultivars of *P. gloxinioides*:

Alice Hindley. Large, pale mauve flowers with white throat and very open, white mouth. Tall, to 90 cm. Royal Horticultural Society Award of Garden Merit (AGM).

Andenken an Friedrich Hahn (syn.*Penstemon* 'Garnet'). Deep wine-red flowers, streaked throat. Bushy habit. Very hardy. AGM.

Apple Blossom. Small, blush-pink flowers with white, finely streaked throat. Dense, narrow foliage. 80 cm. AGM.

Barbara Barker. See **'Beech Park'.**

Beech Park (syn. *Penstemon* 'Barbara Barker'). Large flowers, bright pink corolla lobes with white mouth and throat. 65 cm. AGM.

Blackbird. Deep purple, narrow flowers with heavily streaked throat. Tall, graceful, strong plant. 100 cm.

Blackbird (Ellis Form). Similar to above, but with narrower foliage. 70 cm.

Burgundy. Red-purple, rounded flowers with heavily streaked throat. Tall, robust plant. 90 cm.

Catherine De La Mare. Blue-tinged, pink flowers. Dull blue-green leaves. Spreading habit. Early and long flowering. 70 cm. AGM.

Charles Rudd. See *Penstemon* 'Countess of Dalkeith'.

Cherry Ripe. Cherry red, tubular flowers, streaked throat. Tall, to 100 cm. AGM.

Chester Scarlet (syns. *Penstemon* 'Mrs. Morse' and *P.* 'Souvenir d'André Torres'). Large, tubular, scarlet flowers with streaked throat. Vigorous, to 70 cm. AGM.

Connie's Pink. Slender, rose pink flowers, streaked throat. Tall, to 100 cm. AGM.

Cottage Garden Red (syn. *Penstemon* 'Windsor Red'). Narrow, bright red flowers with streaked throat. Red stems with narrow leaves. Similar to *P. hartwegii*. 70 cm.

Countess of Dalkeith (syn. *Penstemon* 'Charles Rudd'). Large, red-purple flowers with white throat. 85 cm.

Dazzler. See *Penstemon* 'Chester Scarlet'.

Drinkstone. Scarlet flowers, white-streaked throat, dark patches at mouth. Dark red stems. 50 cm.

Evelyn. Small, pink flowers with finely streaked throat. Narrow leaves. Neat, bushy plant. 45 cm. AGM.

Firebird. See **'Schoenholzeri'.**

Flame. Large, scarlet flowers with heavily streaked throat. Similar to 'Chester Scarlet'. 65 cm.

Flamingo. Pink flowers, faintly streaked throat, large, round, white mouth. 50 cm.

Garnet. See *Penstemon* 'Andenken an Friedrich Hahn'.

Hewell Pink Bedder. Red-pink flowers with streaked throat. AGM.

Hidcote Pink. Small, rose-pink flowers with streaked throat. 85 cm. AGM.

Hopleys Variegated. Yellow variegated leaves. Violet flowers with white streaked throat. 65 cm.

King George V. Scarlet flowers. Slightly streaked, white throat. Tall, to 80 cm.

Knightwick. Purple-pink flowers, densely streaked throat. Broad leaves.

Lilac And Burgundy. Large, red-purple flowers with prominent maroon markings on throat. 85 cm.

Madame Golding. Coral-red flowers with heavily marked throat. 60 cm.

Margery Fish (probably syn. *Penstemon glaber*). Small, blue-mauve flowers in dense spikes. Shiny leaves. Spreading habit. Early and long-flowering. Hardy. 60 cm. AGM.

Maurice Gibbs. Magenta flowers with white throat and mouth. 90 cm. AGM.

Midnight. Deep violet flowers, corolla tinged blue, throat heavily streaked. Flowers in a dense inflorescence. Very dark green leaves. 80 cm.

Modesty. Pink flowers with white-streaked throat. 80 cm.

Mother of Pearl. Pale, pearly-white flowers with blue base to corolla. Throat streaked maroon. Tall, to 85 cm.

Myddelton Gem. Rich pink, tubular flowers with white throat. 80 cm.

Old Candy Pink. Rose-pink flowers, white-streaked throat. 75 cm.

Osprey. Large, open, cream flowers, pink corolla lobes. Tall, to 90 cm. AGM.

Papal Purple. Violet-purple, campanulate flowers, white, faintly streaked throat. 45 cm. There is some evidence that this variety should be reclassified as a new species.

Peace. White flowers with pink corolla lobes. More compact habit than 'Osprey'. 65 cm.

Pennington Gem. Pale pink flowers, finely streaked throat. Tall, to 95 cm. AGM.

Pershore Pink Necklace. A new variety raised at Pershore.Large pink flowers with deep pink 'necklace' in corolla tube. Vigorous, tall plant to 90 cm.

Phare. Tubular, scarlet flowers with white throat, slightly streaked at mouth. Red stems. Compact, bushy habit. 70 cm.

Pink Dragon. Deep pink flowers. Low growing. Early.

Pink Endurance. Small, bright pink flowers with white-streaked throat. Dense, narrow foliage. 90 cm.

Port Wine. Large, red-purple flowers with streaked throat. Tall, to 75 cm. AGM.

Prairie Fire. Small, slender orange-red flowers on tall stems. Strongly reflexed lower corolla lobes. Leaves form a basal rosette. Similar to *P. barbatus*, may be a form. 80 cm.

Purple Bedder. Deep purple-blue flowers, streaked throat. Very floriferous. Compact habit. 75 cm.

Raven. Large, deep purple flowers, white throat with prominent purple streaks. 75 cm. AGM.

Red Emperor. Bright red flowers. Similar to 'Chester Scarlet'. Tall, to 65 cm.

Rich Ruby. Large, wine red flowers with heavily marked maroon throat. Tall, to 85 cm.

Ridgeway Red. A new variety with large, red flowers, slightly streaked throat. Vigorous. Tall, to 75 cm.

Royal White. See *Penstemon* 'White Bedder'.

Rubicundus. Large, bright red flowers with large, round, white mouth and throat. 75 cm. AGM.

Russian River. Violet flowers, corolla tinged blue, heavily streaked throat. Dark green foliage. Similar to 'Midnight'. 95 cm.

Schoenholzeri (syn. *Penstemon* 'Firebird'). Dusky red flowers, throat heavily streaked with dark red blotches at mouth. Red stems with narrow leaves. Bushy habit. Vigorous. 70 cm. AGM.

Six Hills. Snowy, bright pink flowers. Early. Low growing, to 15 cm.

Snow Storm. See *Penstemon* 'White Bedder'.

Sour Grapes. Purple flowers with blue base to corolla. Flowers clustered at top of inflorescence. White-streaked throat.

Southcombe Pink. Pink flowers with white-streaked throat. 75 cm.

Southgate Gem. Red, tubular flowers with white-streaked throat.

Souvenir d'André Torres. See *Penstemon* 'Chester Scarlet'.

Stapleford Gem. Opalescent, pale blue-purple flowers, with streaked throat. Tall, to 80 cm. AGM.

Sutton's Pink Bedder. Pink flowers with white throat. 70 cm.

(Tall Pink). An accepted cultivar name is being sought for this plant. Pale, dusky-pink flowers with faintly streaked white throat. 120 cm.

Thorn. Creamy white flowers, corolla lobes pink with colour extending on to corolla tube. 85 cm.

Threave Pink. See *Penstemon* 'Pink Endurance'.

White Bedder (syn. *Penstemon* 'Royal White', *P.* 'Snow Storm', and *P.* 'Burford White'). Flowers pure white, sometimes tingedpink in bud. More compact than 'Snowstorm'. 65 cm. AGM.

Whitethroat, Ron Sidwell form. Red flowers with conspicuous white throat. 105 cm.

Windsor Red. See *Penstemon* 'Cottage Garden Red'.

Other species and their varieties and cultivars:

barbatus Small, orange-red flowers with strongly reflexed lower corolla lobes. Leaves form a basal rosette. Tall. Long flowering.

campanulatus (syn. *Penstemon kunthii*). Small, dark red flowers with white-streaked throat. Narrow leaves. Spreading habit. 60 cm.

campanulatus* f. *roseus. Small, campanulate, purple flowers, streaked throat. Narrow leaves.

confertus. Very small, creamy yellow flowers in dense terminal clusters. Low growing, to 45 cm.

davidsonii var. ***menziesii***. Purple-blue flowers on short stems. Small, leathery leaves. Low growing. Early.

***digitalis* 'Huskers Red'.** Large, purple-tinged leaves. Tall spikes of off-white flowers. Early. 170 cm.

fruticosus. Pale purple flowers, low-growing. Early.

fruticosus* var. *scouleri. Pale purple flowers, small leaves, low-growing, to 20 cm. Early.

fruticosus* var. *scouleri* f. *albus. Creamy white flowers.

gentianoides. Small flowers, flattened violet-blue corolla, white throat. Fine, bushy plant. 30 cm.

glaber (probably syn. 'Margery Fish'). Small, blue-mauve flowers. Low-growing. Early and long-flowering. 60 cm.

gracilis. Small, flattened, violet-blue flowers, white throat. Broad, serrated leaves. Similar to *P. gentianoides*.

hallii. Blue-violet flowers. Prostrate habit. Early. 15 cm.

hartwegii (syn. 'Torquay Gem'). Narrow, blood-red flowers with streaked throat; dark red stems. Long flowering. 80 cm. AGM.

hartwegii* f. *albus. Slender, creamy-white flowers. Fresh green leaves. 70 cm.

heterophyllus. Blue-violet flowers. Early. Hardy. 50 cm.

***heterophyllus* 'Blue Eye'**. Small, deep blue-violet flowers. 45 cm.

***heterophyllus* 'Blue Fountain'**. Small, violet-blue flowers. Mildew free.

***heterophyllus* 'Blue Gem'**. Intense blue flowers. One of the best blue penstemons, but prone to mildew.

***heterophyllus* 'Blue Robin'**. Small, deep violet-blue flowers.

isophyllus. Slender, coral-red flowers, streaked throat. Tall, rigid plant to 140 cm. AGM.

kunthii. See *Penstemon campanulatus*.

lyallii. Small, amethyst-blue flowers in dense clusters. Broad, fresh green, serrated leaves. 70 cm.

newberryi. Large, rosy-purple flowers. Low growing. Early flowering. A good rock garden plant. 20 cm.

ovatus. Small, blue-purple flowers from basal rosette of large leaves. 95 cm.

pinifolius. Very small, orange-red flowers, needle-likefoliage. Very low growing to 30 cm.

***pinifolius* 'Mersea Yellow'**. Small yellow flowers, even dwarfer than species, to 15 cm.

roseocampanulatus. (Botanical Editor note: Name not validated) see*P. barbatus*.

serrulatus (syn. *Penstemon diffusus*). Amethyst-blue flowers in terminal clusters. Broad leaves. Low growing, to 30 cm.

***serrulatus* 'Albus'**. White flowers. 30 cm.

strictus. Deep violet flowers with flattened corolla. Tall spikes of upward-facing flowers. Low habit.

virgatus* ssp. *arizonicus. Similar to *P. digitalis*.

Seedling Production of *Acer griseum*

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INTRODUCTION

Acer griseum, the Chinese paper bark maple, originates from Sichuan and surrounding provinces in Central China and is very hardy.

It was introduced to the West by Ernest Wilson on one of his plant collecting expeditions for Veitch's Nursery in the U.K.

It is a small- to medium-sized tree, up to 12 m in height with a rounded habit, and it is now endangered in the wild.

The most remarkable feature of this *Acer* is the exfoliating bark. As the mature outer bark layer peels off, it exposes the bright copperish coloured underbark. Another outstanding feature is the brilliant red and orange autumn foliage colour. Spring and summer foliage is a dark green. Since its introduction from China it has gained a reputation as one of the most splendid of maples, but because of the difficulties in propagation, its availability has been limited.

Acer griseum is remarkably uniform in its seedling progeny with a limited number of selected forms. Production of seedlings has been the propagation method favoured traditionally by commercial growers.

SEED CHARACTERISTICS

Acer griseum is renowned for its ability to produce large quantities of parthenocarpic seed. A high percentage of these hard, downy nutlets are well formed but hollow and, therefore, lacking viable embryos.

It has been observed that seed viability depends on the number of male flowers and the presence of single fruits showing the scars of male flowers. This often indicates the presence of viable seed. Cutting open a small sample of seed in early autumn will indicate the percentage of potentially viable seed.

The grouping of trees in close proximity in a seed orchard is no guarantee of improved viability. Seemingly isolated trees can yield good seed crops. Once viable seed trees have been found it is important to document germination success rates over a number of years.

Viability as low as 1% to 3% is common, however there are trees which consistently yield regular crops of 70% germination.

STRATIFICATION

Seed is collected in the autumn when the wings have started to change from green to brown. It is cleaned and stored in a cool building before stratification. At no time is the seed allowed to dry, which can trigger seed dormancy which forms in the final stages of seed ripening. Should the seed become dry it is advisable to presoak in water for 24 h.

The seed is stratified in moist sawdust in plastic bins with drainage holes. The bins are well watered and allowed to drain for 24 h before being fully enclosed in plastic covers. This stops the sawdust drying out and the natural wood tannins inhibit mould and fungal infection. Monthly checks are made of media moisture

levels, seed condition, and replenishment of rodent poison baits. The bins are stored in a concrete building, which remains cool and dark all year round.

SOWING AND SEEDLING MANAGEMENT

After 12 months the seed is sieved from the sawdust. It is then treated with a mixture of acrylic paint, Thiram, and Mesurol. This serves as a pest and fungal repellent and for visual assessment while sowing.

Appletons Tree Nursery practises a fixed seedbed production system with the majority of seed being sown in the autumn. The seed bed is thoroughly ripped using a Howard Paraplow and 10 cm of composted pine bark is added to the growing area. The raised seed bed is formed by a Rotohoe with a modified bed-forming attachment. Raised seed beds of 15 cm in height aid drainage, encourage earlier germination and more accurate undercutting.

Acer griseum is a crop which responds well to higher levels of soil nutrition. This is achieved by a combination of coated, slow-release fertiliser, side dressing of balanced NPK granular fertiliser, and foliar feed.

Seed is broadcast by hand at an ideal seedling density of 200 plants per metre. Previous crop records, and the results of the cut test performed at harvesting, are used as a guide to the seed sowing density needed to achieve this. The seed is covered with sawdust and a tunnel of 40% shade cloth for shade and wind protection.

Seed is subjected to a 5-month winter-frost period which helps overcome the chilling requirement prior to germination. Germination occurs in September and careful attention must be paid to pest and disease control. The shade is removed on a cloudy day once the plants are 10 cm in height, so as to allow hardening off.

A reciprocating undercutter is used to cut the tap root of the plant to produce a compact fibrous root system. It is vital that the plant is not stressed, breaking the active growth cycle. Soil moisture at or near field capacity reduces soil movement and plant stress. Irrigation is advisable during periods of desiccating winds.

Using good cultural growing practices it is possible to achieve seedlings averaging 75 cm in height in one growth season.

Notes on Some Factors Affecting the Germination of Palm Seeds

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Hunters Moon, Penpol, Feock, Truro TR3 GRU

INTRODUCTION

The palms (*Palmae*) are a relatively large family (over 200 genera) of monocotyledons which are distinguished, despite their diverse appearances, by their woody habit—an uncommon feature in monocots. They are not, in general, readily propagated by vegetative methods and are, therefore, principally produced from seed.

Despite extensive and diverse uses which are made of palms—as specimens in the landscape, as container subjects, as indoor plants, and as economic crops—the propagation of palms from seed has received scant technical observation. It is, therefore, often a hit and miss affair, often producing erratic responses. There has been little in the way of controlled observation, trial or experiment to determine the limitations of the parameters within which the process occurs, for this group of plants.

The seeds of individual palm species vary dramatically in size from the coco-de-mer (*Lodoicea maldivica*) of the Seychelles, which has the largest seeds of the plant kingdom to relatively small seeds of a few millimetres across. They vary in shape from ellipsoidal, through ovoid, to round, or indeed sometimes they are irregular.

COLLECTION AND STORAGE OF SEED

The first significant factor for reliable commercial propagation is to start with fresh, recently harvested seed. The viability of palm seed tends to decline rapidly after collection and extraction, especially if any significant degree of drying is involved. Palm seeds should, therefore, be stored under water-conserving conditions to maintain viability for as long as possible.

Palm seed contains an embryo which does not reach maturity, in general, until just before the fruit is shed. The embryo is typically small and somewhat conical in shape and is embedded towards the base and on the periphery of an extensive, homogenous and tightly packed endosperm which is turgid when fresh.

If the seed is allowed to dry (the seedcoats and pericarps are generally not impermeable) the endosperm, with its embedded embryo, begins to shrivel away from the seedcoat until contact is lost and it thus becomes separated and isolated within the seed. So direct contact with any potential water source is lost and the inward transfer of water becomes impeded and uncertain thus reducing the seed's ability to rehydrate. The potential for germination then becomes erratic. It may be possible to rehydrate the seed by soaking but any success will be determined by the permeability of the seedcoat, the level of internal shrinkage and the extent to which any points of contact remain. The extent to which this condition has developed may well prove to be one of the reasons for the very long periods and erratic time scales, reported in the literature for the germination of some samples of stored seeds.

Most commercial growers in Florida, Hawaii, and Australia soak palm seeds as a matter of course, for periods of from 1 to 6 days, to ensure an acceptable turgidity before beginning the germination procedures. Aerating the water at this stage may reduce the danger of "drowning" the seed.

Palm seed usually develops within some form of fleshy fruit. The dispersal strategy, under natural conditions, would involve the separation of this from the seed as a result of paring or by digestion on passage through the gut of a bird or animal. In propagation practice this flesh is removed in order to eliminate the potential for rotting agents to establish and for the removal of any chemical inhibitors to germination which may be present. The fruits should not, as a general rule, be picked until they are mature and ready to fall. At this stage they are macerated, placed in warm water and allowed to marginally ferment so that the flesh can be rubbed free and decanted off. The separated seeds can now be washed to clean them off completely. They are then surface dried and if required dressed with fungicide for storage or processing.

There has been considerable discussion in many reports about the feasibility of collecting the fruit while it is still green and/or the necessity for removing the flesh from the seeds. The more conclusive and generalised evidence suggests that mature fruits should be used and that they should have the flesh removed.

TEMPERATURE FOR GERMINATION

Palm seeds, in general, require relatively high temperatures for a full and successful germination, usually in the region of 33 to 37C, a range directly associated with their tropical and subtropical distribution. Because of the high energy inputs required to maintain such temperatures in a conventional propagation system, often for relatively long germination periods, energy efficiency is even more important than it is for temperate woody plants. This may include concentrating the seeds in a limited volume and incubating them *en masse* until the actual emergence phase begins, then sowing the seeds only when the radical is about to emerge.

The limited research literature which exists reports extremely wide variations in germination times, even when looking at distinct seed samples of the same species and from what are often painstakingly measured responses. There are three possible reasons: either they cannot all have used fresh seed, as indicated above; or that they have been derived using a single temperature regime; or, possibly, there is an inherent discontinuity in response. Certainly the age of the seed and the previous history of handling and storage conditions will influence the situation but the single critical environmental feature which has not generally been investigated and determined is the optimum temperature range required to achieve success for the particular subject. If a trial was not using the best germination temperature, then its assessment of time scale becomes of relatively less value.

In a series of elegant and simply based (although practically complex) observations Carpenter (1988), working in Florida and using four native palm species, has demonstrated that germination only occurs rapidly and productively within a distinct and limited temperature range and that even if the temperature is only marginally above or below this range the process of germination may not only be dramatically slower but the number of seeds responding declines considerably. Within the optimum temperature range the highest number of seedlings emerge in the shortest time span and with the greatest degree of synchronisation. That a particular temperature range is critical to each individual species and that one temperature range is not necessarily universally applicable is demonstrated by the

responses he determined:

Sabal etonia	24 to 36C
Coccothrinax argentata	33 to 36C
Thrinax morrisii	33 to 39C
Acoelorraphe wrightii	33 to 39C

This series of results also indicated that the greater the temperature deviation was from the optimum, the longer was the time needed before 50% of seeds had germinated; the more erratic was the emergence and the number of seeds which germinated normally was fewer. If seeds which were exposed to less than ideal temperatures were then transferred to temperatures optimum for germination they quickly responded and germinated normally.

Many reports in the literature provide or cite extensive data on the times for germination and percentage emergence for considerable numbers of species. These responses, however, have virtually always been gathered from observations based on a single temperature regime and it cannot be expected that they represent the optimum response pattern for all the species enumerated. Using the wrong temperature probably accounts in most instances for the variations in response of individual species.

THE EFFECT OF SEED TREATMENTS

The literature provides many examples of the use of artificial treatments being carried out to improve and/or hasten germination.

The most obvious is the use of scarification but simple physical abrasion to reduce the thickness of the pericarp—especially on seeds which are not effectively impermeable to moisture—does not improve the rate of water uptake and is more likely to encourage rotting. It is only likely to provide significant benefit in seriously dehydrated samples. However, in those species which develop an impervious micropylar cap, the careful removal of this structure can be shown to aid imbibition and promote a more rapid germination and greater synchronisation of emergence.

A number of attempts have been made to enhance germination by various treatments using gibberellic acid and although such treatments, in many cases, can be shown to hasten germination response the seedlings usually develop atypically, with elongated stems and these do not easily recover normality. However, many of these observations on the use of growth-promoting substances lose some of their validity if the results have been achieved without considering the need for a critical temperature regime.

THE INFLUENCE OF LIGHT IN THE GERMINATION OF PALM SEED

In general it would appear that light is not a significant feature in controlling germination and that palm seeds are not light sensitive.

However, there is some observational evidence to suggest that the presence of light may inhibit radical emergence in open habitat species—such as *Washingtonia*—where survival depends on establishment beneath the protection of the canopy.

CONCLUSION

It is thus evident that knowledge concerning the pretreatment of, and the environmental influences during, the germination of palm seeds is fragmented and significantly incomplete. Any propagator seeking to determine treatments for a

sample of seeds of any one particular species may well be stymied by the lack of sources of information—the problem which has given rise to these notes!

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ADDENDUM

Palms exhibit such a wide variety of germination strategies (not a surprising state of affairs in such a large and diverse group of plants) and so little information is available about particular species (and that which is available is spread across a wide spectrum of sources). A fuller list of available literature is provided below.

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The Commercial Development of Australian Native Ornamental Plants

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INTRODUCTION

It has been estimated that Australia has up to 30,000 native plant species, a large proportion of which is not in general cultivation. Currently there is some commercial interest in selection and development of native plants for three main markets: cut flower production, pot plant production, garden and landscape planting.

CUT FLOWERS

Considerable development of new plant selections has occurred in this area. A major export market has been developed for a number of genera over the last 20 years, following work of researchers in the state Departments of Agriculture, commercial producers, and enthusiastic amateurs. Funding has been largely provided by the Rural Industries Research and Development Corporation (RIRDC), which is a Federal Government body set up to make most effective use of research and development funds.

Plantation production of native cut flowers is a relatively recent development in Australia. Harvesting of stems from the native bush has been the main source of many native flowers, however, public opinion has built up against this practice on environmental grounds. This has provided a major stimulus to the establishment of commercial field plantations.

Geraldton Waxflower. *Chamelaucium uncinatum* and a number of related species are tall-growing evergreen shrubs native to the southern part of Western Australia. They have been widely exploited for cut flower production, initially from bush-harvested material, but more recently selected flowering forms have been cultivated in plantations in many states. Most selected flowering forms have been selected from natural stands in Western Australia.

During the 1980s New South Wales Department of Agriculture (NSWDA) undertook a breeding programme on *Chamelaucium* resulting in a number of hybrids, some of which were tall growing types suited to cut flower production and some more compact forms which have potential as flowering pot lines. The Department sold the marketing rights to the commercial sector and these hybrids are now coming into cultivation.

There are a number of plantations near Gatton College and, in the heavy soils of southeast Queensland, *Phytophthora cinnamomi* is a serious problem. Some of the NSWDA hybrids are exhibiting strong field tolerance to this pathogen and at Gatton College we are currently researching grafting techniques for sensitive cultivars using these more tolerant hybrids as rootstocks. Side veneer grafts and side veneer cutting grafts have given more than 90% success rates.

Rice Flower. *Ozothamnus diosmifolius* (syn.*Helichrysum diosmifolium*) has been bush-picked in eastern Australia over the last 20 years. The Queensland Department of Primary Industries (QDPI), Redlands Research Station, has now selected a range of types with white or pink flowers. Private growers have also been active in selecting improved forms. Graham and Ester Cook of Helidon, Queensland, have selected an improved white and an improved pink form which have now been protected by plant breeders' rights (PBR).

In developing a commercial industry a number of problems were encountered by QDPI. The plant's cultural requirements were not well understood, propagation techniques had to be improved, and postharvest requirements determined. Research to tackle these problems was begun in 1992 and there is funding until at least 1997. Trials have been established to document yields, longevity, and pest and disease problems. Yields can be high (10 to 50 stems per plant per year) but 10% to 20% plant losses per year are not uncommon due to root congestion, root-knot nematode, and phytophthora root rot.

A 10- to 12-week flowering season is possible with newer strains and good choice of planting location. Vase life is excellent. Some problems have been experienced with post-harvest foliage blackening if stored at high temperatures. Propagation by conventional softwood tip cuttings is satisfactory. QDPI has received provisional PBR protection for a selection named 'Redlands Sandra' and a growing and marketing brochure has been released.

Kangaroo Paw. The genus *Anigozanthos* is native to the southwest of Western Australia and is widely used as a garden perennial and as a cut flower. There have been many selected forms introduced into the trade in Western Australia, especially long stemmed types for cut flower use.

The "Bush Gems" series were bred by Merv Turner, a nurseryman from Victoria, and a number of named colour forms are widely used. *Anigozanthos manglesia* 'Bush Dawn' is a vibrant yellow form and 'Bush Sunset' is a deep red selection.

A selection of naturally dwarf kangaroo paws has been developed by New South Wales Department of Agriculture at the Gosford Research Station. These dwarf forms were developed using embryo rescue techniques in tissue culture and are particularly suited to flowering pot plant production. A wide range of colour forms are available in this series. The plants are fast-growing and will flower in 12 to 14 weeks from tissue culture.

Banksia. Professor Margaret Sedgley of the University of Adelaide has been involved for some years in the development of improved cultivars of *Banksia* for ornamental horticulture use—especially the cut flower industry. The programme has involved the development of a range of characters, including bloom number, quality and colour, and disease tolerance of the plant. *Banksia* species under investigation include *coccinea, hookeriana, menziesii*, and *prionotes.*

A selection of *B. hookeriana* has been registered under the cultivar name 'Waite Orange'. It is believed to be an interspecific hybrid between *B. hookeriana* and *B. prionotes* and it is a very vigorous grower with a much higher yield of blooms than either parent.

The intent of this programme is that once superior cultivars have been selected, major commercial gains will be derived from the establishment of flowering plantations of clonal material. This will require the development of vegetative

propagation techniques to propagate the clonal selections. Work is underway on *B. hookeriana, B. prionotes*, and 'Waite Orange' to develop techniques for propagation by cuttings.

The time span of root formation in *Banksia* cuttings has been very long with some clones taking up to 1 year to develop roots. Professor Sedgley's group is also pursuing the potential for the use of tissue culture in the commercial propagation of *Banksia* clones.

Waratah. *Telopea speciosissima* is the New South Wales floral emblem and it has been grown for some time as a woody plantation cut flower crop there. A number of improved forms have been selected, including a white cultivar which was recently introduced to the trade. The structure of the flower is highly unusual and there is a strong demand. It has been widely grown in New Zealand as a cut flower crop for export, to the chagrin of the Australian cut flower industry.

Koala Fern. *Caustis blakei* is a sedge which is indigenous to southeast Queensland and northeast New South Wales in open woodlands. It is extensively bush harvested for its feathery stems which are popular as cut foliage in flower arrangements. It can be used in the fresh green state, or it can be dried and dyed a number of bright colours. Vegetative propagation has not been successful and we must rely on seed. Unfortunately fruit set is very low, for every 100 flowers only eight or nine fruits are set. Gatton College is currently undertaking a research project which examines factors influencing fruit set as well as developing a commercial tissue culture propagation process for *Caustis* so that it can be cultivated as a plantation crop.

Geebung. *Persoonia virgata* is another bush-harvested species used for floral arrangements. It is a member of the Proteaceae with single yellow axillary flowers. The seed has a hard woody endocarp which acts as a barrier to germination. Work is under way at Gatton College to improve its propagation performance which would make larger quantities available for commercial plantations. Aspects of seed, cutting, and tissue-culture propagation are being examined. At present seed appears to be most promising and good germination is being achieved with removal of the fruit and the woody endocarp.

Christmas Bell. *Blandfordia grandiflora* flowers from November to February. It is a rhizomatous member of the Liliaceae and indigenous over much of central and southern New South Wales. It is in demand as a cut flower and some growers in New South Wales are now exporting it to Japan. Work has been carried out at the University of Sydney to gain an understanding of the factors which regulate its flowering. The two main factors involved in floral initiation appear to be rhizome size and vernalisation.

POT PLANTS

Breeding and selection of annuals and perennials has been carried out both by state Departments of Agriculture researchers and commercial producers, with many projects being funded by the Horticultural Research and Development Corporation, using funds collected through a grower levy.

***Brachycome* Daisy.** In 1989 Plant Growers Australia in Melbourne started a *Brachycome* breeding programme with government assistance. The aims were to

produce a range of cold hardy *Brachycome* cultivars; to increase the range of plant and foliage forms; to increase the range of flower colours, in particular yellow; and to produce plants that could be protected under PBR and earn royalties for Australia.

So far seven cultivars have been protected and released in Australia. Trials have been carried out in several countries and plants will be released in Europe, U.S.A., Canada, New Zealand, South Africa, and Japan in the near future.

Brachycome 'Lemon Drops' and 'Lemon Twist' add a totally new colour to the previous range of mauves, pinks, and white. 'Pink Haze' is a hardier pink-flowered cultivar than previously available. 'Happy Face' is the most outstanding of the series and has large cerise flowers and interesting foliage. It has also proved hardy in cold areas of Australia. To date, royalties of over $20,000 from 'Happy Face' have been donated to World Vision to help needy children.

Other Native Daisies. A large selection programme, supported by the HRDC, with native daisies was carried out at Queensland's Redlands Research Station. An extensive selection programme has identified several species with horticultural potential, many of which can be produced in flower within 14 weeks from sowing. The project also investigated germination requirements and environmental influences, including photoperiod, on growth and flowering. Some of the more promising types identified during this project include:

***Acroclinium roseum* (syns. *Rhodanthe chlorocephala* ssp. *rosea* and *Helipterum roseum*).** Annual "paper daisy" with long flowering stalks highly suited as a cut flower and for massed border displays. Germinates easily but woolly seed is problematic in automated seeding machinery. Flowering promoted by long days.

***Helipterum floribundum* (syn. *Rhodanthe floribunda*).** Annual, although short-lived perennials may occur in cultivation. Germination can be difficult. Soaking seeds in gibberellic acid is beneficial. Flowering is promoted by long days and cool nights during early stages of growth. Suitable as a hanging basket plant.

***Schoenia filifolia* ssp. *filifolia* (syn. *Helipterum filifolium*).** Short-lived perennial in warmer zones. Long-day plant requiring cool temperatures during the early stages of growth for floral display. Suitable for hanging baskets.

***Hyalosperma cotula*.** Small annual paper daisy. Seeds require treatment at 50C for 2 to 3 months for germination. In the wild this plant germinates after bushfires, may respond to smoke treatments. Suitable as a miniature flowering potted plant.

***Lawrencella rosea*.** This paper daisy tends to be perennial, forming short twiggy bushes. Short days required for production of intense pink flowers.

***Brachycome halophila*.** Soft-petalled flower similar shape to *Cineraria*. Annual with potential as bedding plant. Day-neutral flowering.

Mulla Mulla. The genus *Ptilotus* contains over 80 species, several of which have great potential for use as flowering pot plants. It belongs to the Amaranthaceae and the inflorescence is a feathery head of bract-like florets. *Ptilotus exaltatus* has larger and more colourful spikes than most other species and is receiving greater attention as a cultivated plant. Flowering plants *of P. exaltatus* in pots won a

"Flower of the Year" award in Europe in 1993 and this has stimulated commercial interest in its development within Australia.

Seed germination is very variable but can be improved by scarification to remove the perianth. Propagation by cuttings is limited because of the small number of vegetative stems produced by most species. Tissue culture is now well developed.

Sturts Desert Pea. *Clianthus formosus* (syn. *Swainsona formosus*) is one of the most spectacular of Australia's wildflowers. The species has been widely grown as a garden plant but tends to be rather short-lived in cultivation.

There are various structural forms in cultivation, ranging from prostrate ground covers to upright bushy types. Selections have been made of types suitable as a flowering pot line, a hanging basket plant, and a cut flower crop. A number of different flower colours have been selected, which provides greater interest in this species.

GARDEN AND LANDSCAPE

Little government funding has been available for research and development involving native woody species and most of the development and selection of improved forms has been carried out by commercial growers and enthusiastic amateurs. The establishment of the Plant Breeders Rights scheme in Australia during the latter part of the 1980s has been a major incentive for growers and breeders to introduce new plants.

Grevillea. There are some 250 species of *Grevillea*. It is a member of the Proteaceae and widely used as a garden shrub in Australia. In Queensland a range of tropical and subtropical hybrid forms with large terminal inflorescences have been selected. *Grevillea* 'Robyn Gordon' is a low-growing shrubby type about 1 m high. It is a hybrid between *G. banksii* and *G. bipinnatifida* and the original cross occurred in the garden of Mr. David Gordon of Glenmorgan in Queensland. 'Robyn Gordon' is a very free-flowering form with brilliant red flowers and it will flower almost continuously in warmer areas of Australia.

Grevillea 'Sandra Gordon' is another hybrid developed by David Gordon. The parents of this selection are *G. sessilis* and *G. pteridifolia*. This is a much taller growing shrub to about 4 m with bright yellow flowers.

A wide range of other selected forms of *Grevillea* for cultivation in the warmer parts of Australia include: 'Honey Gem', with large orange-yellow flowers; 'Honey Wonder', a selected form of the previous type with variegated foliage; 'Pink Surprise', a tall growing type with bright pink flowers; 'Majestic', reddish-pink flowers; 'Superb', reddish-orange flowers; 'Sylvia', red flowers;'Golden Yul-lo', a recently introduced form with golden yellow flowers; and 'Crimson Yul-lo', a yet to be released form with crimson red flowers.

Hardenbergia. *Hardenbergia violacea* is a native climbing plant with a rampant and straggling growth habit. The selection 'Bushy Blue' originated as a chance seedling in a nursery in California. It has compact growth and develops as a low, bushy shrub. It is extremely free flowering for an extended period over winter and early spring.

Golden Penda. *Xanthostemon chrysanthus* a large shrub or small tree from the rainforests of north Queensland. It was brought into cultivation by Fairhill

Nursery, Yandina, Queensland. Initially it was propagated by seed and the lack of availability of seed restricted its availability. It can now be propagated by cuttings which has increased availability. Golden penda was selected by the Queensland Nursery Industry Association as its major plant release during the 1988 World Expo in Brisbane under the name 'Expo Gold'.

The range of native plants covered in this paper is only a small sample of the selection and development work under way in Australia on native plants. Over the next 10 to 20 years we will see a range of exciting newer plants come into cultivation which will extend the range of Australian native plants with commercial appeal.

ACKNOWLEDGMENTS

A number of researchers and nursery producers in Australia have provided assistance in compiling this paper: Peter Beale and Cynthia Carson of the Queensland Department of Primary Industry; Alex Hansa of Fairhill Nursery, Yandina, Qld; Prof. Margaret Sedgley of the University of Adelaide; Dr Margaret Johnston of the University of Queensland Gatton College; Dr Peter Goodwin of the University of Sydney; Natalie Peate of Plant Growers Australia, Melbourne; Dr Kerry Bunker, Redlands Greenhouses, Qld; Prof. Richard Williams, University of Queensland Gatton College; Edward Bunker, Redlands Greenhouses, Qld.

The Propagation of Some British Columbian Native Plants

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With approximately 3000 species, British Columbia is fortunate in having a diverse and fascinating flora. The plants come from a wide variety of geographical and climatological locations—from the high rainfall areas of Vancouver Island's west coast and the alpine areas of the province's many mountain ranges, to the arid region of the southeast.

As in many other parts of the world, native plants are becoming increasingly important in the urban and highway landscape, which in turn results in more sophisticated production and marketing strategies to provide plant quality and promote sales. This paper outlines specific propagation methods used to produce some of the important genera for commercial sales.

NATIVE PLANTS

Arctostaphylos uva-ursi. This is an extremely important evergreen ground cover, both for commercial and home garden landscapes. It is widely distributed in British Columbia (B.C.) and other provinces of Canada. However, some seed provenances result in crops being variable in habit and leaf size. This also occurs when growers collect cuttings from plants in the wild. Reid, Collins Nurseries Ltd., Aldergrove, B.C., is one of the leading growers of native plants and has spent a considerable amount of time selecting the best provenances as well as formulating and improving effective presowing treatments of the seed. With its wide distribution, *A. uva-ursi* is a good example of the variability to be found in British Columbian native plants. Seeds collected in the Yukon/northern B.C. border area result in relatively compact small-leaved plants—contrasting with looser, larger-leaved plants from central regions of B.C. or the upright growth from seed collected on Vancouver Island.

An effective pre-sowing treatment is a 2- to 4-h period of concentrated sulphuric acid digestion, followed by 3 to 6 months of cold stratification at 1C. An alternative is 2 to 3 months warm stratification at 21C, followed by 4 to 6 months cold stratification at 1C.

In terms of the number of plants sold by the 42 nurseries in the University of British Columbia's Plant Introduction Scheme (PISBG), the selection *A. uva-ursi* 'Vancouver Jade' is the most successful. Nearly 1 million plants are sold per annum. This clone, from Vancouver Island, was selected because of its vigorous uniform habit, bright-green summer foliage, deeper-pink flowers, and its ability to yield 90% rooting from cuttings. There is considerable clonal variation in the rooting of the species.

Three important rules when propagating this plant are:

1) Ensure cuttings are not stressed at the time of collection, preparation, or during their aftercare. Open ground stock plants need to be routinely irrigated during dry weather.

2) Best cuttings are obtained from 3- to 5-year-old plants in the open ground or from a production crop, as long as it has not had high fertilizer applications. It is a mistake to obtain cuttings by regularly heavy pruning plants in the landscape because their vigour will decrease, making them more susceptible to foliar and stem diseases.

3) The rooting mix must be well drained. If not, then the plants succumb to black stem and leaf spot infection caused by species of the pathogen *Exobasidium*.

In B.C., cuttings are best taken in October to February as 10 cm nodal or heel cuttings and treated with 0.8% IBA in talc or 2000 ppm IBA in a 3- to 5-sec quick dip. They are then placed under polyethylene with fog or mist, however, excessive overhead water application should not be given because it leads to stem and leaf rots. Like other *Arctostaphylos*, 'Vancouver Jade' does not like root disturbance, so direct sticking of two to three cuttings per pot is recommended.

Cornus nuttallii. Two effective pre-sowing treatments for the native *C. nuttallii* are 3 to 4 months of cold stratification at 1C or 20 to 30 min of concentrated sulphuric acid digestion, followed by the same cold stratification period. Care needs to be taken that the embryo is not damaged by the acid treatment. Unfortunately, demand for this attractive plant is decreasing in urban landscape planting mainly as a result of the increasing incidence of anthracnose caused by species of the pathogen *Discula*. Plants which are under stress are particularly prone to infection.

Cornus canadensis. The attractive *C. canadensis,* however, is a ground cover which is in constant demand. Again Reid, Collins Nurseries Ltd. has made some interesting observations in the provenances of this species. For example, seed collected in the Yukon yields compact plants with good resistance to leaf spot disease, while some provenances from Vancouver Island are more evergreen, have glossy thinner foliage but show more susceptibility to leaf spot during the production cycle. Two effective pre-sowing treatments are 3 to 4 months cold stratification at 1C or 15 to 30 min concentrated sulphuric acid digestion, followed by 3 to 4 months cold stratification. Again, correct timing of the acid treatment is vital to prevent seed embryo damage. For small quantities of plants propagation by division is reliable.

Vaccinium Species. There are a number of native *Vaccinium* species which are increasing in popularity. These include *V. alaskaense, V. membranaceum, V. ovalifolum, V. parvifolium, V. vitis-idaea*, and *V. uliginosum*. Excellent results are achieved by sowing seed in a cold greenhouse during late February/early March, subjecting the seed to a cold/cool-night and warm-day regime. The seed does not require a specific presowing treatment.

Found in many of the southern coastal regions of B.C., *V. ovatum* (evergreen huckleberry) is a variable plant in habit and leaf size, but is becoming increasingly desirable for native landscape planting. Some years ago the Plant Introduction Committee of PISBG selected a clone which was more compact, had outstanding reddish-brown new growth, and produced masses of pink flowers and black berries. This clone was subsequently named 'Thunderbird' and released for sale in 1994. Readily rooted in 6 weeks from nodal cuttings during late summer and autumn using 0.8% IBA in talc, it does present a problem of uneven bud-break the following spring. The shoots which fail to break are those which had flower buds at the time

of propagation. To assist in overcoming this problem, established stock plants should be relatively heavily pruned to encourage vigorous non-flowering shoots.

Rhododendron macrophyllum. The native *R. macrophyllum* does not require a pre-sowing treatment. The best procedure is to evenly sow in flats during early spring and then carefully pot.

Arbutus menziesii. Noted for its attractive cinnamon-coloured bark and orange-red fruits, *A. menziesii* is another very desirable native plant. It is found on rocky, coastal outcrops of the southwestern B.C. mainland and off-shore islands. This plant does not like root disturbance, high nutritional, or moist regimes. *Arbutus menziesii* likes to be grown in a "harsh mix" with very low nutritional status. Propagation is best achieved by direct sowing in flats or cell trays during early spring in a cold greenhouse. To obtain more even germination, cold stratification at 1 to 3C for 3 months is recommended.

***Penstemon fruticosus* 'Purple Haze'**. British Columbia has some interesting native penstemons. The UBC Botanical Garden selected an improved clone *of P. fruticosus* and subsequently named it 'Purple Haze'. Although easy to root, it is another plant that deteriorates under overhead irrigation and excess nutrition. Growers in B.C. who produce quality plants of this selection appreciate that it does require special requirements compared to the majority of crops grown.

***Paxistima myrsintes* 'Emerald Cascade'**. The UBC selection *P. myrsintes* 'Emerald Cascade' requires similar propagation conditions to our native penstemons, otherwise it becomes susceptible to the soil-borne pathogen *Pythium irregulare*. This low-growing, semi-weeping, broad-leaved evergreen selection is best rooted in September to January using 0.8% IBA in talc under contact polyethylene.

Rosa woodsii. The very hardy, pink-flowering *R. woodsii* is becoming increasingly important for highway planting, reclamation, and erosion control. Best propagation results are obtained by sowing the ripened seed during early August in flats and then leaving them outside to allow natural cold stratification during the winter. Between 40% and 50% germination is achieved by giving a 3 month stratification at 21C, followed by 4 months at 1 to 3C. Experience at Reid, Collins Nurseries Ltd. finds the summer sowing procedure to give the best results.

The Botanical Garden has selected a relatively low-growing free-flowering clone which is readily propagated by softwood cuttings. The Garden's research scientist, Dr. Wilf Nicholls, is currently evaluating the performance of this plant in different locations in the province with the B.C. Ministry of Highways.

CONCLUDING REMARKS: THE NATIVE PLANT INTRODUCTION SCHEME

The B.C. Native Garden at the Botanical Garden is becoming an ever-increasing resource for native plant introductions. Cooperation with the B.C. nursery industry to grow and promote improved native selections is vital to ensure a plant is quality grown and successfully marketed. The plants need to be well trialed in "typical nursery conditions" where irrigation and nutritional programs can often be detrimental to the plants' health. It is important that both sides appreciate the need for some special cultural requirements.

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Woodland and Alpine Plants in the Botanic Gardens and Nurseries of Japan

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INTRODUCTION

The Great Britain and Ireland Region's Mary Helliar Travel Scholarship contributed funding towards a study tour of the islands of Hokkaido and northern Honshu, Japan. The overall aims were to broaden my horticultural knowledge and understanding of Japanese Botanic Gardens and horticultural techniques, while working within the Living Collections Department of Hokkaido University Botanic Garden and by visiting several commercial nurseries and National Parks. Throughout these areas are some of the most important locations for eastern Asian alpine and woodland plant species.

The geographical position of the areas studied range from 45° 25' N, in the sub-Arctic zone, to 36°N. Average annual rainfall was between 147 mm to 184 mm and 1170 mm to 2000 mm of snow, with temperatures from an average of -8.1C in winter, to 25C in summer.

These general climatic conditions combined with the varied geological and topographical components of the Japanese archipelago have given rise to a diverse range of environs in which alpine and woodland plant species can thrive, with more subtle variations where altitude gives rise to the vertical zonation of vegetation types.

The topography of many of the areas visited renders them unsuitable or impossible to exploit for commercial purposes, more than 65% of Japan's surface slopes with a gradient in excess of 25%. This, together with the fact that large expanses of the areas visited are government owned, has resulted in large tracts of land being preserved by keeping industry and tourism to the peripheries.

HOKKAIDO UNIVERSITY BOTANIC GARDEN

The scholarship began at Hokkaido University Botanic Garden, Sapporo, where I spent approximately 3 weeks working within the gardens and participating in field work.

The Botanic Garden was established in 1884 by Professor Kingo Miyabe, whose name is commonly found as a specific epithet, e.g. *Acer miyabei* and *Potentilla*

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[1]The Mary Helliar Travel Scholarship Award, 1994.

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miyabei. The 13.3-ha garden is located in the centre of Sapporo city and consists of an alpine display area; systematic herbaceous perennial collection; "Natural Woodland" of the Ishikari plain (dominated by *Ulmus japonica* (syn. *U. davidiana* var. *japonica*) and *Acer mono*, with a rich under story of *Petasites japonicus* var. *giganteus* and *Cardiocrinum cordatum* var. *glehnii* (syn. *Lilium cordatum* var. *glehnii*); glasshouses, with several tropical displays; an ethnobotanical garden and a museum dedicated to the aboriginal Ainu and the natural history of Hokkaido.

One of the field expeditions was to Nakayama-toge, a 3-ha high-altitude deep-snow wetland only recently discovered after the electricity company installed power lines near the site. The area was not easily accessible, requiring a 45-min walk through *Sasa* and *Rhus ambigua* to get to it. We measured the site so that the successional growth of the *Sasa* could be monitored, and the species present were recorded. The species that predominated were *Hemerocallis middendorffii* var. *esculenta*, a species of *Iris*, and *Hosta sieboldii* (syn. *H. albomarginata*), with less frequent *Platanthera tipuloides* f. *nipponica, Vaccinium oxycoccos*, and *Drosera rotundifolia*.

We also studied Mt. Yubari (1668 m), in the centre of the Yubari mountain range in central Hokkaido. This mountain is predominately composed of Serpentine rock, (crystalline asbestos), a complex magnesium silicate which has resulted in a large degree of endemism resulting from the adaptation of plants to the high levels of aluminum and magnesium in the soil. They are difficult to maintain in cultivation. Many of these plants have the specific epithet *yuparensis* or *yuparense* to denote their geographical origin, e.g. *Viola yuparensis*, (syn. *Viola brevistipulata* var. *crassifolia*), *Taraxacum yuparense*, *Aconitum yuparense*, and the plant which was the subject of the field work, *Primula yuparensis*.

Primula yuparensis is only found on Mt. Yubari and has only two small populations which in recent years have decreased in size. The objective of the fieldwork was to collect seed from naturally pollinated plants from the two sites and compare them with hand-pollinated plants (the hand pollination had been undertaken one month prior to our visit).

ALPINE NURSERIES IN THE SAPPORO REGION

I visited a number of nurseries to see how plants were produced and what materials were used. All the nurseries used very similar techniques and composts. The standard compost was 100% volcanic rock (pumice), which would be sieved and graded, the fine material being used for seed sowing and the larger for general potting. The only exception to this was the addition of peat or leaf mould for species which required a higher organic matter content, such as primulas. This would be added to the volcanic rock at 10% to 30% depending on the species requirement. Peat is only used when necessary because of its high price compared with volcanic rock. Peat will cost ¥20 [yen] per litre compared with ¥2 to ¥5 per litre for volcanic rock. The volcanic rock is so inexpensive because there are large minable deposits found across Japan. Peat, on the other hand is generally imported from Russia.

In addition to this standard compost mixture a few nurseries added a few grains of controlled release fertiliser to each container at the time of potting. A more common fertiliser was Aburakasu, a pelleted organic compound fertiliser made from Soya bean and brassica waste from the food industry, and fish blood and bone. Two of these pellets are used per 9-cm pot. Liquid feed, usually high in potassium,

was also used by some nurserymen to supplement the Aburakasu and to increase the generally low potassium levels in the predominantly acid composts.

The majority of nurseries produced most of their stock from seed, sown in a fine mixture of volcanic rock and leaf mould. However, certain plants, e.g. *Dicentra peregrina*, were produced in raised beds of volcanic rock, to aid winter drainage, and allowed to seed freely across the beds. These seedlings were then lined-out for the successive year's crop. *Dicentra peregrina* is usually grown in these raised beds for 1 year and then containerised and sold in the second year.

The nurseries of Hokkaido produce very high quality compact alpine plants compared with those produced on the main island Honshu. This is due to the lower summer temperatures and shorter growing season. As a result the plants from Hokkaido are more expensive to produce. However, certain plants, such as *Soldanella* species, can only be successfully grown on Hokkaido.

The majority of nurseries visited are very small compared with similar European establishments. These smaller nurseries, some specialising in only a few genera, then sell to larger wholesale nurseries which in turn exported or sell to retailers throughout Japan.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank all of those who contribute to the annual award of the Mary Helliar Scholarship for enabling me to study Japanese alpine and woodland plant species in their natural environs and visit nurseries throughout Hokkaido.

Clematis Old and New from Around the World

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The Guernsey Clematis Nursery Limited, Domarie Vineries, Les Sauvagees, St.Sampsons, Guernsey, Channel Islands

HISTORY OF *CLEMATIS* IN CULTIVATION

The only clematis species native to England is *Clematis vitalba*, commonly known as "old man's beard."

The first clematis introduced into England was *C. viticella* in the 1500s, closely followed by other European species, such as *C. cirrhosa* var. *balearica*, *C. integrifolia*, and *C. recta*, the latter two being herbaceous clematis.

Then travellers to the middle East started to introduce species, such as *C. orientalis*; and as the New World of North America opened up, *C. pitcheri*, *C. viorna*, *C. reticulata*, and others started to arrive in England.

The first clematis hybrid was raised in 1835. This was a cross between *C. integrifolia* and, most probably, *C. viticella*. *Clematis* ×*eriostemon* retained the perennial-type habit of one of its parents, *C. integrifolia*. It is non-clinging in its habit and only grows to approximately 5 ft or so in height.

The great surge of interest in the development of hybrids happened as soon as *C. patens* and its many forms and cultivars were introduced from Japan. These started to come into England from 1830 onwards. The introduction of these large, flat, open-flowered types gave breeders of that time a marvelous opportunity. Isaac Anderson Henry, in Scotland, was one of the first to produce a very large, flat, open-flowered clematis, *C. reginae* in 1856 and in 1858, *C.* 'Jackmanii' was raised by Jackmans of Woking.

There followed a great surge of clematis breeding and, between the 1850s and the turn of the century, some 500 different cultivars were listed. Most of them, sadly, have been lost to cultivation. *Clematis* 'Fair Rosamond' was one of the Jackman cultivars raised at that time and, today, it is still the only large-flowered clematis to have a slight scent.

The appearance of clematis wilt after the turn of the century meant interest in hybridisation started to decline a little. However, some new introductions were still made, including *C.* 'Beauty of Richmond', raised by the Russell family.

Clematis 'Ernest Markham' is well known throughout the world. Ernest Markham was the Head Gardener for William Robinson at Gravetye Manor. The pair did a great deal of work with clematis, mainly introducing cultivars or good forms of the species which mostly came to them from France.

In this century two families' names are linked to the introduction of new clematis taxa. The Pennell family did a great deal of hybridization and their nursery is probably the only one to have actually intentionally raised cultivars under a proper breeding programme in the 1960s and 1970s. The Fisk family, who run Fisk Clematis Nursery, did very little direct breeding but introduced many cultivars raised by their customers. When I was a junior partner and managing director of Treasures of Tenbury Ltd in England, we also, like Fisk and Pennells, exhibited clematis at the Chelsea Flower Show. Our three companies were the main ones responsible for promoting and marketing clematis during the early 1970s.

MODERN INTRODUCTIONS

***Clematis* ×*cartmanii* 'Joe'.** A fascinating hybrid between two New Zealand species, *C. marmoraria* and *C. paniculata*, both evergreen clematis. It is very compact and free flowering in its habit.

***Clematis cirrhosa* 'Freckles'.** Raised by the author and introduced from wild collected seed from the Balearic Islands. Its advantage over the species is that it flowers during October, November, and December.

Hardy *C. alpina* and *C. macropetala* types. To export clematis to Scandinavia and North America we have introduced some extremely hardy clematis. These include *C. alpina* 'Tage Lundell', 'Pink Flamingo', and 'Constance'. We have been, and still are, looking for good hardy forms *of C. montana*. During the severe winter of 1980-81, most of the plants growing in the central part of England were lost when temperatures dropped to -20C, or in some cases -26C.

Japanese Forms. From what I understand, *C. patens* may well be a Chinese species which has naturalised in Japan. Certainly, some of my colleagues have collected many forms of *C. patens* in the wild in Japan, including double forms. While visiting Japan in 1984 and 1994, I had the chance to find various forms of *C. patens* in the wild, including doubles. Some were similar to *C.* 'John Gould Veitch', which was introduced into England in the mid 1800s.

Amongst the *C. patens* cultivars I have introduced are 'Guernsey Cream', 'Royal Velvet', 'Sugar Candy', 'Anna Louise', 'Liberation', and 'Arctic Queen'. This latter was a chance seedling which occurred in our nursery and has fully double white flowers throughout the season. It flowers much more freely and is much stronger than *C.* 'Duchess of Edinburgh', the only other double white.

***Clematis viticella*.** These are really marvelous garden plants. They do not suffer from clematis wilt and should be promoted and grown much more widely. They grow and flower well in hot summers and do well in the U.S.A. *Clematis* 'Södertälje' is one of the selections in evaluation work that we are doing at the Chicago Botanic Gardens.

***Clematis integrifolia*.** One of our latest introductions is *C.* 'Petit Faucon', a chance seedling which we were extremely lucky to find in our nursery. Its female parent was 'Daniel Deronda', which has huge 8- to 10-inch flowers. We are not sure of the identity of the male parent but it may be *C. integrifolia* or *C.* ×*eriostemon*.

***Clematis florida*.** This was introduced into Sweden by Thunberg, then re-introduced by Von Siebold in the 1830s. It has always been difficult to propagate, but slowly we have found a technique and are now currently producing substantial numbers. Forms include 'Alba Plena' which arrived as a sport from *C. florida* 'Sieboldii' during the 1830s.

Neither 'Sieboldii' nor 'Alba Plena' are completely stable and it was with great joy that, about 5 or 6 years ago in our nursery, we found that 'Alba Plena' had sported and reverted back to what I believe to be the true *C. florida*, which has not been grown commercially since the early 1800s. One stem of 'Alba Plena' was flowering quite normally with one flower each side of the node as 'Alba Plena'. Then suddenly, one of the nodes produced a flower of the true species *C. florida* on one side and *C. florida* 'Alba Plena' on the other. As this stem developed, 'Alba Plena' slowly disappeared

and every node produced the flower of what I believe to be the true *C. florida*. Therefore, we were able to propagate from this plant. Another three or four plants also sported the following year. We have selected out a particularly good form that is reasonably stable and are using it in our breeding programme.

However, this form of *C. florida* then "reverted" further to give us a plant which we are currently calling *C.* 'Guernsey' which has slightly pinkish anthers but the centre has aborted and it is totally sterile. It is an extremely free-flowering plant and we believe we have now stabilised it and we look forward to introducing this onto the market in the not-too-distant future.

Restriction of the Root System, A Survey of Non-Chemical Methods

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INTRODUCTION

Regulation of the root system is an obvious necessity whenever plants need to be transported from the site of production to the final habitat. Therefore, in any commercial plant production the question of how to minimize root damage must be dealt with. Since the use of copper compounds is treated elsewhere in this symposium this will be a brief survey of other means of root regulation.

Methods that confine the root system in a limited space, i.e., container culture, differ markedly from methods of pruning that entail a loss of existing root mass, which usually is the youngest part of the root system. In the evaluation of these methods their effects on essential root functions should be considered. The importance that various root problems may have on plant quality depends on the culture in question, but a number of typical effects of root system restriction may be outlined.

ROOT/SHOOT RATIO

The root/shoot ratio (which = dry weight of root/dry weight of shoot) in a woody plant attains a value typical of the climatic adaptation of the species in question. In a stable environment the ratio is stable, but with a long-term decrease with age. Environmental conditions affect this equilibrium within certain limits; protection from winds, ample water supply, and high concentration of nutrient salts tend to reduce the ratio, whereas wind and light exposure tend to increase it.

The homeostasis is maintained by means of cytokinins, produced mainly in the roots which stimulate shoot growth, and auxin, produced within the top which is required for root development. When conditions for either part of the plant are changed, for instance by pruning, compensatory growth occurs in such as way as to reestablish the previous ratio (Kramer and Kozlowsky, 1979; Geisler and Ferree, 1984).

Effects Of Cutting The Root System. Root cutting usually means removal of the peripheral parts of the root. This affects the cytokinin production both by the loss of production sites and by the stress reaction. In conjunction with root cutting the roots are often subjected to some desiccation, which also decreases the cytokinin production and increases ABA production (Hubick et al., 1986).

Root cutting usually results in a reduction in shoot growth (Rook, 1971). There are indications that the generation of side shoots is also inhibited (Harmer and Walder, 1994; unpublished observations in this lab). Depending on the culture this could be an unwanted or desirable effect.

Provided that growth conditions are suitable, the root system responds to cutting with increased growth rate and branching, probably due to an accumulation of auxin in the roots that remain. The reaction is observable 2 to 14 days after the cutting

(Geisler and Ferree, 1984). Branching occurs mainly immediately behind the cut, and usually several minor branches emerge from the same point, thus forming a much finer root system than before (Harmer and Walder, 1994). Some species, however, tend to produce only one or few replacement roots, so that a branched system is difficult to achieve by root surgery.

The consequences of replacing the strongest roots with a multitude of finer ones are not fully known. It is assumed that some of the new roots take on a dominating role and by secondary growth reach the same proportions and mechanical properties as the original laterals. However, Coutts (1983) showed that the major roots in 9-year-old *Picea sitchensis* all had much primary xylem, indicating that they had been among the largest roots initially. Heterogeneity in the soil environment can cause local proliferation of roots, but usually this does not lead to a lasting dominance of that part of the root system (Coutts and Philipson, 1977).

Since most of the carbohydrates stored in roots is located in the central parts of the root system, loss of the peripheral parts of the root does probably not affect the function of the root as storage organ and sink to any great extent. Obviously, strong pruning can reduce the stores considerably. For instance, Insley and Buckley (1985) found a 20% to 60% loss of root storage carbohydrates with various cutting regimes. Reduced water and ion supply from the root can also limit photosynthesis in the days after root cutting and hence cause an overall decline in the carbohydrate status of the plant (Geisler and Ferree, 1984). Impeded shoot growth and increased root development after root cutting may in fact result in a situation in which a relatively larger part of the plant carbohydrates is stored in the root (Rook, 1971).

The time after cutting is critical for the plant, particularly with respect to temperatures and precipitation. Uptake of water and ions are naturally affected by the reduction in the root surface and loss of many of the young, non-suberized parts. However, it is now widely accepted that the mature roots absorb a substantial amount of water and ions. No ion deficiencies have been detected as a result of root cutting (Geisler and Ferree, 1984). When new growth and branching has taken place the absorbing surface will be more than compensated for.

The biological effects of air pruning are probably rather much the same as by mechanical root cutting, although the process is continuous and the roots that stay within the substrate block are largely unaffected by it.

CONFINEMENT OF THE ROOT SYSTEM

By growing the plants in containers actual cutting of the roots is avoided. The root tips remain intact, apart from those escaping through the drainage holes, and the size hierarchy of roots is maintained. However, the orientation of the roots are strongly affected by the curvature of the pot.

Confinement of roots may in itself affect the physiology of the plant. Plants in small containers have relatively small leaves (lower leaf-area ratio), and other growth parameters are likewise reduced in small containers as compared to plants in large containers (Dubik et al., 1992; Rieger and Marra, 1994). This is not only due to differences in amount of substrate, similar results are obtained when the availability to nutrient ions is kept the same in all container sizes. Even in hydroculture crowding of roots results in reduced leaf size and growth rate (Ternesi et al., 1994). This effect is associated with a marked rise in the ABA content of the root.

Lasting root deformations in trees caused by container production are amply documented and can often be traced several years after planting (Halter et al., 1993). Asymmetrical root systems and winding and bent roots are among the typical problems. This leads to instability and impeded secondary growth. Specially shaped containers (vertical rims, corners, slanting bottom) improve the situation somewhat (Lindström, 1978). Most important is not to let the plant remain too long in the same container. Because of their permanent nature these deformations have serious consequences, particularly for large and long-lived plants, as compared to the short-term physiological setbacks that a cultivation system can otherwise impose.

OTHER KINDS OF REGULATION

Plasticity of the root system makes it possible to produce almost any root form. Not only the relative size of the root, but also the shape, can be manipulated by growth factors. The root reacts with strong local proliferation in pockets of nutrient salts or water resources in the soil. Growth is also concentrated in the most penetrable layers of soil. By applying point fertilizer, restricted watering, or using the right soil management, these reactions can be exploited to produce root development where it is required. For a practical example, see Gilman et al. (1994). These options are not used to their full potential.

CONCLUSION

Methods of root restriction all have their merits and drawbacks, and none are ideal. The preferred method much depends on the culture in question and the duration of production.

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Control Of Woody Root Systems Using Copper Compounds

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INTRODUCTION

Nursery production of woody plants has traditionally been a field-based production system. Undercutting or transplanting of plants during the production system has enabled the nursery producer to develop a well-shaped root system with no circling or other root distortions.

In many countries container plant production has become a dominant production technique for woody plants. In the case of the Australian nursery industry container plant production has become the norm. A container production system has many operational and marketing advantages over field production. The climate of Australia is more conducive to the production of woody plants in containers. The lack of any real winter dormancy over most of the country is a major factor in this country-wide trend to container plant production of woody plants.

Although the climate of northern Europe still encourages large-scale field production of woody plants, there appears to be an increasing move into container production. This is particularly noticeable at the propagation stage with large-scale commercial propagation of seed- and cutting-propagated plants being produced in small multicelled containers (Morgan, 1995).

The propagation stage is the most crucial stage in commercial nursery production and if root distortions are created on the plants during propagation the plants can be seriously affected later in their life, often long after they have left the nursery. The shape and volume of many multicelled propagation containers may be responsible for the development of root distortions and it is the aim of this paper to explore means by which the nursery producer can minimise the extent to which root system distortion will develop during nursery production of plants in containers.

THE NATURE OF THE PROBLEM

In a paper presented at the New Zealand Region annual conference in 1994, I outlined the types of root distortion problems that occur in nursery container production and the main reasons why these distortions occur (Gordon, 1995).

PREVENTION OF ROOT DISTORTION

There are three main strategies that can be used to reduce or eliminate the degree of root distortion which occurs with small plants in nursery containers:

1) **Avoid Leaving Young Plants in Nursery Containers for Too Long.** Keeping plants in the nursery for excessive periods of time inevitably leads to severe root binding. This is a serious operational problem for many nurseries and it requires a serious decision to destroy plants with badly spiraled roots, rather than to pot them up

into a larger container size. Potting plants with spiraled roots does not solve the problem; it merely masks the problem.

2) **Use Nursery Containers Which Are Designed to Minimise or Eliminate Spiraling of Roots.** There have been many examples of nursery containers which have been designed specifically to redirect the growth of roots so that spiraling does not occur. Containers which are designed to deflect the roots downwards and out through the container base so that air pruning of roots can occur are probably the most popular. Some containers also allow root development through slots in the side walls.
There is no doubt that if these containers are used properly they will result in a major improvement to the quality of the root systems of woody plants. The real problem is that most nursery producers are reluctant to use these types of containers. Some of the reasons given are: "they are too expensive", "they don't fit our production systems", "our customers don't like them", "our staff don't like them", or "we can't grow a good quality plant in them". Whatever the reasons, most nurseries refuse to use these types of containers. This means that the customer is not getting the quality root systems which they should. It is also the reason why we are seeing this third option becoming a potentially viable one for the nursery industry.

3) **Use Chemical Compounds to Control the Young Developing Roots**. Most early work on evaluating the effect of copper compounds was carried out in the U.S.A. and Canada and was primarily concerned with coniferous forestry species such as pines and spruce (Beeson and Newton, 1992). Early problems focussed on how to apply the compounds to nursery containers. The most common method of application now in use is to incorporate the copper compound into a latex or acrylic paint and to paint or spray the compound onto the inside wall of the nursery container.
Subsequently, a number of researchers have evaluated the technique with a wide range of woody ornamental trees and shrubs. Furuta et al. (1972), working in California, demonstrated that the technique could be used on many ornamental trees, including *Eucalyptus* species. Struve (1990), working at Ohio State University incorporated copper treatment of containers into a wider tree production system called "The Ohio Production System" (OPS). This system enables nurseries to produce tree whips to a plantable size in containers in 1 year compared to the 3 to 5 years normally required for conventional field production.

FORMULATIONS OF COPPER

A number of different formulations of copper have been assessed by different researchers. Copper carbonate was the formulation used by most early researchers but many forms of copper will produce similar root inhibition. However, copper hydroxide now appears to be the most widely used compound. Copper hydroxide is the active constituent of the registered fungicide Kocide™. It is manufactured by the

Griffin Chemical Company of Valdosta, Georgia, U.S.A. This company is currently marketing a product in the U.S.A. under the trade name of Spin Out™ which consists of 7.1% copper hydroxide in a latex paint solution.

Spin Out™ has now been registered in a number of countries—Australia, New Zealand, and some from Europe—for use as a root-controlling compound. The basic material consists of copper hydroxide incorporated in a latex paint. In some countries bulk supplies of the liquid preparation are sold for incorporation onto the inside surfaces of containers by the individual nursery producer.

The Griffin Chemical Company, which markets the product, is now offering a number of other options including polystyrene propagation containers with copper impregnated into the walls, pre-sprayed growing-on containers, flexible polyester growing bags with copper impregnated, and woven weedmat materials with copper incorporated to prevent root growth out through the base of containers. It is likely that we will see a wider range of pretreated products become available and these will certainly provide a greater convenience to the individual nursery producer.

In South Africa a similar product is available and is marketed under the trade name Prune™. This product was initially developed as a coating for polystyrene speedling type trays to prevent root growth in between the polystyrene beads of the trays. Root growth into the spaces between the beads of used trays makes seedling extraction very difficult and dipping of the trays into a solution of this compound eliminates the problem.

Prune™ is now registered in Australia for root control in containers and is now becoming widely used by forestry nurseries and seedling producers, but I am not aware of any intent to market this product in Europe at this stage.

BENEFITS OF COPPER TREATMENT

Redistribution of Roots Within Container. The primary effect of the copper treatment is the prevention of root circling within the container. At the point where the root tip comes in contact with the container wall, the root tip ceases growth. Secondary lateral root growth develops from further back and when these laterals reach the container wall they are also inhibited or "pruned" by the copper.

Overall root distribution within treated containers is quite different to untreated containers. In an untreated container, most of the roots will be located on the outside of the ball of media in the interface area between media and container wall. This type of root distribution is relatively inefficient as most water and nutrients are located within the volume of media in the pot. With treated containers, the young feeder roots tend to be located within the container media volume rather than on the outside and this leads to more effective utilisation of water and nutrients from the growing media. A number of researchers have reported a greater total amount of growth on plants in treated containers and it is likely that this improved utilisation of water and nutrients is the principal reason.

In trials carried out at HRI Efford in England during 1994 and 95 a number of ornamental woody plant species were propagated from cuttings stuck in plug trays with and without a coating of copper. It was established that the plants from the treated trays were much easier to extract and that they had a much denser root system with fewer emergent roots. (Scott, 1995)

These plants were then potted into treated and untreated 9-cm liner pots and grown on. Again it was found that the plants from treated pots had a much greater

density of root of a more fibrous nature compared to the plants in the untreated pots.

Longer Shelf Life for Plants in Small Containers. Probably the main reason why we experience serious problems with woody plants grown in small nursery containers is that frequently the seedlings remain in the containers for far too long before planting out or potting on. This may not be the fault of the nursery producer as factors such as availability of water for planting, weather conditions, and land preparation may contribute to this problem.

Plants grown in copper-treated containers will not experience the extensive root-circling problems experienced in untreated containers. This means that the plants can be held in treated containers for much longer before planting out without root distortion problems occurring.

Prevention of Root Growth Through the Base of Containers. In many nurseries container plants are grown on ground level beds with a capillary sand base. Root growth through the drainage holes of the container into the sand layer beneath the pot is frequently a problem. Where this rooting through occurs a large proportion of the young feeder roots develop outside of the container and are lost during order assembly. Work carried out at HRI Efford (Scott, 1995) determined that SpinOut™ greatly reduced the amount of rooting through in most species tested.

Many other nurseries use closely woven weedmatting as a surfacing material over sand or gravel beds and root growth downwards through the weedmat can also be a serious problem. HRI Efford has also shown that a copper compound applied to the surface of the weedmat will also markedly restrict the number of roots growing through the weedmat (Scott, 1995). Similar work carried out by the Forestry Authority Research Division, Midlothian, Scotland, has confirmed this ability for copper to inhibit root growth through woven weedmatting (Morgan, 1995).

Better Root Establishment After Planting in the Field. Burdett (1978), working with lodgepole pine in Canada, demonstrated that roots which were inhibited by copper treatment in the nursery container would resume growth once the plant was planted into a field position. This means that the natural pattern of root development will occur after these treated plants are planted out. As the root system grows outwards and downwards in the natural pattern, the root system will provide greatly improved anchorage compared to untreated root systems with distortions present.

It also means that the root system is better able to seek water and nutrients and that results in faster establishment after planting out. Many other researchers have confirmed that plants with copper-treated root systems have faster rates of establishment after planting out compared to plants with untreated root systems.

Increased Survival After Planting Out. McDonald et al. (1981) compared the survival rate of ponderosa pine planted into a forest location from copper-treated containers and from containers which had varying patterns of holes for air pruning to occur. Survival of plants which had been exposed to copper treatment was 93%, while survival of plants from air pruning containers was 39%.

CONCLUSION

It is clear from the work of a number of researchers that the use of copper for woody-root-system control is an effective substitute for the various air pruning systems

outlined earlier in this paper. As more formulations of copper are registered, its popularity with nursery producers will increase.

The most significant current barrier to its use by nurseries is that it has to be applied to containers in the nursery. This constitutes another step in the plant-production process and an additional cost to the producer and many nursery producers will be reluctant to use the products for this reason. There is undoubtedly an opportunity here for the pot manufacturers to follow the lead of the Griffin Chemical company in the U.S.A. and supply pretreated containers directly to the nursery producer. The additional convenience of purchasing pre-treated containers may make acceptance of this process by nursery producers more likely.

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Cytokinin Effects on Shoot and Root Formation in *Miscanthus ×ogiformis* 'Giganteus'

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INTRODUCTION

Miscanthus ×ogiformis Honda 'Giganteus' is a sterile cultivar which traditionally has been propagated through rhizome division (Nielsen, 1987). In vitro propagation is an alternative method which could become important for large scale propagation. For in vitro propagation the type and concentration of the cytokinin used are of great importance. In the present study the short- and long-term effects of 6-benzyladenine (BA), thidiazuron (TDZ), kinetin (KIN), and isopentenyladenine (2iP) on in vitro cultures of *M. ×ogiformis* are reported.

MATERIALS AND METHODS

Actively growing shoots of *M. ×ogiformis* Honda 'Giganteus' were selected from greenhouse-grown plants. Nodal segments of about 15 mm in length were cut and surface sterilized for 20 min in 1.5% (w/v) sodium hypochlorite followed by three rinses in sterile deionized water. The nodal segments were trimmed to give 5- to 10-mm-long explants.

Murashige and Skoog medium (MS) (Murashige and Skoog, 1962) with 20 μM BA, 1.3 μM naphthaleneacetic acid (NAA), 58.4 mM sucrose, 3 g liter^{-1} Gelrite (Phytagel, Sigma), and 3.7 mM $MgCl_2$ was used. The pH of the medium was adjusted to 5.5 before Gelrite was added. After melting, 50 ml of the medium was dispensed into each 12-cm-high and 8-cm-diameter jar and autoclaved for 15 min at 121C.

Four explants were grown in each jar at a temperature of 27±1C, a photon fluence of 50 μmol m^{-2} s^{-1} provided by the Philips fluorescent TLD 58/33 tubes, and a photoperiod of 16 h. After 28 days of growth, the developed shoot clusters were divided. Single shoots were trimmed to a length of 15 mm and subcultured on the BA-containing MS medium at least four times.

Trimmed axillary shoots from the 20 μM BA-containing medium were transferred to a new type of cytokinin-containing medium. Other growth conditions were as described above. After 28 days, a representative shoot from each shoot cluster was trimmed and transferred to a new jar with the same or new type of medium. After each subculture the number of shoots per shoot cluster were recorded.

Experiment 1 (Nielsen et al., 1993). The concentration of 20 μM BA in the medium was replaced with different concentrations (0.01, 0.1, 1, 10, 30, or 100 μM) of BA, TDZ, KIN, or 2iP. Shoots were grown for four subcultures on the same cytokinin-containing medium. After the 4th subculture, shoots from 30 μM BA- or 30 μM TDZ-containing media were transferred to rooting medium consisting of MS medium with the following modifications: 1/2 strength macronutrients, 5.4 μM NAA, 58.4 mM sucrose, 3 g liter^{-1} Gelrite, 3.7 mM $MgCl_2$, and 5 g liter^{-1} activated charcoal. After each subculture the length of each shoot from the base to the upper

end of the longest leaf sheath, percentage of shoots with chlorosis on a least one leaf, and number of roots per shoot cluster were recorded.

Experiment 2 (Nielsen et al., 1995). The concentration of 20 μM BA in the medium was replaced with 30 μM BA, 30 μM TDZ, 10 μM KIN, or 100 μM 2iP (optimum concentrations for axillary shoot formation) and shoots were grown for four subcultures on the same cytokinin-containing medium. After the 4th subculture shoots were transferred to a 30 μM BA-containing medium.

Experiment 3 (Nielsen et al., 1995). The concentration of 20 μM BA in the medium was replaced with 30 μM BA, 22.5 μM BA + 7.5 μM TDZ, 15 μM BA + 15 μM TDZ, 7.5 μM BA + 22.5 μM TDZ, or 30 μM TDZ. This series of media contained a total of 30 μM cytokinin due to optimum axillary shoot formation on media containing 30 μM BA or TDZ. To test if the response was dependent on one specific cytokinin, the total cytokinin concentration or the ratio between the two cytokinins, another series of media was set to contain a total of 60 μM cytokinin. This was obtained by using 60 μM BA, 30 μM BA + 30 μM TDZ, or 60 μM TDZ.

RESULTS

Experiment 1 (Nielsen et al., 1993). The mean number of shoots formed per shoot cluster for all concentrations of TDZ, KIN, and 2iP in subculture 1 was significantly higher compared to the number of shoots formed in subculture 2, 3, or 4. At each BA concentration, a constant number of shoots per shoot cluster was produced in all four subcultures. The improved shoot formation on TDZ-, KIN-, or 2iP-containing media which was observed only in subculture 1 indicates that the shoots were influenced by the previous subculture with 20 μM BA in the medium.

The optimum concentration for shoot formation in subculture 2 to 4 was 30 μM BA, 30 μM TDZ, 10 μM KIN, and 100 μM 2iP. In descending order regarding shoot formation, the four cytokinins at the optimum concentration could be ranked as follows: BA, TDZ, KIN, and 2iP. Root formation was generally absent at these optimum concentrations. Kinetin and 2iP did not inhibit root formation at 1 μM. Generally, mean shoot size as well as the percentage of chlorotic shoots decreased with increasing concentration of the cytokinins. This indicates that cytokinin concentrations that produce many shoots also produce smaller and less chlorotic shoots.

Although shoot formation in subculture 4 differed significantly between BA and TDZ, no difference in shoot formation was observed after transfer from cytokinin-containing medium to rooting medium. Shoots grown previously on TDZ-containing medium formed a significantly lower number of roots and taller shoots on rooting medium compared to shoots previously grown on BA-containing medium, although the number of roots and shoot size were not significantly different when grown on the two types of cytokinin-containing media. The percentage of chlorotic shoots on BA- or TDZ-containing media and after transfer to rooting medium were not significantly different.

Experiment 2 (Nielsen et al., 1995). The carry-over effect observed in subculture 1, Experiment 1, was also observed in Experiment 2 (Table 1). When transferring shoots from BA-containing media to KIN- or 2iP-containing media the number of shoots formed corresponded to the number of shoots formed by continuous culture on BA-containing medium. The movement from BA- to TDZ-containing medium

resulted in a doubling in the number of shoots formed. When transferring shoots from KIN- or 2iP-containing medium to BA-containing medium the number of shoots formed corresponded to the number of shoots formed by continuous culture on KIN- or 2iP-containing medium, respectively. Shoots exposed to TDZ acted differently because transference to BA-containing medium resulted in a much reduced number of shoots. Continuous culture on TDZ-, KIN-, or 2iP-containing media induced fewer shoots compared to continuous culture on BA-containing medium (Table 1).

Table 1. Axillary shoot formation when transferring shoots between different cytokinin-containing media.

Cytokinin-containing media			
Previous subculture	Subsequent subculture	Number of shoots per shoot cluster	Treatment
BA	BA	5.3	1
BA	TDZ	10.9	1
BA	KIN	5.3	1
BA	2iP	6.2	1
BA	BA	6.2	2
TDZ	TDZ	3.0	2
KIN	KIN	2.9	2
2iP	2iP	3.1	2
BA	BA	6.2	3
TDZ	BA	2.3	3
KIN	BA	3.8	3
2iP	BA	3.2	3

Treatments:

1= Shoots grown on a medium containing 20 μM BA were transferred to a medium containing 30 μM BA, 30 μM TDZ, 10 μM KIN, or 100 μM 2iP.

2= Mean values of four subcultures of transfer from one of these cytokinin-containing media to the same medium.

3= Mean values after transfer from one of the four media to a medium containing 30 μM BA.

Experiment 3 (Nielsen et al., 1995). Different combinations and concentrations of BA and TDZ in one medium were used to test whether the synergistic effect of BA and TDZ in the first subculture could be obtained and maintained in subsequent subcultures (Table 2).

Generally, in the first subculture, shoot formation increased with increasing concentration of TDZ, whereas increasing concentrations of BA increased shoot formation in the second and third subculture. Neither the ratio of TDZ to BA in the medium, nor the combined concentration of cytokinin had any systematic effect on shoot formation. Again the change from BA- to TDZ-containing medium caused the carry-over effect with significantly higher shoot formation on media containing

more than 7.5 μM TDZ. However, shoot formation fell to a lower constant level in subsequent subcultures, also on media containing both cytokinins.

Table 2. Mean number of axillary shoots formed per shoot cluster. Shoots grown on a medium containing 20 μM BA were transferred to media containing different concentrations of BA, TDZ, or BA+TDZ and grown for three subcultures. All cytokinin concentrations are in μM.

	Axillary shoots/shoot cluster Subculture		
Cytokinin-containing media	1	2	3
30 BA	7.7	10.3	10.6
22.5 BA + 7.5 TDZ	10.9	9.4	9.9
15.0 BA + 15 TDZ	13.0	7.7	8.8
7.5 BA + 22.5 TDZ	15.4	7.4	6.9
30 TDZ	15.8	5.6	4.3
60 BA	9.6	10.2	9.5
30 BA + 30 TDZ	14.7	9.3	10.7
60 TDZ	13.9	5.5	6.0

DISCUSSION

The commonly observed cytokinin effects on shoot formation, inhibition of root formation, reduction of stem growth, and delay of senescence occurred in *M. ×ogiformis* 'Giganteus' with BA, TDZ, KIN, and 2iP. The activity of TDZ was comparable to the effects of the three ordinarily used cytokinins in vitro cultures.

When shoots were grown on medium containing one type of cytokinin and transferred to a medium containing a different cytokinin the carry-over effect was only seen in one subculture. By large-scale production of *M. ×ogiformis* it is advisable to grow shoots on 30 μM BA-containing medium and transfer them to a 30 μM TDZ-containing medium in one subculture before the shoots are transferred to a rooting medium.

From the results with BA and TDZ effects on axillary shoot formation in *M. ×ogiformis* a model for mode of cytokinin action in the plant cell is proposed in Nielsen et al. (1995).

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Somatic Embryogenesis in *Miscanthus*

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Shoot apices and leaf explants of *Miscanthus* shoot cultures were grown on Murashige and Skoog medium supplemented with 1.36, 13.6, or 136 µM of the auxin 2,4-dichlorophenoxyacetic acid (2,4-D). The explants were exposed to 2,4-D for 1, 2, 4, or 8 weeks and then transferred to 2,4-D free MS medium. A higher percentage of shoot apices produced callus and embryogenic callus than leaf explants. Shoot apices were less sensitive to 2,4-D than leaf explants. Transfer to growth-regulator-free medium after short exposure to 2,4-D caused some of the callus to die. High concentrations of 2,4-D suppressed the development of roots until transfer to growth-regulator-free medium.

INTRODUCTION

Somatic embryogenesis is a potential method for mass propagation of cultivars like the triploid *Miscanthus* ×*ogiformis* Honda 'Giganteus' where propagation is restricted to vegetative propagation methods. The different steps involved in the development of a somatic embryo propagation system are: (1) Induction and selection of a highly embryogenic callus type; (2) Maintenance and proliferation of embryogenic callus either on solid or in liquid medium—when fast-growing suspensions are established they can be transferred to bioreactors where large quantities of cell aggregates can be handled in an controlled environment; (3) Induction and maturation of somatic embryos; (4) Control of germination; and (5) Encapsulation of somatic embryos and germination of artificial seed in the field.

Often several different callus types are produced during callus induction which will differ in their capacity to form somatic embryos, shoots, and roots. For establishment of a reliable and efficient somatic-embryogenesis propagation system it is crucial to induce and select fast-growing highly embryogenic callus. It is also important to control the production of root-forming callus types as they can outgrow the embryogenic callus types (Morrish et al., 1987).

In *Miscanthus* three different callus types—an embryogenic, a non-embryogenic, and a root-forming—were formed when explants were cultured on medium with 4.5 to 31.7 μM of 2,4-dichlorophenoxyacetic acid (2,4-D) (Holme and Petersen, 1996). It was observed that 2,4-D did have some impact on the distribution between callus types but only relatively small differences were found. It would be of great value for somatic embryogenesis in *Miscanthus* if the formation of embryogenic callus could be further increased and the production of root-forming callus decreased.

In order to further specify the effects of 2,4-D on the callus induction percentage and the subsequent differentiation of callus into embryogenic- and root-forming types, a broader 2,4-D range (1.36 to 136 μM) was investigated. Furthermore, the explant exposure time to the different 2,4-D concentrations before transfer to medium without growth regulators was tested.

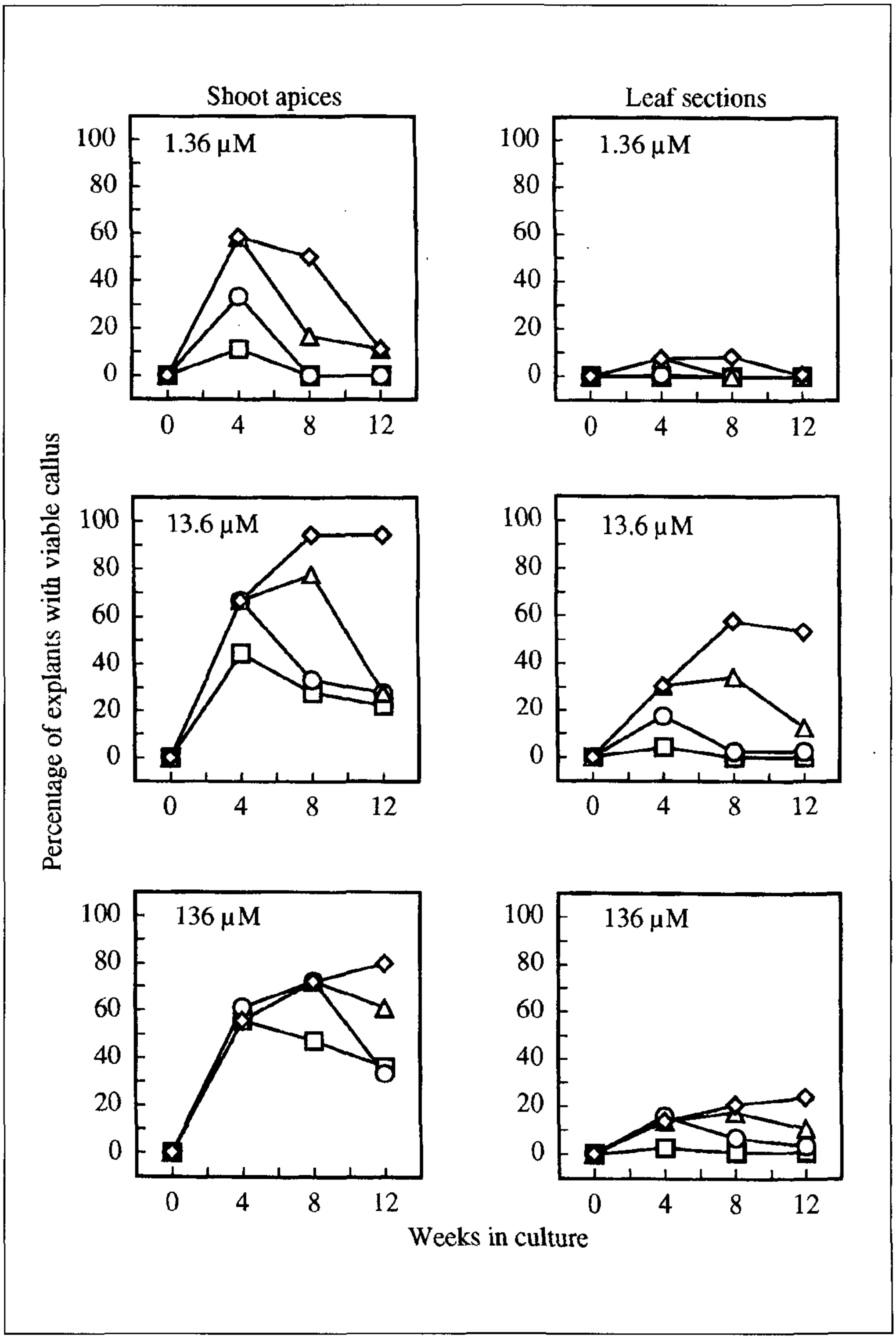

Figure 1. Percentage of explants from *Miscanthus* ×*ogiformis* 'Giganteus' with viable callus as influenced by explant type, 2,4-D concentration, and exposure time recorded after different periods in culture. The exposure times to 2,4-D were □ = 1 week, ○ = 2 weeks, Δ = 4 weeks or ◊ = 8 weeks.

MATERIALS AND METHODS

Plant material of *M.* ×*ogiformis* 'Giganteus' was obtained from in vitro shoot cultures propagated according to Nielsen et al. (1993) with 22.2 μM benzyladenine (BA) and 1.3 μM α-naphthaleneacetic acid (NAA). Four weeks after subculture shoot apices and 2-mm sections from the most basal part of the three youngest leaves were dissected. The callus induction medium was MS basal medium (Murashige and Skoog, 1962) containing 30 g liter^{-1} sucrose, 500 mg liter^{-1} casein hydrolysate, 300 mg liter^{-1} L-glutamine, 2 g liter^{-1} gelrite, 750 mg liter^{-1} $MgCl_2$ $6H_20$, and 0, 1.36, 13.6, or 136 μM of 2,4-D.

Media pH were adjusted to 5.5 prior to autoclaving. Explants were transferred from 2,4-D-containing medium to the same medium without growth regulators (0-medium) after 1, 2, 4, or 8 weeks. Explants were incubated in darkness at 27C and subcultured at l-week intervals for the first 2 weeks and thereafter at 2-week intervals. The percentage of explants with viable callus, viable embryogenic callus, and roots were recorded 4, 8, and 12 weeks after culture initiation.

RESULTS AND DISCUSSION

Percentage of Explants With Viable Callus. No callus was induced on medium without growth regulators. Overall shoot apices produced more callus than leaf explants and were less sensitive to high and low concentrations of 2,4-D (Fig. 1). It is common to find different response patterns between different types of explants dependent on auxin concentration (Conger et al., 1982; Henke et al., 1978). In the present investigation the shorter the period of exposure to 2,4-D the less callus was induced especially on leaf explants. After transfer to 0-medium part of the callus died and the lower the 2,4-D concentration the faster the callus died. Comparison of the callus induction (Fig. 1) and the percentage of explants with viable embryogenic callus (Fig. 2) shows that it is primarily non-embryogenic callus types that die.

Percentage of Explants With Viable Embryogenic Callus. A much higher percentage of embryogenic callus was produced on shoot apices as compared to leaf explants. Shoot apices produced the highest percentages of embryogenic callus when exposed to 13.6 μM 2,4-D for 4 or 8 weeks or to 136 μM 2,4-D for 1 week. Exposure for 1 or 2 weeks to 1.36 μM 2,4-D did not induce embryogenic callus and the other treatments were either suboptimal or superoptimal for embryogenic callus production on shoot apices. The production of embryogenic callus on leaf explants compared to shoot apices is restricted to a more narrow exposure time and 2,4-D concentration range. Differences in the optimal auxin concentration for embryogenic callus formation differs between species and explant types, and the optimal concentration range is often found to be more narrow than for callus induction (Pareddy and Petolino, 1990; Thomas and Scott, 1985).

Percentage of Explants With Roots. The higher the 2,4-D concentration the more suppressed was the development of roots (Fig. 3) when explants were still exposed to auxin, and no roots developed on 136 μM 2,4-D until transfer to 0-medium. Likewise, in suspension cultures of *Dactylis glomerata* (orchardgrass) root development was reduced with increasing concentrations of the auxin dicamba up to 60 μM (Gray and Conger, 1985). In *Sorghum bicolor* 0.09 μM 2,4-D resulted in root development on all calli whereas 2.7 μM 2,4-D reduced the development of roots to 4% of the calli (Wernicke and Brettell, 1982). In *Miscanthus* it was not possible to

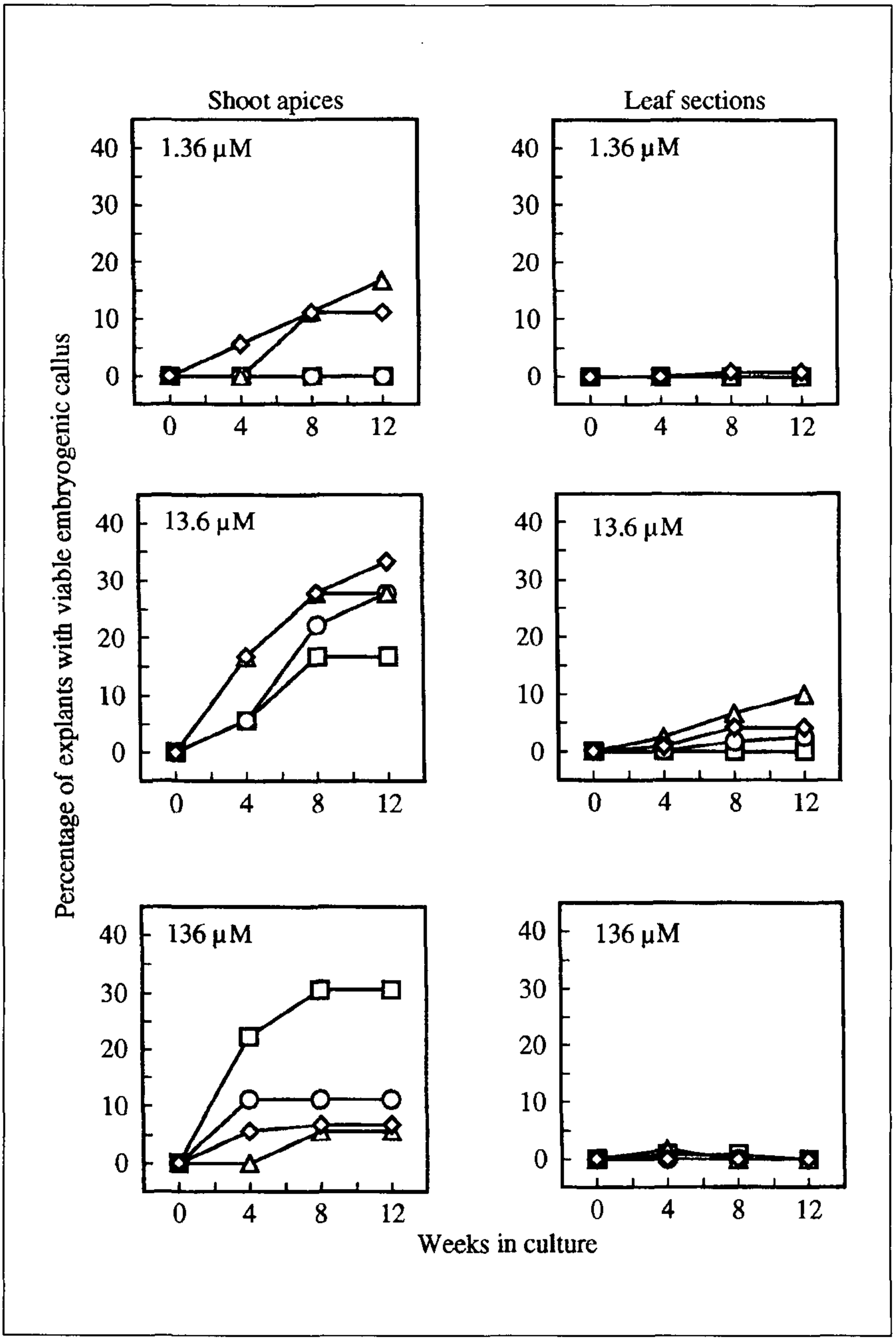

Figure 2. Percentage of explants from *Miscanthus* ×*ogiformis* 'Giganteus' with viable embryogenic callus as influenced by explant type, 2,4-D concentration, and exposure time recorded after different periods in culture. The exposure times to 2,4-D were □ = 1 week, ○ = 2 weeks, Δ = 4 weeks, or ◊ = 8 weeks.

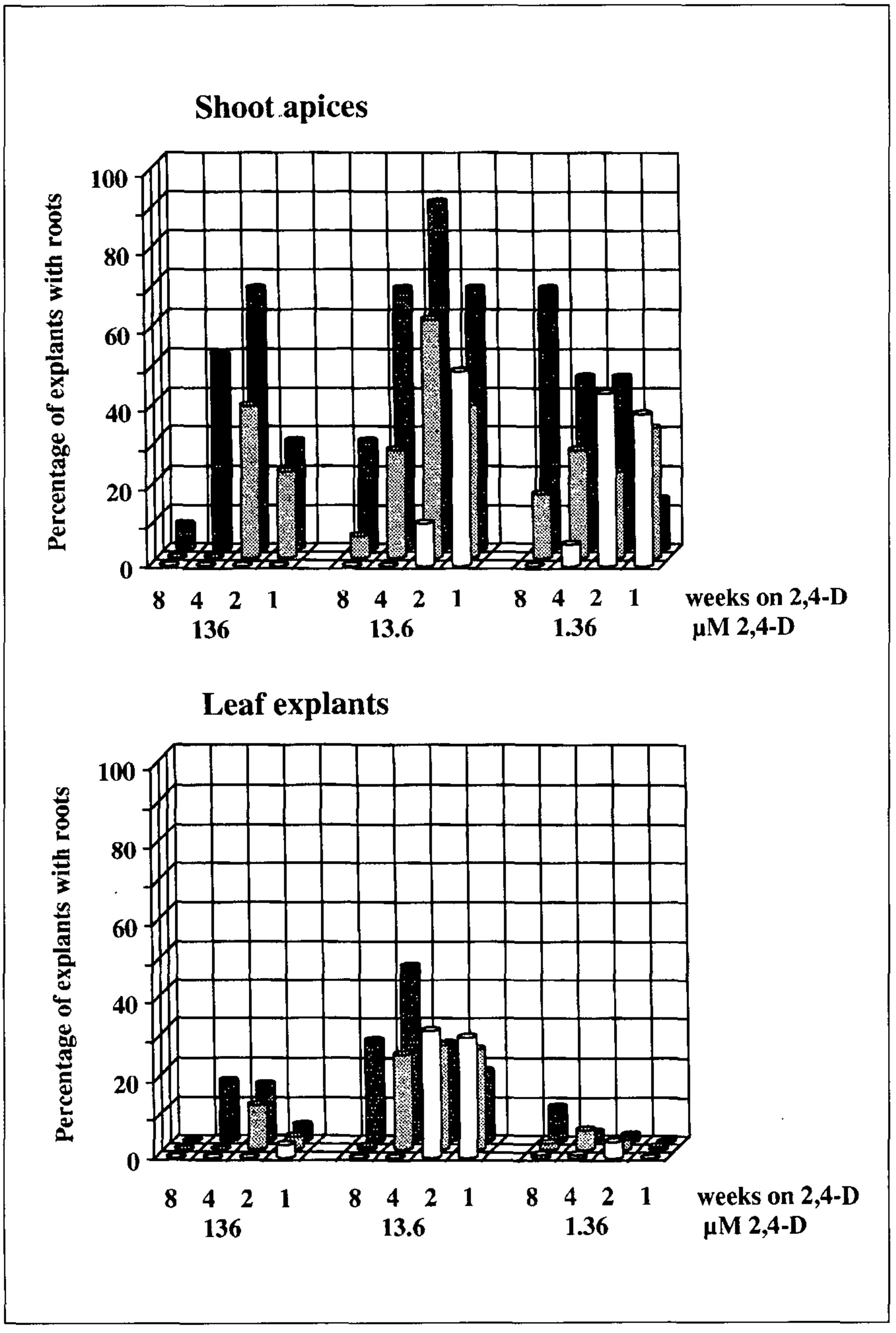

Figure 3. Percentage of explants from *Miscanthus* ×*ogiformis* 'Giganteus' with roots as influenced by explant type, 2,4-D concentration, and exposure time recorded after different periods in culture. □ = 4 weeks, ◻ = 8 weeks, or ■ = 12 weeks in culture.

inhibit the formation of the root-forming callus type with high concentrations of 2,4-D, only to suppress the development of roots. Careful selection is therefore decisive to obtain highly embryogenic cultures.

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Long-Term In Vitro Storage of *Miscanthus* Cultures

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In vitro cultures of *Miscanthus* consisting of single shoots on rooting medium were stored at a temperature of 8, 12, 16, or 20C and a photon fluence of 5, 10, or 20 µmol m-2 s-1 for 0, 4, 8, 16, or 26 weeks. With increasing storage period the survival and root and shoot formation measured after 14 days of acclimatization and 14 days of growth were improved considerably. A storage temperature of 8C resulted in the best survival of plants and a temperature of 16C was optimal for shoot formation. Root and shoot formation were improved with increasing photon fluence during storage.

INTRODUCTION

Miscanthus is a potentially important crop particularly due to its high biomass production (Nielsen, 1987; Schwarz, 1993) and large capability to keep the nutrients in the rhizosphere (Jørgensen, 1994). To avoid the risk of spreading *Miscanthus* seeds to nature where *Miscanthus* will provide a weed problem, only sterile cultivars should be planted. This implies that clones and cultivars have to be propagated vegetatively by division, mechanical separation (Kjeldsen 1994), or in vitro propagation (Nielsen et al., 1993, 1995).

Approximately 10,000 plantlets are needed per hectare. A large demand for plants may provide severe problems for tissue culture laboratories because the planting season only is of 2 to 3 months. In vitro storage of *Miscanthus,* thus, could enable a supply of a large number of plants within a limited period of time without having a large in vitro-laboratory capacity.

MATERIALS AND METHODS

The triploid cultivar Miscanthus ×*ogiformis* Honda 'Giganteus' was used. In vitro cultures of axillary shoots grown on propagation medium (a modified MS medium, Murashige and Skoog 1962) containing 5 mg litre^{-1} benzyladenine were divided into single shoots and transferred to rooting medium (a modified MS medium) containing 1 mg litre^{-1} α-naphthaleneacetic acid. After 3 days on rooting medium the containers with 20 plants each were stored at a temperature of 8, 12, 16, or 20C and a photon fluence of 5, 10, or 20 μmol m^{-2}s^{-1} for 0, 4, 8, 16, or 26 weeks. The experiment was repeated three times at different times of the year.

At the end of the storage period, plants were potted into peat in 5.5-cm diameter pots and acclimatized for 14 days in a controlled environment room at a temperature of 23±0.5C, a photon fluence of 35 μmol m^{-2} s^{-1}, and a photoperiod of 16 h. Thereafter the plants were transferred to a glasshouse and grown for a further 14 days at natural light conditions and a minimum temperature of 23C.

At the end of storage, acclimatization, and 14 days of growth the percentage of dead plants and percentage of plants with roots were calculated and the number of new shoots per plant was measured.

RESULTS AND DISCUSSION

On an average basis, the percentage of dead plants calculated at the end of the storage period increased gradually from 1% after 0 weeks of storage to 8.1% after 26 weeks of storage. At the end of the growth period the results showed a significant decrease in percentage of dead plants with increasing storage period from about 40% after 0 weeks of storage to 16% after 26 weeks.

Table 1. Percentage of dead plants after acclimatization and 14 days of growth. Average of 18 containers per treatment.

Storage temperature (C)	Storage period (weeks)				
	0	4	8	16	26
8	40.5	27.3	12.7	11.8	9.4
12	37.5	31.2	42.3	34.7	20.0
16	39.0	31.2	36.1	-	14.5
20	38.4	30.2	28.7	27.9	24.3

Containers that were stored at 8C generally had the lowest percentage of dead plants at the end of the growth period. Storage at other temperatures resulted in higher percentages of dead plants (Table 1).

With increasing photon fluence during storage a reduction in the percentage of dead plants was observed after acclimatization and 14 days of growth. This reduction was most pronounced when plants were stored for a period of 4 to 8 weeks (Table 2).

Table 2. Percentage of dead plants after acclimatization and 14 days of growth. Average of 24 containers per treatment.

Photon fluence (μmol m^{-2} s^{-1})	Storage period (weeks)				
	0	4	8	16	26
5	38.6	38.5	42.2	28.7	19.3
10	44.0	24.5	23.5	18.2	14.8
20	36.2	21.2	12.9	18.2	12.9

The decrease in dead plants with increasing storage period and photon fluence indicates that a longer period than 3 days on rooting medium before storage is necessary in order to develop plants that can survive short-term storage.

Improved survival probably also would be the result if shoot clusters were stored instead of single shoots. Handling of nonstored shoot clusters with about five shoots grown on rooting medium during the last subculture usually only results in very few dead plants after a period of acclimatization and growth.

Root formation measured at the end of the growth period increased with storage time from 53% after 0 weeks of storage to 83% after 26 weeks of storage. Root formation was only slightly influenced by storage temperature but there was a stimulating effect of increasing photon fluence particularly when stored for 4 or 8 weeks (Table 3).

Table 3. Rooting percentage after acclimatization and 14 days of growth. Average of 24 *containers per treatment.*

Photon fluence (μmol m^{-2} s^{-1})	Storage period (weeks)				
	0	4	8	16	26
5	53.6	56.4	46.8	57.9	81.5
10	49.8	69.0	69.7	69.7	79.4
20	56.5	74.3	83.4	72.7	86.8

Shoot formation measured at the end of the growth period was promoted by increasing temperature during storage with 16C as the optimal temperature (Fig.

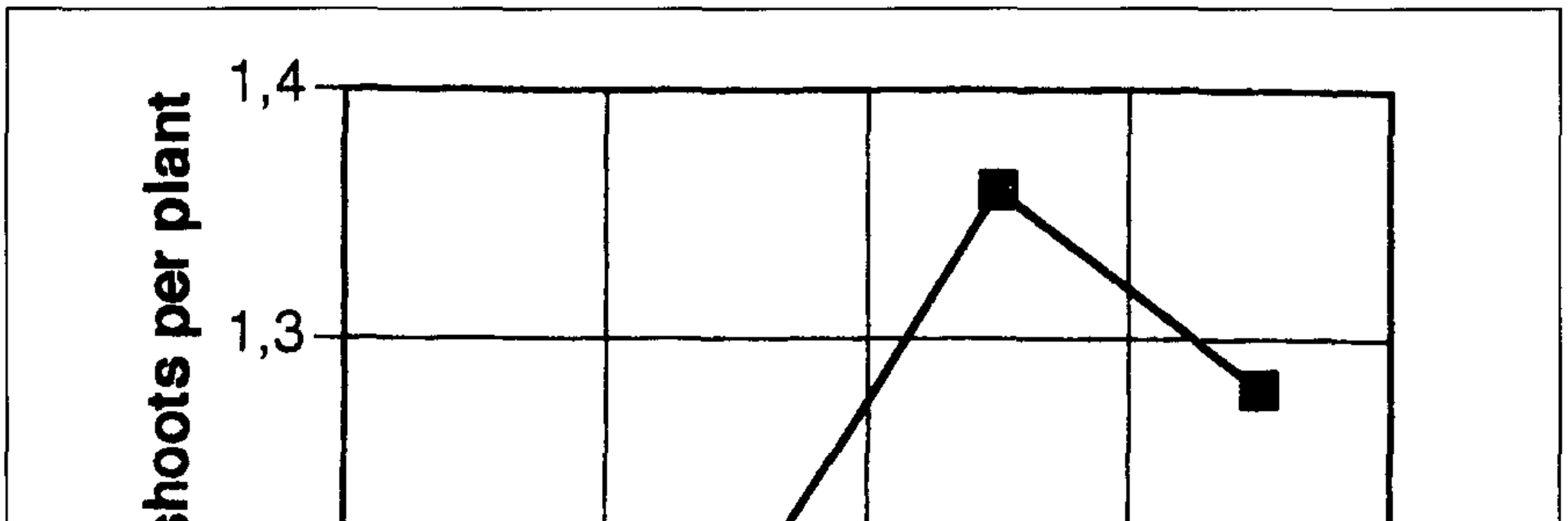

Figure 1. Number of shoots per plant as a function of storage temperature. Average results after 14 days of acclimatization and 14 days of growth.

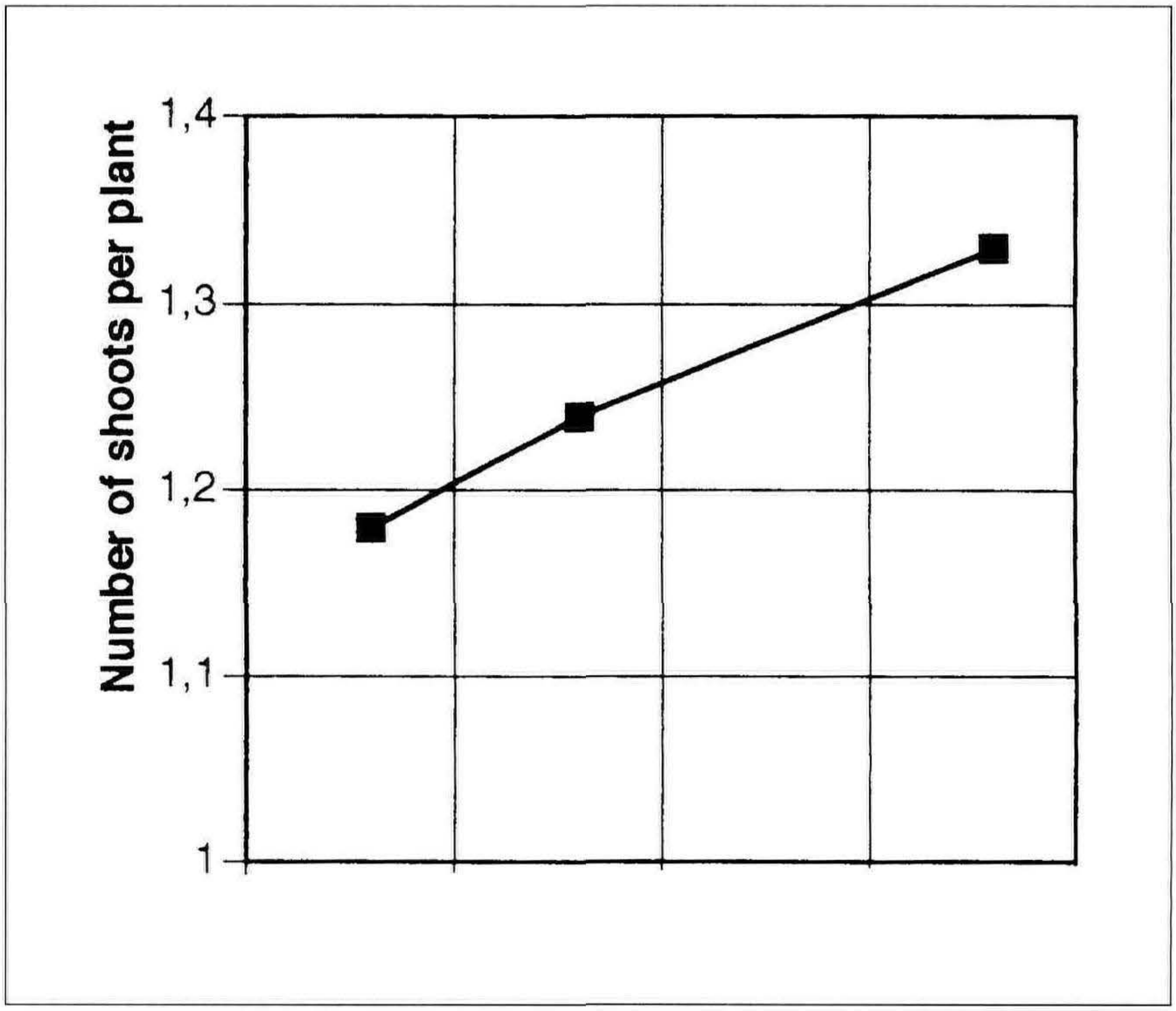

Figure 2. Number of shoots per plant as a function of photon fluence during storage. Average results after 14 days of acclimatization and 14 days of growth.

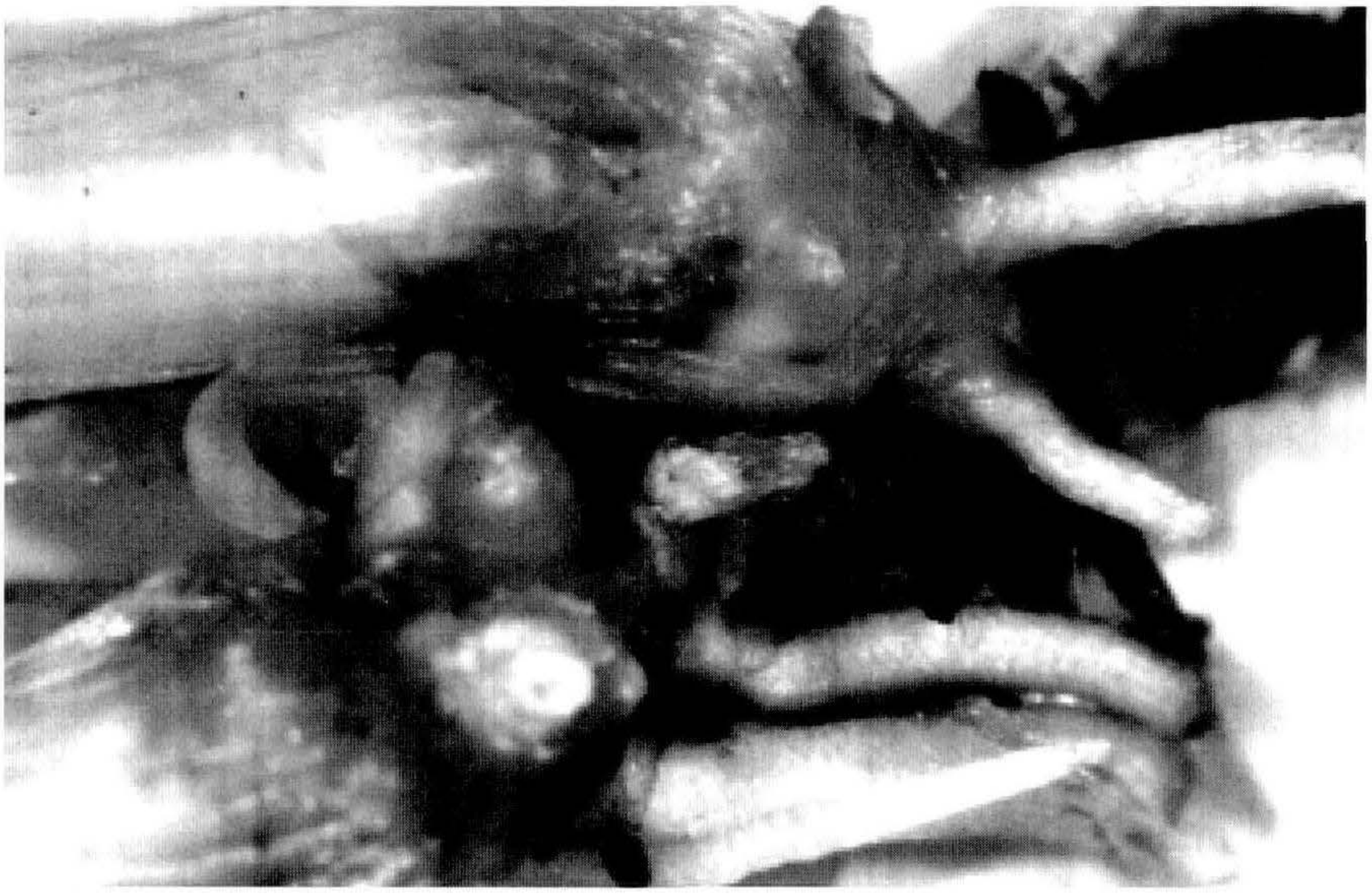

Figure 3. Basal part of a *Miscanthus* plantlet with visible shoot primordia after 26 weeks of in vitro storage.

1). Shoot formation was also improved by increasing photon fluence during storage (Fig. 2).

Leaves of in vitro stored *Miscanthus* plants gradually became more and more necrotic during storage and after 26 weeks of storage almost no green leaves were present. During storage the plants developed a firm rhizome with a few visible shoot primordia (Fig. 3) ready to grow and produce new shoots after transplanting the rhizome to peat.

Long-term in vitro storage of *Miscanthus* cultures at 16C and 20 μmol m^{-2} s^{-1} on rooting medium provides a possibility to efficiently propagate plants more or less continuously thus avoiding bottleneck situations in the laboratory.

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Development of Embryo Dormancy and Abscisic Acid Concentration During Seed Maturation in Beech

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Nuts of beech (*Fagus sylvatica*) were harvested from a single tree at nine different developmental stages during the period 3 June to 28 September 1993. Seeds were tested in a standard germination tests at 5 and 15C. Seeds incubated at 15C were unable to germinate at any stage of development. Seeds harvested after 16 August had reached a point of maturity where they were able to germinate at 5C. To test the effect of covering structures on dormancy, seeds harvested 16 August and later were germinated as whole seeds, seeds without pericarp, and seeds without pericarp and testa (naked embryos). Again only seeds incubated at 5C germinated after at least 3 months at 5C meaning that the seeds possess true embryo dormancy, requiring cold treatment for dormancy breakage.

At all stages of development ABA was extracted and quantified by a radio-immunoassay. The development in ABA concentration showed a pattern well known from other orthodox seeds, with a sharp rise in concentration at the time where the seeds reached maximum fresh weight. The ABA content decreased during the maturation phase—upon full maturity we found a low concentration of ABA. Concurrently with a high level of ABA an increase in protein accumulation is found, especially in the heat-stable fraction. These heat stable proteins belong to a group of proteins called late embryogenesis abundant (LEA) proteins. The function of these proteins are yet unknown, but their appearance in practically all species with orthodox seeds has been correlated to development of desiccation tolerance and dormancy.

INTRODUCTION

Mature seeds of beech (*Fagus sylvatica*) are dormant and require a cold treatment to break dormancy before the seeds are able to germinate. The cold treatment is traditionally performed at 5C on fully imbibed seeds. Because the seed lot is heterogeneous, some seeds will have their dormancy broken before others and start to germinate. If the treatment is interrupted some seeds will still be dormant and unable to germinate in a seed bed. The result is a partial loss of a seed lot either caused by dormancy, or caused by damage to germinated seeds during sowing.

This study is part of a project with the main aims to develop efficient methods to break dormancy without germination, and to get a better understanding of dormancy mechanisms in tree seeds on a molecular level.

MATERIALS AND METHODS

Plant Material. Beech nuts were collected from a single tree in Lundtofte, every 2 weeks from the beginning of June to the end of September.

Germination. Seeds were germinated in 3 or 4 replicates of 25 seeds on top of filter paper in germination boxes. The filter paper was supplied with deionized water from a wick, ensuring constant moisture content during the germination period. The beech nuts were germinated in the dark at constant temperature at 5 or 15C

ABA Extraction and Purification. Seeds for ABA extractions were removed from the capsules at the day of harvest and frozen in liquid nitrogen. Lyophilized seeds were ground in a pistil mortar (minimum 10 seeds) and duplicate extractions were made for each sample. One hundred milligrams dry matter was extracted in 4 ml of 0.02 M sodium-phosphate buffer (pH 7.3). To stop enzymatic degradation of conjugates, the samples were immediately heated in boiling water for 5 min (Loveys and Dijk, 1988). The extraction continued over night at 5C. Solid matter was spun down and 1 ml of extract was taken out. Three drops of 1M H_2SO_4 were added and ABA was extracted in 3 × 1 ml of water-saturated ethyl acetate. Ethyl acetate and buffer were thoroughly mixed and separated by centrifugation to ensure an effective extraction. The organic phase was passed through a Sep Wac. silica cartridge (Waters Associated, 3 ml, 500 mg sorbent). The elute plus further 3 ml wash (water-saturated ethyl acetate) was pooled and reduced to dryness under a stream of air. ABA was redissolved in 1 ml of water.

ABA Measurements. The concentration of ABA was measured according to Quarrie et al. (1988).

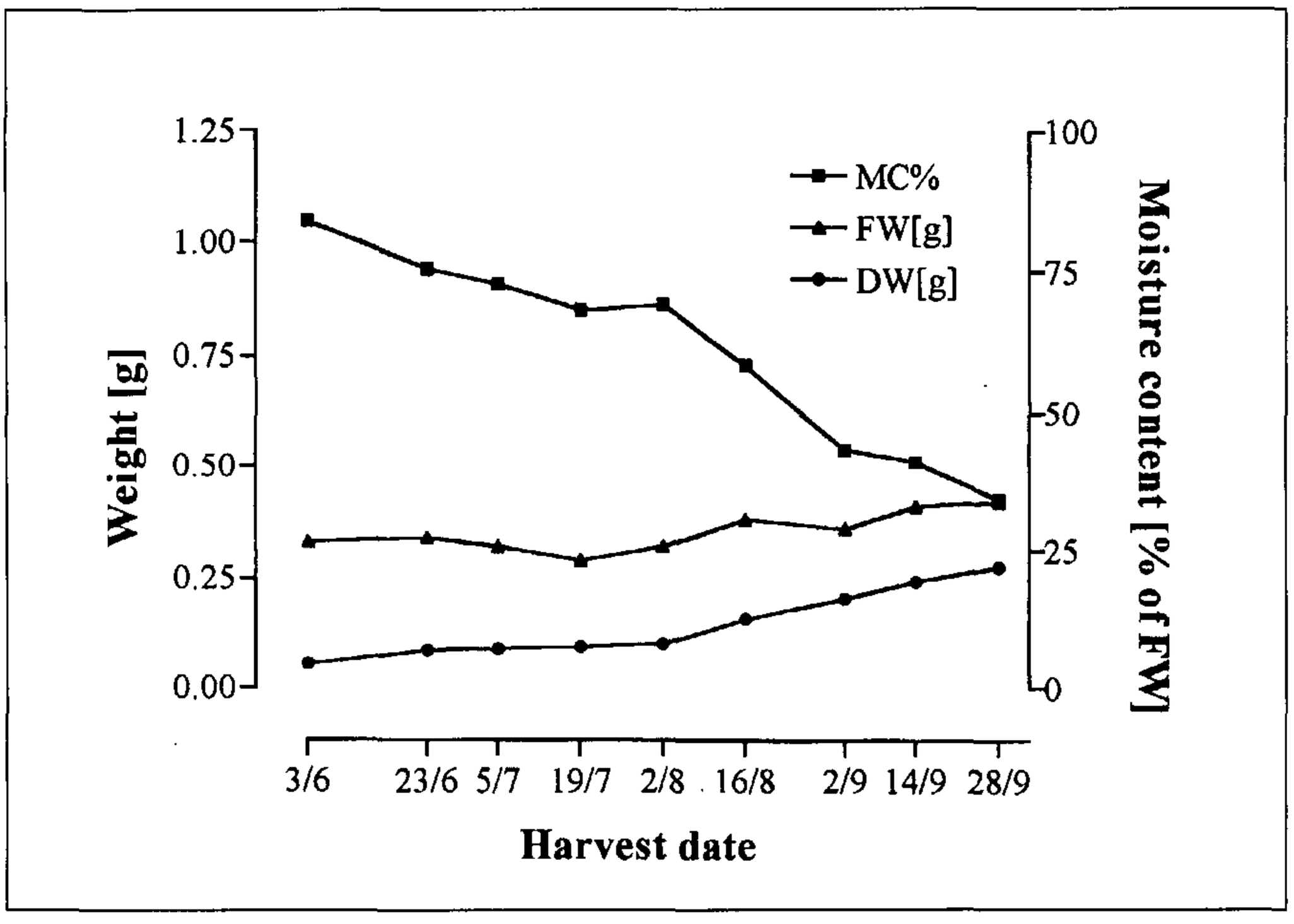

Figure 1. Fresh weight, dry weight and moisture content during seed development in *Fagus sylvatica*. Each point is an average of two measurements.

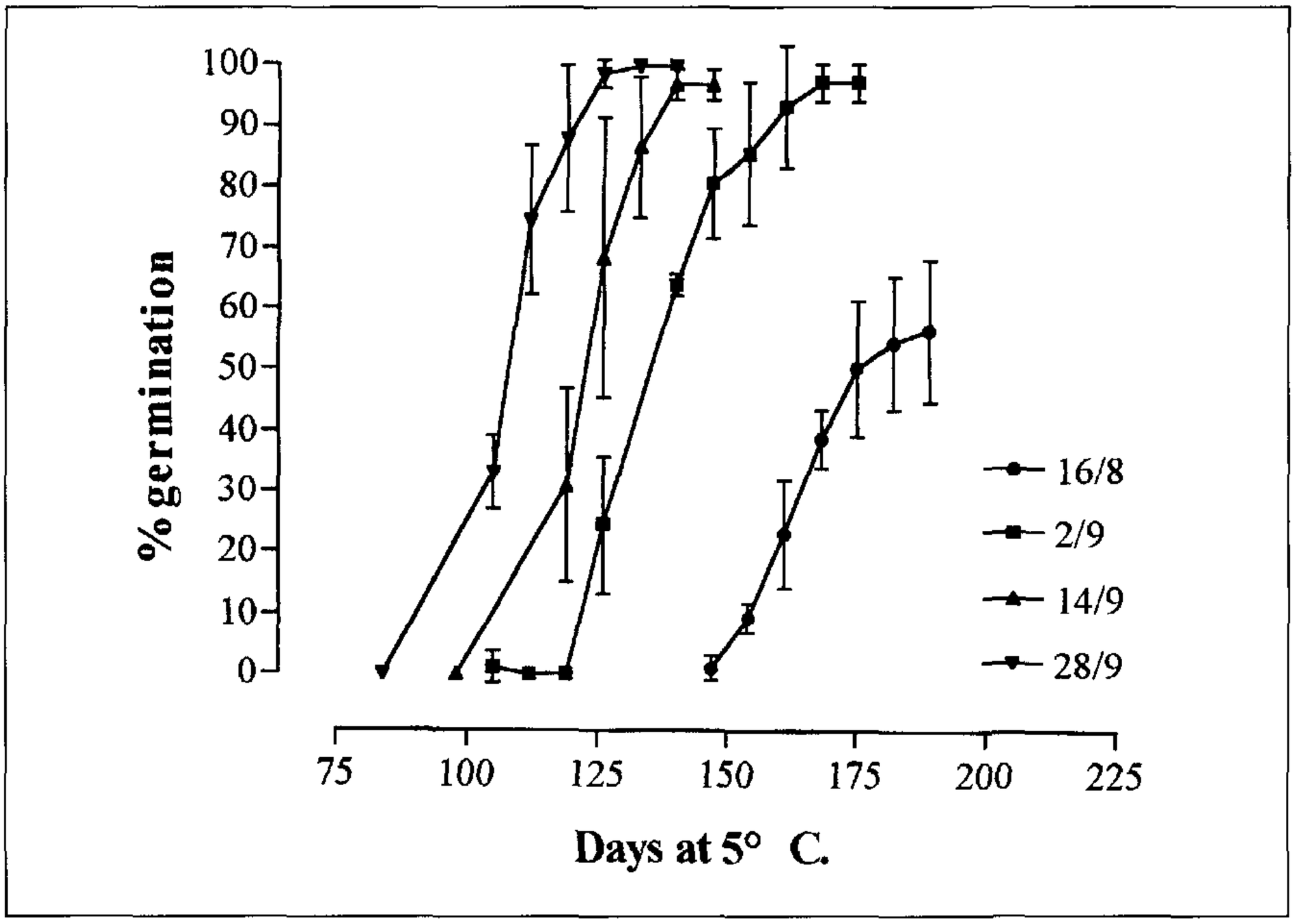

Figure 2. Accumulated germination for seeds harvested at different developmental stages. Harvest dates according to legends. Each point is average of 3 or 4 replicates ± S.D.

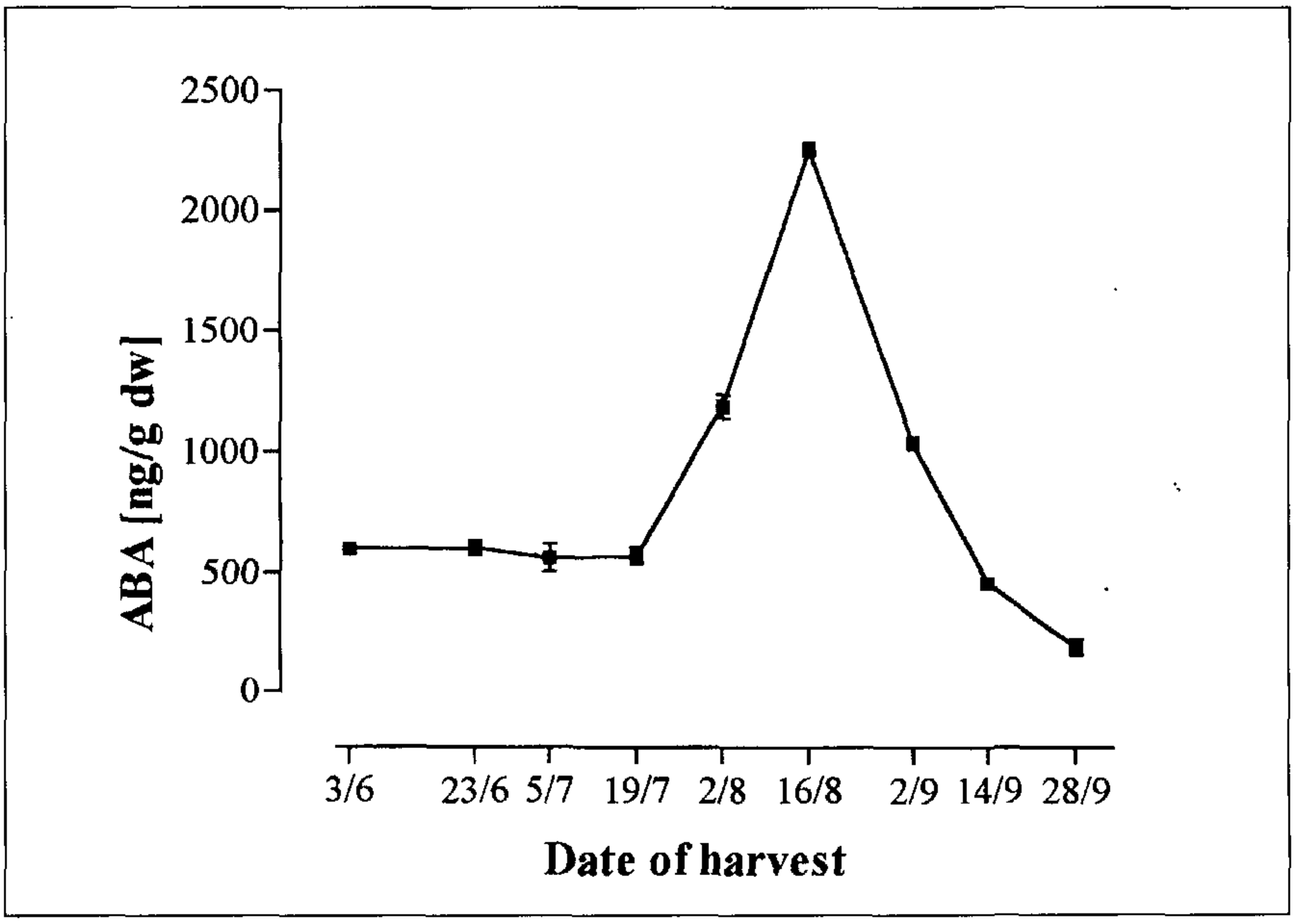

Figure 3. Abscisic acid concentration on dry weight basis at different developmental stages. Each point is an average of two extractions ± S.D.

RESULTS

From 3 June to 16 August the seed fresh weight increased which correlated to a visible increase in size of the embryo. The size increased fast during a short period from 5 July to 2 August, when the embryo filled the pericarp. The pericarp only changed slightly in size during the period examined. The moisture content showed a rather constant drop from 84% at 3 June to 34% at 28 September when the seeds were shed (Fig. 1).

No seeds were able to germinate at 15C, but seeds harvested 16 August and later were able germinate at 5C. From 16 August to 2 September the number of germinable seeds increased, but seeds harvested 2 September and later germinated to nearly 100%. The speed of germination increased during the maturation phase (Fig. 2)—meaning the later the harvest the lesser the dormancy.

The changes in ABA concentration showed a pattern well known to other species including both woody and herbaceous species. The concentration on a dry-weight basis is constant until 19 July, after which a sharp rise in concentration occurs with the highest concentration reached at 16 August, the same date the seeds reached a point of maturity where they were able to germinate. During seed maturation the ABA concentration declines, and at full maturity the ABA concentration is even lower than the one found in very young seeds (Fig. 3).

Proteins accumulated in the seeds after they filled the pericarp and we found an increasing protein concentration during the period 2 August to 28 September. The accumulation of heat-stable proteins started 16 August which coincided with the time of highest ABA concentration. Especially in the acidic part of the gel, a group of heat-stable proteins accumulate during the maturation phase of seed formation.

DISCUSSION

In this study we are unable to conclude, whether the higher ABA level at 16 August is correlated to development of dormancy, as the seeds are already deeply dormant, as they reach the point of maturity, where they are able to germinate. We are therefore unable to distinguish between changes connected to dormancy and changes correlated to maturation of the seeds. One role of ABA in seeds could be to prevent precocious germination while the seeds are still on the mother plant, as ABA is known to be an efficient inhibitor of germination. The correlation between the high ABA concentration and the ability to germinate after cold treatment on 16 August, supports this theory. The fact that the ABA concentration drops upon full maturity implies that ABA alone does not control dormancy, as the fully mature seeds are dormant and require about 3 months at 5C to break dormancy.

Heat-stable proteins have been reported to accumulate late in seed development in several species. Blackman et al. (1991) found a correlation between accumulation of heat-stable proteins and the development of desiccation tolerance in soybean (*Glycine max*). Several LEA proteins are heat stable, e.g., dehydrins (Close et al., 1993), and ABA inducible (Skriver and Mundy, 1990). The correlation between high ABA content in the seeds and accumulation of heat-stable proteins supports the theory that ABA is inducing transcription of LEA genes.

The function of *LEA* proteins is unknown but their hydrophilic nature implies that they are involved in protection against desiccation damage. Further studies will examine the development of desiccation tolerance during seed maturation in correlation to changes in ABA concentration in the seeds, and the use of antibodies

against dehydrins will show if the accumulation of dehydrins is correlated to development of desiccation tolerance.

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The Diverse Origin of New Plants for the Nursery Industry

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The last decade has shown that the introduction and marketing of new plants are vital for the successful economic growth of the nursery industry. A major feature of many nursery catalogues is promotional information on new plant introductions. This paper reflects upon the diversity of the origins of plants which are commercially grown.

The 19th and early 20th centuries were an important era for the discovery of new species. Reading about the travels of the early plant explorers such as David Douglas, George Forrest, and Ernest H. Wilson, one is able to appreciate the hazards and personal risks they took to collect seed and plants for European and American institutions. David Douglas was renowned for his discoveries in western North America. His collections included *Arbutus menziesii, Mahonia nervosa,* and *Ribes sanguineum*. George Forrest's collections in China, Burma, and Tibet included such excellent plants as *Pieris formosa* var. *forrestii, Magnolia campbellii* subsp. *mollicomata,* and *Rhododendron sinogrande,* while the extensive travels of Ernest H. Wilson in China gave gardening *Acer griseum, Clematis armandii,* and *Salix magnifica.*

As more international boundaries have opened up for plant collection, the last decade has seen considerable activity in both the discovery of new species and the re-collection of known species. Plantsmen such as Peter Cox, Christopher Brickell, Tony Schilling, and Roy Lancaster have generously distributed their seed to botanical gardens, arboreta, and horticultural societies. The University of British Columbia Botanical Garden has been particularly indebted to Roy Lancaster for wild-collected seed from China which has added to their collections in the David C. Lam Asian Garden. A new species of*Hypericum*, subsequently named*H. lancasteri*, was collected in 1980 by Roy Lancaster.

Rowland Jackman, Henry M. Eddie, and Ed Lohbrunner are just three of the well-respected "pioneer nurserymen" whose foresight and work have lead to some excellent and reliable plants. The violet-purple, large-flowered *Clematis* hybrid, *C.* ×*jackmanii* (*C. lanuginosa* × *C. viticella*) was raised in the nursery of Jackman in Woking, England, in 1858. Today *C.* ×*jackmanii* is still one of the best selling cultivars in the marketplace. Originally from Scotland, Henry M. Eddie established nurseries in Vancouver and Chilliwack, British Columbia. He saw the commercial potential of breeding new plants, which lead to his selections of roses, pears, and yews. However, it was his work in hybridising *Cornus nuttallii* with selections of *Cornus florida* for which he will be most remembered. Today *Cornus* 'Eddie's White Wonder' is one of the very best selections of dogwood grown. Born in Victoria, British Columbia, Ed Lohbrunner established an alpine plant garden on Vancouver Island. In a friend's garden, among some seedlings of*Genista pilosa*, he noticed a floriferous, intensely golden-yellow seedling. The fact that it also did not set seedpods after flowering made it a potentially good garden plant. He originally referred to this plant as 'Mayfair' because of the location in which it was found. It was subsequently

given to the University of British Columbia Botanical Garden, named *Genista pilosa* 'Vancouver Gold' and became the first plant to be released through the UBC Plant Introduction Scheme.

Today the contribution plant propagators and nursery growers have made to the development of new plants is not always appreciated. Peter Dummer, whose life's work was in the propagation department at Hillier Nurseries (Winchester) Ltd., has bred some excellent plants. Besides his personal interest, it was his in-depth knowledge and his ability to project the potential benefits of hybridising certain species or cultivars that lead to his selections. Among the plants his work has given us are *Cotinus* 'Grace' (*C. obovatus* × *C. coggygria* 'Velvet Cloak'), *Berberis* 'Goldilocks' (*B. darwinii* × *B. valdiviana*), and *Phygelius* ×*rectus* 'Moonraker' (*P.* ×*rectus* 'Winchester Fanfare' × *P. aequalis* 'Yellow Trumpet'). Peter Dummer's infectious enthusiasm encouraged his colleagues at Hillier Nurseries to also develop new plants. Peter Moore hybridised *Choisya arizonica* with *C. ternata* resulting in *C.* 'Aztec Pearl', while Alan Postill selected a superior hardy form from seedlings out of *Daphne bholua* 'Gurkha' which he subsequently named *D. bholua* 'Jacqueline Postill'. Peter Catt, owner of Liss Forest Nursery Ltd., now has one of the most comprehensive listings of woody plants. He is another person who can perceive the benefits gained from hybridising specific plants. Among the excellent selections he has developed and introduced are the bright-yellow foliaged *Choisya ternata* 'Sundance', *Lavatera* 'Burgundy Wine', *L.* 'Candy Floss', and more recently *Ceratostigma willmottianum* 'Forest Blue' and *Lavatera* 'Lilac Lady'.

A number of excellent variegated plants have been introduced from nurseries. Using perennials as examples, David Ward, propagator at the Beth Chatto's Gardens, Essex, England, saw in Beth Chatto's garden a coral-red variegated form of *Pulmonaria rubra*. Subsequently named *P. rubra* 'David Ward', this selection is considered the best of the various variegated forms. *Gaura lindeimeri* has been growing in popularity as a perennial for borders and at the same nursery a striking variegated form arose which was later named *G. lindeinfri* 'Corrie's Gold'. *Osteospermum* are now having a revival as tender summer-flowering perennials for borders and patios, which has stimulated some breeding programs. The best variegated selection was found a few years ago in Kenya by Christopher Fairweather, Hilltop Nursery, Hampshire, England. Named *O.* 'Silver Sparkler', it is now widely distributed.

John Massey and Philip Bault retain the National collection of *Lewisia* at Ashwood Nursery, Kingswinford, England. Their great enthusiasm for this genus has lead them to study the different species in their native habitats in western North America. Some 17 years of hybridising the evergreen *Lewisia cotyledon* led to what is now sold as the "Ashwood Strain". It contains a galaxy of vibrant colors, making it an ideal plant for impulse buying at garden centers. Besides *Lewisia,* Ashwood Nursery is hybridising alpine show auriculas, hardy cyclamen, and hellebores.

Many excellent plants have been developed by home gardeners who have spent a lifetime cross pollinating specific genera. Roses, rhododendrons and clematis have particularly benefitted from the work of amateurs. Conrad Erlandson of Abbotsford, British Columbia, became very interested in hybridising *Clematis* after he retired from the printing industry. One of his best hybrids was the result of crossing *C.* 'Nelly Moser' with *C.* 'Ramona'. This superb free-flowering hybrid was later given to the UBC Botanical Garden, named *C.* 'Blue Ravine' and released through its Plant

Introduction Scheme. Though not part of a breeding program, one of the best recently introduced Euphorbias was found by Jill Paxton, Mere, England, in the Dordonge region of France. Named *Euphorbia dulcis* 'Chameleon', it has very attractive mahagony new growth that turns deep purple in summer, followed by various shades of autumn color.

Plant societies whose goals are to preserve cultivars thought lost to cultivation and to encourage the "re-introduction" of garden plants which should be more widely grown have also played an important role. A good example is the promotion given by Bridgemere Nurseries Ltd., Cheshire, England, at the 1992 National Garden Festival of Wales for *Dahlia* 'Bishop of Llandaff'. Its history, intense red flowers and deep purple foliage made this a sought-after plant. It is now widely available in Europe and is becoming known in North America. "Show auriculas" were especially popular in the 18th and 19th centuries and a number of different cultivars arose. Micropropagation, combined with effective promotion, has now made a number of these cultivars, such as *Primula auricula* 'Argus', available again.Their renewed popularity has also made it possible for some of the cultivars raised in the last 50 years by members of Primula societies to be commercially grown, for example, 'Rajah', 'Sheila', and 'Prague'.

Research and experimental stations, universities, botanical gardens, and arboreta have played a very important role in developing new plants. The Morden Research Station, Morden, Canada, is a classic example where the past breeding work of W.A. Cumming, W.G. Ronald, and H.H. Marshall resulted in new plants that would successfully adapt to the harsh climate of the Canadian prairie provinces. These plants, such as *Caragana arborescens* 'Walker' and *Fraxinus nigra* 'Fallgold', were subsequently grown in many other countries. It is unfortunate that current financial restraints have lead to a radical reduction in funding for breeding ornamental plants.

Today the successful launch of a new plant entails considerable investment in both time and funding. The plant needs to be thoroughly evaluated to establish its potential markets, its best propagation and growing technique must be determined, and finally a "marketing package" must be formulated for promotion and sales. The last few years have shown how important it is to give the plant a cultivar name which is easily remembered by the consumer. As well, there are still ongoing problems with plant nomenclature, which are sometimes made more difficult by trademarking and patenting. However, in order to provide a fair economic return to the originator, it is essential that nurseries "play by the rules" with licensed and protected plants. There have been too many instances when this has not been the case. To ensure good new introductions there must be both an economic return and proper recognition of the originator.

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Practical Details of Importing Plants

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I want to thank the I.P.P.S. for the invitation to come and speak to you today. I count this as a honor to speak before "The Cream of the Crop" of the nursery industry. Of all the different aspects of the nursery trade, shipping, marketing/sales, production, administration, my favorite area of responsibility has always been propagation. I feel a real kinship with you and your interest, so I count this as a distinct privilege to be here today.

I would like at the outset to admit to you a bias you will see throughout this presentation. I have been involved with the importation of nursery stock from Holland since 1975. I am familiar with the mechanics of the importation as well as its strengths and weakness. So, up front, my bias is favorable to importing plant material from Holland. And in conjunction with my bias, I acknowledge some limitations. I have only imported from New Zealand and Japan twice, so I can't speak with any authority concerning those topics.

In 1947, my father-in-law, Mr. Jack Spaargaren, immigrated from Boskoop Holland and spent 5 years under the sponsorship of Malmo Nursery in Seattle. In 1952, Jack started his own landscaping/nursery business. In November of 1955, an early and severe frost killed 80% of his nursery. He wrote to his brother in Holland and asked him to send a large shipment of plant material so that he would have a crop to sell come spring. The success he enjoyed from this first shipment, facilitated continued shipments annually.

From 1955 until 1975, Jack Spaargaren continued importing and selling plant material to other nurseries. In 1975, I joined Jack in the business, until his retirement in 1985. At that time I took on the responsibilities of the Dutch trade.

One of the first steps prior to importing material from out of the country is to apply to the U.S.D.A. using PPQ Form 546, Application to Import Plant Material. This form can be requested from your state department of agriculture, and is forwarded to U.S.D.A. in Hyattsville, Maryland for approval.

I would also recommend at the same time to apply for a Post Entry Quarantine Permit. This is an additional amendment added to your permit that, in the long run, will save you many headaches. The Post Entry Permit is an agreement between you and the U.S.D.A. to submit to a few additional regulations. The agreement calls for the importer to hold the plant material for two growing seasons prior to sale, as well as keeping a physical boundary of 10 feet from any domestic stock of the same species, to prevent the spread of disease.

The U.S.D.A. is concerned that some types of material are susceptible to black stem rust, crown gall, or other diseases. By holding the material for 2 years, the U.S.D.A. has the ability to inspect at least once each growing season. Upon completion of the post-entry period, the U.S.D.A. releases the material for disposition. One word of caution, don't think ignorance is an excuse for early disposition of material under Post Entry Quarantine. The U.S.D.A. takes a dim view of those who ignore signed agreements and import permits have been revoked for failure to adhere to the rules.

The following plant material has been listed as Post Entry Quarantine material: *Acer, Actinidia, Aesculus, Berberis (approved cultivars), Chaenomeles, Corylus*

(fruiting), *Crataegus, Cydonia,* fruit and nut plants, *Hibiscus, Hydrangea, Jasminum, Juglans, Mahonia, Malus, Monis, Prunus, Pyrus, Quercus, Rosa, Rubus, Sorbus,* and *Vaccinium.*

Also of note is the following list of material prohibited for importation: *Abies, Berberis, Euonymus, Cedrus, Chrysanthemum* (botancial editor's note: see also *Argyranthemum, Dendranthema, Rhodanthemum, Leucanthemopsis, Arctanthemum, Tanacetum, Nipponanthemum, Ajania,* and *Leucanthemella), Dianthus, Dictamnus, Fraxinus, Juniperus, Larix, Ligustrum, Philadelphus, Picea, Pinus, Populus, Pseudolarix, Pseudotsuga, Ribes, Salix, Skimmia, Ulmus,* and *Vitis*

You should also be aware that any plant material patented in the United States cannot be shipped into the country by foreign nurseries.

When deciding to import material I would recommend trying to locate a reputable exporter. The exporter should be familiar with all U.S.D.A. regulations as they pertain to proper preparation of plant material for export (e.g., which plants are permissible, which plants are under Post Entry Quarantine, etc.). The exporter should be able to prepare the necessary documents for export as well.

The exporter will then hire an export broker to handle the shipment from his nursery to the airport in Holland. The export broker will then arrange for shipment to the United States. They handle tons of freight weekly, so they are in a position to negotiate a better freight rate for the customers.

The export broker will contact a customs broker in the United States to handle the shipment upon arrival. The customs broker will then contact the importer and have you sign a Power of Attorney, so they can act on your behalf to process the shipment through the airlines, U.S.D.A., U.S. Customs, and the forwarding companies after release. Some of their responsibilities include: (1) coordinating with both US Customs and the U.S.D.A.; (2) arranging for labor to move boxes into the U.S.D.A. Station for inspection; (3) coordinating and negotiating rates for fumigation, if needed; (4) assigning proper Duties Schedules, for submission to calculate duties; (5) providing a U.S. Customs Bond that exceeds 3 times the value of the shipment; (6) arranging for the transportation of all consignments after clearance from the U.S.D.A. and U.S. Customs have been given; (7) consolidating all charges; and (8) forwarding bills to the client.

A brief word about the U.S. Customs Service. They primarily assign most of the responsibility for physical inspection to the U.S.D.A.. Since 1975, when I first started with importation, U.S. Customs has only requested a physical inspection 3 times after U.S.D.A. approval. However, they have the right and obligation to verify that no contraband is included in any shipment.

The U.S.D.A. will be the primary federal government agency you will be dealing with on your importations. It is their responsibility to verify that the plant material you have purchased can enter into the United States, to check to see if anything is on the Post Entry List, and to check for any pathogens, insects, or damage. If they find any questionable items, they will take a slide and send it to Hyattsville, Maryland by overnight express and have the pathologist verify that it is nothing harmful. If any insect eggs (aphids, thrips, mealy bugs) or scale are found, there are 3 options: (1) the material can be fumigated at the importers risk and expense; (2) the material can be destroyed; or (3) the material can be sent back to the country of origin. As the importer you have the right to have the material fumigated or reject the shipment and return the material to the custody of the customs broker. They will

contact the exporter and determine if he wants the material returned or destroyed. When the U.S.D.A. inspects the material they will inspect a representative sample of about 2% of each taxa. If problems are found they will inspect a larger percentage until they determine if the original problem is systemic to the entire species or only on a very small sample. I would also emphasize the words "small sample". The U.S.D.A. also requires that: (1) labor be available to move the boxes into the station; (2) the boxes be opened; (3) plant material be placed in front of the inspectors; and (4) plant material be repacked and moved out to pallets for pick-up by the airlines. When the inspection has been completed, a release will be given and the broker will take possession of the shipment and prepare the documents for submission to U.S. Customs.

There are costs associated with importing. I would like to divide the costs into two categories, fixed and variable costs. First, lets talk about fixed costs. Those include the following: price of the plant material, customs brokers fees and the custom bond. Most other costs are dependent on each individual shipment.

Variable costs include the following: U.S. Duties, airfreight, inspection, packing, insurance, fumigation, and rate exchange. The following two examples will help you to understand associated costs for budgeting purposes.

EXAMPLE #1

SHIPMENT DATE		December 1994
DOLLAR AMOUNT OF PLANT MATERIALS		$8,745.00
WEIGHT OF SHIPMENT		418 pounds
FIXED COSTS		$176.00 (Custom brokers fee, custom bond)
VARIABLE COSTS:		$1622.70 (Freight, duties, packing, Dutch inspection certificates, insurance, and delivery)
TOTAL COSTS:		$1798.70
SUMMARY:	1. Freight	$1.35 per pound
	2. Fixed costs	2%
	3. Variable costs	18.6%
TOTAL EXPENSES:		20.6%

EXAMPLE #2

SHIPMENT DATE:	March 1995
DOLLAR AMOUNT OF PLANT MATERIAL:	$1595.00
WEIGHT OF SHIPMENT:	50 pounds
FIXED COSTS:	$176.00 (Custom brokers fee, custom bond)

VARIABLE COSTS:		$615.50 (Freight, duties, packing, Dutch inspection certificates, insurance, delivery and rate correction)
TOTAL COSTS:		$791.50
SUMMARY:	1. Freight	$3.12 per pound
	2. Fixed costs	11%
	3. Variable costs	24%
	4. Rate correction	14.5%
TOTAL EXPENSES:		49.5%

One thing that needs to be understood from the beginning is that when you buy in U.S. dollars and they are exchanged to a foreign currency, you will be required to pay the difference or receive a rebate in excess of the first 5%. For instance, if the U.S. dollar fluctuates 4%, the exporter will be responsible for the first 5%. Any fluctuation in excess of 5% will be for your account. For instance, if the dollar decreases by 9%, the exporter will absorb the 5% decrease and you will be required to pay an additional 4%. However, if the U.S. dollar increases by 9% the exporter will pocket 5% increase and you will be rebated 4% on your invoice. The prices in Dutch catalogs are set in May to a fixed exchange rate and then at time of shipment the currency is calculated to assess extra charges or rebates.

I recommend that you keep two concepts in mind, long-term relationships and lead time. If you only want to import once, I would recommend that you piggy-back with someone who imports consistently. There are too many regulations and uncertainties to approach importing on a one-time basis, as evidenced by Example #2 above. I recommend that you pick and stay with a reputable exporter, so you can become accustomed to his procedures and quality. Lastly, find a custom broker who deals with plant material on a consistent basis. When dealing with time sensitive material like nursery stock, you don't want a broker who doesn't understand that concept.

The other concept you need to be conscious of is lead time. When you apply for permits from government agencies, especially with current and forthcoming budget constraints, you need to give them plenty of time so your plant material doesn't sit at the airport waiting for permits from a government agency closed for the weekend. The old saying "a lack of planning on your part, does not constitute an emergency on my part" really applies here.

Another issue needing your consideration is time of shipment and size of your order. If you order a small amount after we have shipped the majority of the orders, you will be paying a much higher freight rate. Note the currency exchange rate at the time of shipment.

You might asked yourself after this presentation, is it worth importing material from outside the country? For some, the answer is probably no. For others, the answer is yes. If that is your decision, be aware that if proper procedures are followed and you understand the costs and terms, you will have access to many new cultivars as well as the opportunity to fill in production holes on items that might be short in the United States.

Introducing Foreign Woody Species to Australia and Associated Marketing Techniques

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INTRODUCTION

Australia's geographic remoteness is a magnificent bonus for plant-lovers, with very few serious diseases and protected by stringent quarantine regulations. Despite its hot and dry climate, most foreign woody species introduced into Australia seem to thrive and adapt themselves well to the environment.

Without compromising the unique beauty of Australian native plants, they tend to be relatively short-lived and spindly in growth habit. Whilst being well-adapted to Australia's rather harsh conditions, "natives" are generally "poor performers", having great degrees of variability. This could be attributed to inbreeding.

Most Australian native trees are currently propagated from seed and possess self-incompatibility systems and partially or completely reject their own pollen. We are all aware that genetic diversity is needed to produce healthy vigorous progeny and research is currently underway into methods of strongly out-breeding Australian native trees to produce superior cultivars.

Despite eucalyptus trees constantly shedding their leaves year-round, Australian native plants are not deciduous and, therefore, do not have the striking brilliance of autumn colors. The gum tree is indeed at its striking best in the more natural surroundings of parklands, forests, and Australian bushland.

Australia also has the problem, and the tendency, of drought and bushfire and indeed many of the "native" species require fire to regenerate. Exotic woody species tend to "slow" a fire's progression and it is not unusual to see surrounding bushland devastated by fire with a home remaining unburnt surrounded by introduced foreign species.

Australia thus has the need to import exotic species and new and exciting foreign species are much sought after in Australia.

Because of Australia's geographic remoteness and freedom of many of the pests and diseases prevalent in other countries, Australian authorities are indeed most stringent in their quarantine laws.

INTRODUCING FOREIGN 'WOODY' SPECIES TO AUSTRALIA

After obtaining the necessary import permit, all nursery stock entering Australia must be approved and inspected by the Australian Quarantine Inspection Service (AQIS) where they are confined for a period, depending upon the genus, species, and degree of risk.

Plants usually fall into three risk categories:

High Risk—3 Years+ Confinement. Plants in this group are more likely to carry exotic pests and diseases and could ultimately affect important agricultural crops. Sometimes the confinement time can be reduced if the material has been obtained from an "approved" source, such as Prosser IR2, Washington (e.g.,*Pyrus* and*Malus*, as Australia is currently free of fireblight). All high-risk material is quarantined in

an AQIS post-entry nursery for the required time frame and indexing procedures.

Medium Risk—3 Months to 2 Years Confinement. Generally, this category covers ornamentals and bulbs and enters either the Australian Quarantine post-entry nursery or private screen house where they are examined for their potential to host any disease, such as Dutch Elm disease (*Ulmus* and *Prunus* as Australia is free of Dutch Elm disease and Plum Pox).

Low Risk—Subject to Certain Conditions, no Post-Entry Quarantine is Necessary. Plants that are not considered to host serious pests or diseases and includes tissue cultures of medium-risk plants and elite stock from high health accredited sources.

Quarantine costs can be quite expensive, especially with the high-risk-type imports, with costs ranging from A$900 to A$3500 if heat treatment is necessary. Australian Quarantine is operated on a "User Pays" system.

MARKETING TECHNIQUES IN AUSTRALIA

Promotion and marketing within Australia needs careful consideration because of the varying climatic conditions, especially areas where there is extreme heat stress levels. Overall, winters are relatively mild, especially when compared to those in the United States, and as a result Australia does not generally experience winter damage.

After Plant Breeders' Rights and/or trademarking protections are obtained, promotion and marketing takes place. Australia has two major national gardening magazines and two national television programs, as well as various leisure programs. Consumers, Australia-wide, can be inspired by wholesalers and retailers whose product is featured on the television programs, without the wholesaler or retailer incurring the prohibitive costs of direct advertising.

Likewise, the majority of the public can be reached by either advertising in the gardening magazines, or submitting editorials for publication.

Fleming's Nurseries have developed an extremely adept technique of marketing their product which encompasses the use of an extensive and informative private photographic library. This photographic library is invaluable for the following reasons:

- An up-to-date reference.
- Are an integral part of our catalogue.
- Sets our product apart from other products by way of an "exclusive", distinct, and informative label.
- Are the source behind our posters and other promotional material, such as the back cover of gardening magazines.
- Are available to garden centers for their own use.

Fleming's Nurseries have successfully marketed "public" cultivars by the unique approach of an "umbrella" trademark (e.g., Indian Summer™)—The Dream Tree series of "public" *Lagerstroemia*s from Washington Arboretum. These *Lagerstroemia* cultivars bear the names of American Indian nations and were marketed under this trademark, with outstanding success in Australia.

In addition to the above, in recent times, Fleming's Nurseries has adopted another approach to advertising, whereby we now advertise direct to the consumer, especially for the exclusively licensed species.

Fleming's approach includes:

- Posting brochures of current and future species available.
- Recommending a retailer selling "Fleming's" trees.
- Receiving orders from retail garden outlets.
- Sourcing a potential new retail outlet customer if the reader has supplied details of his preferred garden outlet.
- Retaining the end-consumers' names on a database list for future mail-outs of leaflets introducing new products.
- Creating a demand for the product.

CONCLUSION

Australia has often been called "the lucky country" and this applies especially to horticulture. Despite its harsh environment, introduced woody species generally adapt themselves very well.

Australia is indeed lucky in that it is a relatively young country, the population is increasing, and there is an abundance of room in which to spread and of course plant trees of significance. And, with the introduction of exotic species to our temperate regions, the Australian landscape is now being complemented by vibrant autumn coloring.

"The World of Propagation" Question-Answer Period

Bruce Briggs: We see and hear the recommendation to plant "natives". What are "natives"?

Bruce Macdonald: Perhaps we do go overboard sometimes when determining what is a native. Some plants we consider as natives are, in fact, exotics that have been grown for some time and gone wild.

Bruce Briggs: How do we change this concept so the whole public understands what is a good, healthy plant, and what should we plant?

Bruce Macdonald: Obviously, it's an education process which all of us (university, nursery, extension service) have to work on. When you have a movement for growing native plants, only natives are considered worth planting. Our experience with our native west coast plants is that few of them have been promoted, such as the *Penstemon* 'Purple Haze'. We introduced *Arctostaphylos uva-ursi* 'Vancouver Jade' which is a native but as soon as you put that in a climate with high summer temperatures the plant doesn't do well. A plant that is native to a particular area won't necessarily do well across North America. I think the gardening writers and mail order companies must realize that as well.

Dick Bir: I have a book on native plants on the market and I have been involved with programs that have existed in the east to draw attention to our native plants. What we need to do as horticulturists is get to the conferences and have the J.C. Raulston's, Mike Dirr's, and others speak to these conferences and let them know that criteria exist for quality plants in landscapes and understand between re-establishing a marsh and having a home landscape.

Denise Laycock: Can you propagate plants while they are in quarantine?

Fleming's approach includes:

- Posting brochures of current and future species available.
- Recommending a retailer selling "Fleming's" trees.
- Receiving orders from retail garden outlets.
- Sourcing a potential new retail outlet customer if the reader has supplied details of his preferred garden outlet.
- Retaining the end-consumers' names on a database list for future mail-outs of leaflets introducing new products.
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Denise Laycock: Can you propagate plants while they are in quarantine?

Rick Eggiman: Yes. But, you are required to hold onto the plant material that has been propagated until the end of the stock plant quarantine. As soon as your quarantined stock plants are released the vegetative propagation material will be released as well.

HortBase: A World-Wide Electronic Information System

James L. Green
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INTRODUCTION

HortBase is an innovative, peer-reviewed electronic information system for storage-distribution of horticultural information used in the classroom, in distance education, in life-long learning, and in commercial agricultural production. HortBase will retain the current roles and activities of: (1) Land Grant University agricultural production, communications, and library information science faculty who create and distribute information; (2) national professional societies, such as the American Society for Horticultural Science, who verify quality of information in their respective academic disciplines through peer review; and (3) national organizations such as the U.S.D.A. Cooperative State Research, Education, and Extension Service and National Agricultural Library who provide guidelines, standards, and support on a national level.

There are three innovative concepts in HortBase: (1) national peer review—HortBase includes national peer review of synthesized extension and educational information similar to current peer review applied primarily to reports of original research; (2) nationwide distribution of the workload and costs involved in creation, review/revision, and diffusion of the electronic information will result in the ability to do more than can be done independently by the individual faculty and individual states; and (3) HortBase calls for 3-dimensional team-creation of the electronic information files—a subject author, a communications specialist, and an information science faculty working together to outline and create the file.**The capabilities of the electronic information systems facilitate, indeed require, this new approach to information development and delivery.**

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Responsibility for creating "chunks" or files of specific, concise information on agricultural subjects can be distributed nationwide among production teams comprised of agricultural subject, communication, and library faculty at land grant universities. By centering the author, review, and information distribution network at the national/international academic societies and their members rather than at the individual universities, university and geographical boundaries can be transcended in forming virtual production and review teams— "dream teams". Production team members may be at diverse geographical locations, but work as a virtual team through electronic communication.

Nationwide distribution of the array of information topics to respective teams for their creation-maintenance for international access reduces the current redundancy of faculty in each county-state independently creating these extensive, wide-ranging information files for use solely within their respective states. National distribution of the workload could result in a 50 : 1 reduction in redundancy. The individual faculty will have more net time for assisting clientèle in identifying the "questions" and retrieving information from the HortBase that is specific to their needs. Rather than spending all their time scurrying around finding and transferring information, faculty will have more time to interact with the information users (students, extension clientele, etc). Faculty can become coaches. *"Teachers are coming out from behind their lecture podiums to interact more with their students.....deploying new high-tech tools to reach their students, ranging from using computers to help them visualize the abstract laws of physics to performing chemistry experiments on their computer screens. But as much fun as these new tools are to use,* ***they're no substitute for a faculty member's presence*****....."** (Gibbons, 1994).

The lines among information used in life-long learning, extension education, extended or distance education, and on-campus education are rapidly blurring as we become information synthesizers. According to Cetron and Owens (1994), " ... *individuals will learn more on their own, the "places" of learning will be more dispersed, and the age at which things are learned will depend on individual ability, not tradition. Education is becoming more individualized as interactive computer / videodisc systems and other new media permit students to learn according to their needs and abilities. Corporations now invest some $85 billion per year in employee education and retraining. That will double by 2001."* With "chunked and linked" electronic information in the HortBase, information retrieval and education is "inquiry-driven" by the interested learner.

Primary authors/reviewers of the publicly accessible HortBase files will be both extension and teaching faculty. Faculty will be both file creators and file users of nationally peer-reviewed, validated files, e.g., tissue-culture propagation of specific plants, etc. Information content will be current in the maintained files. Students and other users will access the electronic information system to explore special interests, to research assignments or for review. With quality horticultural instructional information readily available, the total quality of K-16, extended education, and life-long learning will be enhanced.

THE WORLD-WIDE HORTICULTURE INFORMATION SYSTEM

Creation, Revision, Update of Network Information Files.

Creation. Subject matter faculty are members of the file-creation team. Each individual subject matter faculty will assume primary responsibility to author and maintain a discrete, reasonable number of files on the national electronic information system. The author's national peers, say in New York and Georgia, would peer review the production information for completeness, accuracy, and geographical adaptations. However, because of the new and expanded characteristics of electronic information systems, the files will not be created by the subject matter faculty alone. The file-creation team will be a tri-member team: subject matter, communications, information management.

Communication faculty are co-creators. *"The hardest topics for me to get across are the things that I can see in my head that the students don't have a clue about,"* says chemist Nathan Lewis of the California Institute of Technology. *"We want to put those things on screen for them."* Lewis's efforts involve a team of communicators led by a Hollywood special effects producer. The 10-min videos show complex processes in 3-D; at the end of the $2 million project, *"You'll be able to watch atomic orbitals dance with Jurassic Park-style"* (Culotta, 1994). Communication faculty members of the team will assist in communicating the information to the target audience by selecting appropriate media, information sequence, electronic document design, . .

Library information science faculty specializing in electronic storage, search, retrieval, and distribution of electronic information are members of the file-creation teams. The files will be designed from the beginning to facilitate indexing, archiving,

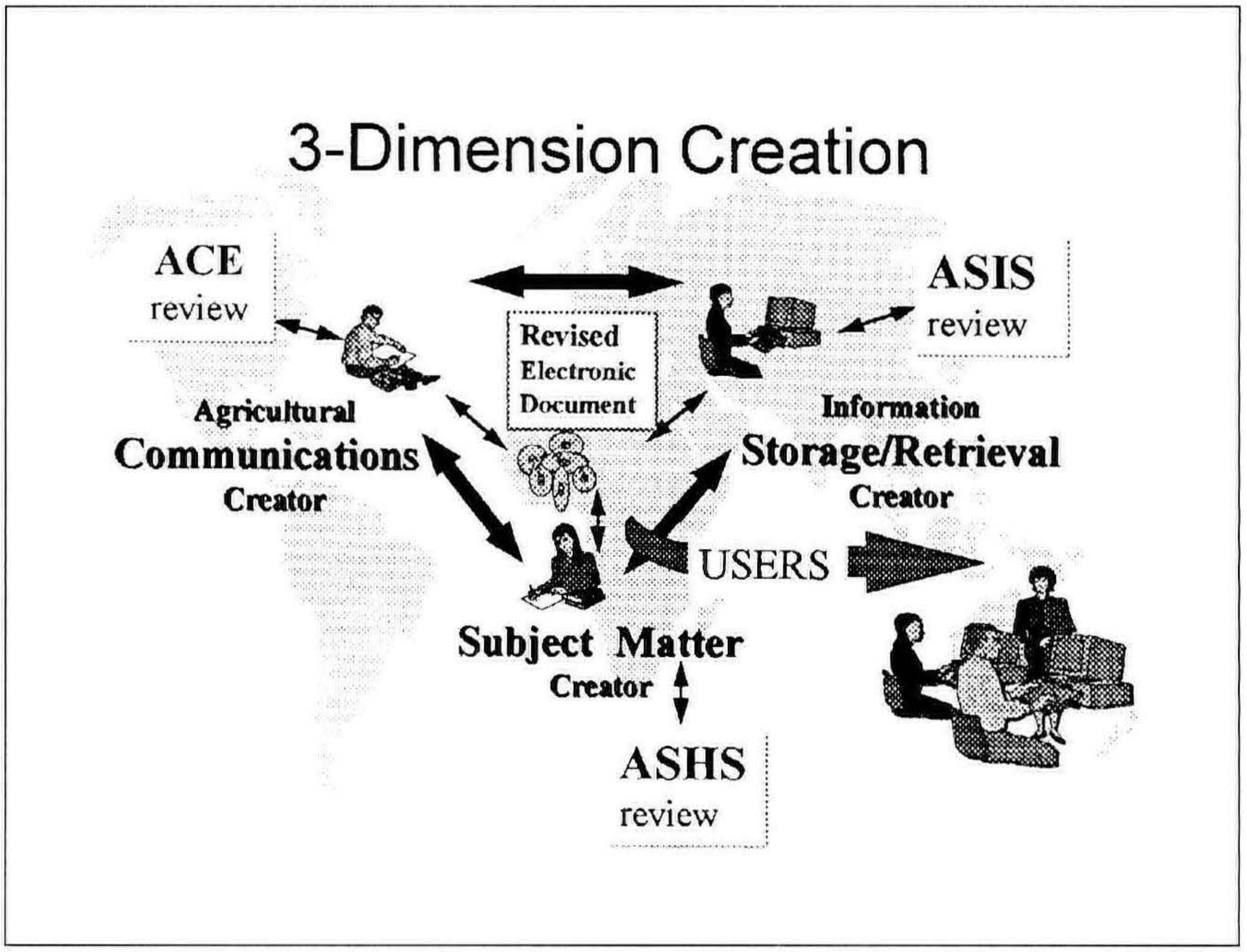

Figure 1. Creation, revision and update of network information files.

and distribution of the electronic information. Design is integrated from the beginning and throughout the information file creation as compared to cataloging, and possibly required redesign, of the completed subject document. Daniel E. Atkins, Dean of the School of Information and Library Studies at the University of Michigan, envisages *"the new librarian. . . will combine the skills of the computer scientist, the business graduate and even a little of the old-school librarian. . . to help make sense of the labyrinth of different information sources available on the Internet. You can waste 24 h a day browsing,"* (Stix, 1994). Rather than waiting until the labyrinth is out there, in HortBase the library faculty will be co-creating the files and making sense of the information files before they are on the World-Wide Web (WWW).

Concurrent, rather than sequential input into file development by the subject, library, and communication faculty will create a unified electronic publication. Subject authors will develop concise, easily indexed-retrieved "chunks" of specific information, rather than books, chapters, or paragraphs. Communication faculty will develop illustrations and document design to ensure information transfer. Library faculty will develop text-communication design to ensure rapid retrieval, searching, and distribution of the information file.

Because the information is in electronic form and readily transmitted on the WWW, national-international distribution and specialization can occur: The members of a file-creation team do not need to be at the same geographical location. "Virtual teams" can be formed with subject, communications, and information management team members at diverse geographical sites.

Review/Revision: *".....educators and publishers have started to worry about a time when the Internet might become clogged with programs that are mediocre or even worse, filled with inaccuracies"* (Service, 1994). Stix (1994) states, *"Some academics fear that the sheer volume of literature and a growing inability to distinguish the good from the bad in what gets published (on the Internet) may lead to an overall decline in standards."*

After team creation of the file by the subject matter, communication and library faculty, the file will be transmitted electronically to the team members' respective national societies for peer review of the subject matter (e.g., American Society for Horticultural Science), review of the communications aspects (e.g., Agricultural Communicators in Education), and for review of the information management facets (e.g., American Society for Information Sciences). National peer review will not only validate and maintain the credibility of the files, it will also serve as continued education, development, and peer recognition for the creators in their respective professional fields. To maintain creator, validator identification and support, specific information retrieved by client will include a 'TAGLINE':

Subj. Author_____, Comm. Author_____, Info. Syst. Author _____

Reviewed / Approved by (Academic Societies, e.g. ASHS, ACE, ASIS) on (date).
Revised files will be added to the HortBase network for public access.

Revision. Query-driven development of new files, continual revision-update of existing files and deletion of unused files will ensure a user-responsive system.

SUMMARY

HortBase will initially build and link "text" chunks of information for delivery via the Internet. The basic, essential information on a specific topic would be in the text chunks. The Internet is not yet the superhighway-size broad-band network needed to handle media-rich products, such as Microsoft's Encarta '95 (CD-ROM). But, we can start with the basic layer of "chunked text" information with the goal of later adding the media-rich layers of graphics, animation, sound.....to eventually achieve a full, multimedia information system as network technology evolves.

With the new technology, by forming alliances with the private sector and with the national societies and by nationwide distribution of the workload and costs of developing and maintaining a national electronic information service, we can do more with less!

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Plants Grow Children: A Master Gardener School Enrichment Program

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The Benton Franklin Master Gardener's Plants Grow Children program has grown like Jack's beanstalk since it began in 1988. Master Gardeners started teaching plant science to elementary school children in Benton and Franklin counties that year. The success of the program is evident in the over 51,000 children reached since 1988. They started out reaching 1291 children the first year. The 10,305 children participating in 1995 were from 439 classes and attended 34 different schools.

LESSONS

The Plants Grow Children program is targeted at kindergarten through 6th-grade levels. Elementary schools are given seven choices of lessons: the Miracle of the Seed for kindergarten level, the Mini-Greenhouse for 1st grade; the Fantastic Peanut for 2nd grade; Tree-mendous Trees for 3rd grade; Composting with Worms for 4th grade; Everyday Insects for 5th grade; and the Flower for 6th grade. Each lesson involves an action learning activity that yields a "product" to take home, such as a seed planted in a cup or an insect magnet the children make themselves.

In addition to the action learning activity product, each student also receives a handout to take home to her/his parents. The handouts explain the Plants Grow Children and Master Gardener programs, thereby increasing the awareness of WSU Cooperative Extension. The handouts also provide seed and plant culture information for the appropriate lessons. Spanish versions were made available in 1993.

PARTICIPATION

The highest participation is usually at the kindergarten, 1st, and 2nd-grade levels. Participation by grade level in 1995 was 1290 at the kindergarten level, 1412 at the 1st-grade level; 1568 at the 2nd-grade level, 1195 at the 3rd-grade level; 1559 at the 4th-grade level; and 1036 at the 5th and 6th-grade levels. The most popular classes have traditionally been the Miracle of the Seed, the Mini-Greenhouse and the Fantastic Peanut. Approximately 18% to 20% of the audience has been minorities each year.

EVALUATION

Classroom teachers consistently have positive reactions to the program and look forward to its return every year. More than 90% of those teachers returning evaluations every year indicate that the classes introduce new topics or reinforce previously taught material. Over 90% also rate the quality of instruction as excellent.

BENEFITS

The Plants Grow Children program does more than teach plant science and stimulate an interest in gardening. Classroom visits by Master Gardeners spread programming opportunities and extend awareness of WSU Cooperative Extension to potentially new audiences, especially minorities. At the same time, the classroom visits initiate a partnership between the classroom and WSU Cooperative Extension that's rewarding to students, Master Gardener volunteers, and teachers alike.

Another wonderful thing about the program is its adaptability for local clientele and special program needs. Various other counties and states have utilized the concept and modified the curriculum to fit their needs.

The program has received the 1989 Search for Excellence Award in Youth Programming from the National Association of County Agents, the Search for Excellence Award at the National Master Gardener Conference in 1989, and the Search for Excellence Award at the International Master Gardener Conference in 1993.

CONTACTING THE SCHOOLS

In late-February or early March, forms are sent to all local elementary and parochial school principals to see if they are interested in signing up for the program. If they are interested, they must sign an agreement form, indicating that they will pay 20¢ per child to cover the cost of the learning activity supplies. They sign up for the classes on a registration form that allows teachers to indicate which lesson is requested, the teacher's name, class size, and grade level. Each school designates an individual to be the contact person for scheduling the classes. This may be the principal, an office secretary, or a teacher. The deadline for forms to be returned is usually before the end of March.

UNIT LEADERS

Unit leaders are in charge of a specific lesson. They are responsible for organizing the volunteer teachers and assistants for that particular lesson. They determine when each volunteer is available to teach the classes and then they communicate this information to the volunteer doing the scheduling. Unit leaders are also responsible for assembling the needed supplies, parent letters, and evaluations needed by the volunteers who teach that lesson. Unit leaders may or may not teach, depending upon their preference.

ENLISTING THE MASTER GARDENER VOLUNTEERS

While schools are in the process of signing up for the lessons, the Master Gardeners are being asked to sign up as unit leaders, teachers, and teaching assistants for the lessons of their choice. We ask every volunteer who will be working with children to submit to a state patrol check of their criminal history and we ask for the names of two references who will indicate their suitability for working with children. Training by experienced Plants Grow Children teachers is provided. New teachers will often accompany experienced teachers to several classes before teaching the lesson by themselves.

SCHEDULING

Once the registration forms are received from the schools, they are entered into a database (FileMaker Pro) set up to keep track of the information for scheduling,

billing, and evaluation purposes. The needed information is collated and provided to the individual who is doing the scheduling. The scheduler calls the schools and schedules the classes. Once the classes are scheduled, this information is communicated to the volunteer teachers by the unit leaders. The unit leaders then assist the volunteer teachers in finding teaching assistants and make sure they have their class supplies when needed.

GETTING READY

Classes are taught primarily in April and May. Volunteer work parties are organized by the Cooperative Extension agent and the unit leaders to put together the materials needed for the action learning activities, such as filling cups with potting soil or stapling tree booklets together.

EVALUATION

Each volunteer teacher leaves an evaluation form at the end of class for the classroom teacher to fill out and return to the Extension office. This evaluation provides affirmative action data, information on performance, and any changes that are needed. As soon as all the classes are completed, the evaluation results are entered in the database. The numbers of students contacted are tallied and the schools are then billed. Contacts are reported to the university as part of their 4-H School Enrichment program.

In late-summer or fall, all those Master Gardeners who helped with the program, especially the unit leaders and the teachers, are invited to an evaluation meeting to assess how the program went and to discuss needed changes for the next year.

BILLING

Schools are billed on the basis of the actual number of students reached in the program. Schools are invoiced by the Benton-Franklin Master Gardener Foundation who co-sponsors the program. Bills are sent to the schools before the end of June and payment is received by the end of September.

This is a self-supporting program. Donations of seeds and other supplies are solicited every year, with donations defraying some of the costs of supplies. Donors are thanked and often provided pictures of the students benefiting from the program. They also receive a yearly report.

PROBLEMS MOST OFTEN ENCOUNTERED

- Principals who lose the registration form or who don't notify their teachers on a timely basis of its availability.
- Late registration forms.
- Last minute schedule changes at the schools.
- Getting the billing out before the schools dismiss for the year.

Sustainable Production of Cut Flowers

Paul Sansone and Susan Vosburg
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A sustainable system of cultivation is one that requires minimum inputs from off the farm and is not dependent upon synthetic fertilizers or pesticides to produce a marketable crop.

Serious consideration of sustainable systems for the cultivation of cut flowers is important to commercial success because of increasing environmental regulation and chemical costs. Every year more chemicals are banned from use in agriculture, especially those for minor crops such as specialty cut flowers. Chemical companies lack the economic justification for the registration necessary for the use of chemicals on minor crops. Environmental law is shifting the cost of cleaning up pollution from agricultural chemicals to the producers and users of these chemicals. More farms in the future will be burdened with the cost of removing agricultural chemicals found in soils, water tables, runoff, or spray drift. In addition, many pesticides become less effective over time as their intended targets develop resistance and immunity to these measures. Decreasing soil fertility and plant vitality are also symptoms of less than adequate cultivation methods.

BIODYNAMIC METHOD

The foundation of Biodynamic production of cut flowers is the growing of a healthy fertile soil. Through the cultivation of biologically rich soils the production of healthy and disease- free plants is made possible. The need for toxic controls is dramatically reduced.

The Biodynamic method concentrates on practices that increase biological diversity in the soil. Soil sterilization and the application of synthetic fungicides and pesticides are incompatible with the Biodynamic method. Biodynamics approaches the farm as a living organism that needs to be cultivated by the farmer for optimum soil health.

The Biodynamic method is the oldest sustainable system of agriculture practiced in the western world today. The principles on which it is based were introduced by Rudolf Steiner in Austria during the 1920s. The method was later refined in the United States by Dr. Pfeiffer. In the late 1960s and early 70s Alan Chadwick further developed the method into the Biodynamic French intensive method of horticulture. Chadwick established a research facility and demonstration farm and garden at the University of California in Santa Cruz. The Biodynamic French intensive method is labor intensive and developed for small acreages and operations functioning without mechanical equipment.

Here & Now Garden has adapted these methods of horticulture to commercial floriculture production. Improved technologies are available today for the application of the Biodynamic method. Modern agriculture has developed specialized

tractors and bed shaping equipment, mechanical mulchers, reusable polypropylene mulch, computerized drip irrigation, and mechanical spraying, and injection systems.

SOIL AND COVER CROPS

Production fields should have a soil analysis defining soil structure, humus content, and chemical nutrient levels. The optimum soil is a sandy loam soil that is well-drained and has a high humus content. Specific deficiencies can be corrected through altering the content of the organic plant food mix and additives to the Biodynamic compost.

The current weed population and surrounding field populations should be analyzed for development of a weed control program. Specific cover crops can be chosen to discourage or eliminate weeds. Spring/summer sowings of buckwheat followed by overwintering with annual rye/vetch will eliminate joint-grass and dramatically reduce morning glory (*Convolvulus*). Sudan grass produces incredible quantities of vegetative matter to aid in building soil humus levels. In addition, Sudan grass has an extensive fibrous root system that is very valuable in healing the damaging effects of improper cultivation practices like the digging or sowing of crops in wet soils.

Cover crops are an excellent means of preparing the soil of cut flower production fields. It is possible to get as many as five different rotations of cover crops in a single year. Other excellent cover crops are crimson clover, fava beans, oats, and alfalfa. Cover crops are generally tilled in at peak flower before seed is set in the plants. Crops are generally mowed or flailed and then tilled in. The value of the cover crop is greatly diminished by leaving the mowed vegetative material on top of the field too long.

A year in a cover crop rotation can significantly improve both soil structure and biological activity in the soil. The latter is important if the use of fungicides and pesticides is to be avoided. Substantial quantities of plant material incorporated into the soil by tilling in cover crops promote the growth of abundant microorganisms in the soil. These microorganisms are 99.9% beneficial to plants. Many microorganisms are natural predators to the fungus and bacterial diseases of cut flowers. Properly prepared compost applied annually to the field is important in maintaining soil fertility and increasing microbial activity.

It is useful to visualize the amount of plant material produced by the farm that is exported. These bunches of cut flowers leaving the farm require that an equal amount of composted plant material be returned to the soil if the production system is to be sustainable. The production and application of compost must equal the mass of plant material exported, or the soil is being "mined" of its nutrients for the crops sold. Unless this material is replaced soil will lose fertility, stable humus levels will decline, and cultural problems will increase.

The structure of the soil can be significantly improved by cover crops. The deep penetrating roots of some cover crops can shatter soil hard pans created by cultivation. The decomposed plant material tilled into the soil eventually becomes stable humus that improves the aeration and drainage of the soil thereby enhancing the nutrient-absorbing ability of the crops fine root hairs.

Cover crops should be tilled in before they dry out completely. The soil should be sprayed with a soil inoculant to speed the decomposition of the plant material and

establish beneficial soil microorganisms. Either the "Pfeiffer Field Spray" or BD Barrel Compost can be used. The time necessary for the soil to break down the vegetative matter can be reduced to as little as 2 to 3 weeks with these field sprays.

FERTILIZATION

Depending upon the requirements dictated from a soil analysis, generally the application of compost, manure, and organic plant fertilizer is necessary for optimum growth. Table 1 details the rate of application by soil fertility.

Perennial plants should be top-dressed each spring with 1/4 to 1/2 in. of ripened Biodynamic compost. Biodynamic compost is a specific kind of compost that requires 9 months to a year to break down and become fully stable for use. The specific compost most suited to cut flower production is the Pfeiffer recipe that is made from layering materials into a windrow pile 12 to 15 ft wide, 6 ft tall, and as long as is necessary to produce the quantity of compost necessary for production. This compost is comprised of dairy manure, soil, plant trimmings (from the fall clean-up), leaves or some highly carbonaceous plant material such as straw or spoiled hay. The materials are layered onto the pile to assure a carbon/nitrogen ratio of approximately 30 to 1. Soil additives are also incorporated into the compost to become stabilized for more efficient utilization by the plants. These additives are greensand, rock phosphate, oyster shell, and kelp. Approximately 50 lb of each additive is used per 25 tons of compost. The compost is treated with the six Biodynamic compost preparations to produce a balanced plant food and soil conditioner. The preparations are created through the controlled composting of specific herbs:

#502	Yarrow
#503	Chamomile
#504	Stinging nettle
#505	Oak bark
#506	Dandelion
#507	Valerian

This finished compost is rich in trace elements and the microflora necessary to produce a healthy soil capable of inhibiting fungus and viral diseases. An excellent description of making this compost is in Dr. E. Pfeiffer's book *Practical Guide to the Use of the Biodynamic Preparations*.

An organic plant food is banded into the bed where the cut flower plants will be planted when the bed is being shaped or it is worked into each planting hole for the plants as they are being planted. This balanced plant food is 4 parts seed meal, 1 part rock phosphate, 1/2 part kelp, and 1 part greensand. See Table 1 for an exact formulation to meet specific growing requirements.

TILLAGE

The intensive French Biodynamic method of horticulture includes an emphasis on deep cultivation and raised beds. Alan Chadwick observed that plants growing in land slides had increased growth. The tumbling action of a land slide produces an upper soil horizon with increased pore space between soil particles, better soil aeration, and increased root growth in plants. This resulted in increased production and plant vigor.

The intensive French Biodynamic method duplicates this environment with the double digging and raising of the plant beds. Raised beds increase plant growth and

flower production by increasing the area of the upper soil zone available for root growth. Mechanically produced raised beds can be constructed with tractor-mounted bedding equipment. In clay soils the intensive method calls for double-digging or deep non-soil horizon-mixing tilling of the soil. This can be accomplished mechanically with a articulating spader attachment on a tractor, such as the Celli spade cultivator. Here & Now Garden plants in 10 in.-high, 3 ft-wide raised beds.

PLANT SPACING

Most perennial cut flowers are planted 1.5 plants per lineal foot of bed in a matrix pattern. This gives each plant a 16-inch-diameter root zone. In perennial plantings this spacing produces a bed that is completely covered by the leaf canopy by the end of the second growing season. Most annual cut flowers are planted 2.5 plants per lineal foot of bed.

The utilization of matrix planting on raised beds significantly increases the number of plants that can be grown per acre. For example, in peony production, raised beds matrix planted result in 10,000 peony plants per acre compared to about 3000 plants per acre in row-cropped fields.

WEED CONTROL

The use of precision mulching in the cultivation of cut flowers seeks to reduce the area of the field available to weed growth through restriction of light to the soil. Woven polypropylene fabric is used to cover any field area not utilized by the plants.

Bed tops are covered with the most porous material available to allow adequate water and air to the soil. Soil will not turn anaerobic under woven polypropylene as it does under black plastic. The mulch must restrict light to weed seeds but allow the soil to breathe.

When the beds are formed the soil has been worked to a fine tilth and is weed-free. These beds are then covered with a highly porous, woven-polypropylene weed barrier. Plant holes 6-in. square are burned into the 3 ft-wide weed barrier arranged in the matrix pattern described earlier. The paths of the beds are covered with a U.V. inhibited woven polypropylene. This material is commonly used under containers in nurseries and can withstand tractor and foot traffic while allowing some air and water penetration.

The top of the bed is then mulched with a 1- to 2-in. layer of horse manure/wood shavings. This mulch is spread with a tractor mounted mulcher capable of mulching 4 or more acres of raised bed in a single day. The polypropylene weed barrier prevents weed germination on most of the bed, and the layer of horse bedding mulch smothers weeds in the uncovered planting holes. The perennial plants can easily break through this mulch and crowd out any weeds. The bed tops require weeding 3 to 4 times annually to remove small wind-borne weed seeds that attempt to establish in soil of the planting holes in the weed barrier. The amount of weeds that germinate in this area is small and two persons weeding by hand can clean a 2-acre field in a day. Weeds are eliminated using this method without herbicides.

The weed barrier remains on the bed for 2 to 3 seasons until the perennial plants establish themselves and the crowns begin to crowd the planting hole. By the third growing season the plants have established a heavy leaf canopy that will cover the entire bed and out compete most weeds. Depending upon the quality of the weed barrier purchased the useful life can exceed 10 years.

Table 1. General fertilizer program per crop per 100 square feet. (Assuming no soil test is performed. It is best to perform a soil test, especially for a garden of 500 square feet or more—see bottom of page.). (Printed with permission of Ecology Action, 2225 El Camino Real, Palo Alto, California 94306).

Functions	Sources (one for each function)	1st & 2nd year (Assuming poor soil)	3rd & 4th year (or 1st or 2nd year in average soil)	5th year (or 1st year good soil)	Maintenance (Every year thereafter[1])	Add to soil (Before or after double-dig)
Nitrogen*						
2.5%	Alfalfa meal	16.0 lb	10.5 lb	5.0 lb		After
12.0%	Blood meal[2]	3.5 lb	2.5 lb	1.25 lb		
9.75%	Fish meal	4.0 lb	2.25 lb	1.25 lb		
12.0%	Hoof & horn	3.5 lb	2.5 lb	1.25 lb		
7.2%	Soy meal	5.5 lb	3.5 lb	1.75 lb		
Phosphorus	Bone meal	4-5.0 lb	2.0 lb	2.0 lb	2.0 lb	After
	Phosphate rock	10.0 lb	5.0 lb	3.0 lb		
	Soft phosphate	10.0 lb	5.0 lb	3.0 lb		
Potash & trace minerals	Kelp meal[3]	1.0 lb	1.0 lb	1.0 lb	0.25 lb	After
	Wood ash[4]	2.0 lb	1.0 lb	1.0 lb	1.0 lb	
	Granite	10.0 lb	5.0 lb	3.0 lb		
Microbiotic life, humus, multiple nutrients	Compost[5] (or manure)	8.0 ft^3 (each crop[6])	8.0 ft^3	8.0 ft^3	8.0 ft^3	After, for best results[7]
Calcium	Eggshells[4]	2.0 lb	1.0 lb	as available up to ½ lb		After
	Oyster shell	2.0 lb	1.0 lb			

* Nitrogen = (% of protein) - 6.25. The first and second year amounts will provide 0.4 lb pure nitrogen per 100 ft^2.

[1] Beginning with the 6th year your legumes, compost crops, and recycled plant materials (in the form of compost) can provide most of your nitrogen, phosphorus, and potash. Double-check this periodically with a soil test.

[2] Do not plant for 2 weeks if using more than 3 lb blood meal per 100 ft^2. It can burn the plants during this time since it releases nitrogen rapidly at first.

[3] For trace minerals: kelp is up to 33% trace minerals.

[4] Save your own.

[5] Top priority in typical adobe soil. Breaks up clay, improves drainage, releases nutrients, and lowers pH.

[6] Eight cubic feet will cover 100 ft^2, 1 in. deep; 2 ft^3 will cover 100 ft^2, 1/4 in. deep. You can substitute manure for compost the first year if you do not have a ready supply of compost.

[7] Except for the first double-dig, when it is usually added before.

To revitalize an old lawn: Use 1.5 lb hoof and horn meal, 2 lb bone meal, and 1 lb kelp meal per 100 ft^2. Apply in spring and water well twice a week for 2 weeks. You should see results in 6 weeks.
Fruit trees: Use two heaping tablespoons alfalfa meal per foot of height, up to 2 lb of bone meal per full grown tree, and a light sprinkling of kelp meal (up to 1.4 lb per full-grown tree) around the drip line. Apply in spring when leaves first start to appear and water in well.
Citrus trees: Same as fruit trees with the addition of 5 to 8 lb phosphate rock to full-grown trees once every 3 to 5 years. Line the planting hole with crushed red rock for a long-lasting source of iron.
Soil testing service: Timberleaf, 5569 State Street, Albany, Ohio 45710.

Fields irrigated with a drip irrigation system will water only the planted area of the field and dramatically reduce weed growth in other areas. This can produce a significant reduction in weeding costs.

All tractor paths are sown in a permanent cover of perennial low-growing grasses and white clover. These paths are mown and the clippings collected for compost. A 2-ft-tilled swath is maintained around the sections of the production fields covered with polypropylene mulch. This prevents invasion of weeds by runners into the poly-mulched area.

FIELD HYGIENE

A field free of weeds will have less competition for water and plant nutrients. To avoid problems associated with monocropping, cut flower fields should be interspersed by species. If some crop diversity can be maintained on the farm and weed populations are kept in check, the incidence of viral diseases and pest infestations is dramatically reduced. At the end of the season all perennial plants are mowed down to the ground and this plant material is removed and composted. The beds are then top dressed with 1/4 to 1/2 in. of Biodynamic compost and then mulched with the 1 to 2 in. of horse bedding. This fall clean-up and top dressing is important for control of disease. Many future disease problems are eliminated by the removal and composting of potential pathogens. The application of finished compost (and plant food as necessary) increases soil microbial activity which inhibits remaining pathogens. The removal of weeds eliminates competing plants and possible hosts of more pathogens. As long as specific crops are kept in small units on a diversified farm, the field will not be a reservoir for the production of cut-flower specific pests.

WATERING

Cut flowers benefit from precise watering. Although many perennial cut flowers can be observed sustaining tremendous amounts of neglect around many old houses, the plants do produce more flowers and grow healthier with proper watering. The ideal watering system is one that allows both overhead and drip irrigation. The drier the foliage during the flowering season, the lower the incidence of fungal diseases and botrytis. Drip systems delivering water only to the roots are ideal. Overhead watering is an efficient way to foliar feed and apply prophylactic sprays to prevent botrytis and powdery mildew.

FUNGUS AND BOTRYTIS CONTROL

Fungus and viral infections are controlled first by proper soil cultivation and secondly by proper stimulation of plant growth. The extensive effort placed in soil preparation and compost application are to foster the development of plants that are naturally resistant to infection. The BD Field Spray 500 (composted horn manure) is used in early spring to stimulate healthy root growth. In the early summer BD spray 501 (quartz) is utilized to inhibit fungus and virus disease and stimulate leaf growth and plant vitality. Small quantities of these sprays are required for large areas. Four gallons will treat 2 acres.

It is unwise to overfeed cut flower plants with nitrogen. The resulting fleshy growth is highly susceptible to fungus and viral infections and more prone to insect predation.

Botrytis is of particular concern for many cut flowers in the Pacific Northwest.

Botrytis damage has been prevented by utilization of the Biodynamic method. Two efforts are required: enhancing the plants resistance to the incubation of the*Botrytis* spores, and encouraging microbial activity in the soil to draw fungal activity away from plant foliage.

The resistance of plant foliage to fungus and*Botrytis* infection can be increased by foliar feeding every 10 days during cold wetweather in early spring. The leaves of the plants are wetted with a foliar spray of kelp and BD preparation 508 (*Equisetum arvense*). One ounce of chopped dry equisetum is required to make about 4 gal of 508 tea which is sufficient for 2 acres of thick foliage. The 508 is diluted into 50 gal of the kelp/fish spray and applied at the same time. These sprays can also be injected into overhead irrigation for easy application.

Plants should be scouted daily for *Botrytis*. Infected plant parts are pruned, collected, and sent to the landfill. These prunings are not burned since*Botrytis* can spread in smoke. If botrytis erupts to a problem level despite these preventative measures, a copper sulfate spray can be used as a control method to limit the infestation to an economically acceptable level.

After the crop has died back for the season, all the plants are mowed to the ground and the dead plant material is composted in treated compost piles. This field sanitation is an important element in control of fungus diseases.

INSECT PEST CONTROL

Flea beetle (*Epitrix*, various species) and cucumber beetle (*Acalymma vittatum* or *Diabrotica undecimpunctata*) are the primary insect pests that can do extensive damage to the flower buds during formation. The beetles chew the edges of the flower or they bore into the bud slightly. Scouting of the field is necessary to determine if the beetle populations are reaching damaging levels. Long periods of warm weather can increase the beetles to levels where the damage affects the crop. One or two applications of pyrethrum or Rotenone sprays can reduce populations enough to harvest undamaged crops. Timing of these sprays is critical to their effectiveness. The most productive time to spray is early afternoon when beetle activity is highest. These control methods should be used sparingly because populations of beneficial insects are also reduced by these broad spectrum insecticides.

In a well-established Biodynamic operation high populations of beneficial insects often develop without artificial introduction. Parasitic enemies of cucumber beetles include a tachina fly,*Celatoria setosa*, a braconid wasp, *Syrrhizus diabroticae*, and a nematode,*Howardula benigna*. The most important predator of cucumber beetles is a soldier beetle, *Chauliognathus pennsylvanicus*.

Insect, disease, and weeds are visible symptoms challenging the grower to understand what part of the farm organism is weak or out of balance. Changes in cultural methods, elimination of habitat, introduction of biological controls, or specific application of biologically derived pesticides are all acceptable methods to maintain economic production and continue building a sustainable ecological growing operation.

RESOURCES

General information and publication list:

- Biodynamic Farming and Gardening Association, P.O. Box 550, Kimberton, Pennsylvania 19442 (215) 935-7797.

- Biodynamic preparations are commonly made by experienced Biodynamic farmers, or produced cooperatively by local Biodynamic groups. The preparations are available for purchase from: Josephine Porter Institute, P.O. Box 133, Woolwine, Virginia 24185. (The Institute is a non-profit service to encourage the use of Biodynamic preparations. They can accommodate small orders and have a subscription service to supply greater quantities on a scheduled basis for larger operations. Annual cost of preparations for a 10-acre farm is under $200.)

OTHER REFERENCES

- Jeavons, J. 1974. How to Grow More Vegetables. Ten Speed Press, P.O. Box 7123, Berkeley, California 94707. (This is an excellent primer on the Biodynamic French Intensive Method.)
- Woven Polypropylene: Dewitt Company, Highway 61 South, RR3 Box 338, Sikeston, Missouri 63801.

"The Future" Question-Answer Period

Casey Van Vloten: Did you have contracts already established with various locations or is it hit-and-miss in terms of demand for your product?

Paul Sansone: There are no contracts in the cut flower market, world-wide. You have a customer list that you FAX out availabilities to the night before and then either they call you or you call them and secure the sale in the morning. Everything is completely speculative.

Casey Van Vloten: Do you lose much with this system? Do you have to throw much away by guessing and missing?

Paul Sansone: I don't (knock on wood). We are very aggressive in our marketing and when we see a market go down we look elsewhere. This year, peonies would be a great example. Oregon peonies came on the market at the same time as those from New Jersey and the Great Lakes, which are the three major peony-producing areas in the United States. Normally, we are separated by over a two-month period, so the market was completely glutted. Another grower that I market with had $60,000 worth of product that he threw away and he's been growing for 20 years and had never had more than a couple thousand dollars of lost product. We contacted buyers in Japan and Hong Kong who we had not sold to before and we sold 25% of our production into those new markets. So, sometimes it's how quick you can move.

Kristin Yanker-Hansen: Have you ever considered developing your inoculants or are they available through Rodales for the home gardener? How does the cut flower industry get flowers out of the garden with so little insect damage?

Paul Sansone: The preparations themselves are available through the Biodynamic Association to retail people and the home gardener can buy enough to do a little pile in the backyard. On the commercial level, there's a Josephine Porter Institute that now has subscription services for nurseries and farms. They are dealing with farms as large as 2000 acres where they'll supply preparations and inoculants on a

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subscription basis. I supportthat organization although I make my own as well because I wanted to see them exist. So, for my nursery it's $200 per year for all the sprays and inoculants I need. It's very inexpensive and very easy to use. I hope to write, in the next year or so, a flow chart of when you do what according to the book and make it easier for people to get into doing it. Then, at that point you have to develop your own feel since every farm is different.

New Woody Plants from Tissue Culture

Lynne Caton
Briggs Nurseries, Inc., Olympia, Washington 98501

***Exochorda serratifolia* 'Northern Pearls'.** A University of Minnesota Landscape Arboretum introduction, which was selected from a seedling population from Beijing Botanic Garden, China. A spectacular display of pearl-shaped buds resembling a string of pearls, open to large, white flowers. Good flower effect and best used as a single specimen against an evergreen backdrop, or massed in the shrub border. Grows 6 to 8 ft tall and 4 to 6 ft wide at maturity, coarse texture, golden-yellow fall color with added winter interest from the persistant fruit which is a 5-valved capsule that changes from green to brown at maturity. 'Northern Pearls' is very hardy (-34F) Zone 4a, drought and heat tolerant, with no serious disease or pest problems. Propagation methods include softwood cuttings and tissue culture. As a member of the Rose family it can be cultured on Woody Plant Medium with BA.

***Sorbus hupehensis* 'Pink Pagoda'**. `Pink Pagoda' is a University of British Columbia introduction. The wild species is native to China, 'Pink Pagoda' is a selection from Gayborder Gardens in B.C. A deciduous tree growing to 30 ft, with blue-green compound leaves, red twigs and petioles, and white flower clusters in spring. The outstanding feature is the autumn and winter color of the fruit that turn pink by late summer and change to white in mid winter. Foliage turns orange to red in the fall. Use as a specimen tree, or in groups along highways. Good for retail container sales as fruits form early in the production cycle. This cultivar is hardy to Zone 5. Propagation by budding or grafting on rootstocks of *Sorbus aucuparia* or grown on its own roots from tissue culture. A member of the rose family it's tissue cultured on Woody Plant Medium with BA.

***Aronia melanocarpa* 'Autumn Magic'**. A University of British Columbia introduction the species of which is native to the East Coast. A small, deciduous shrub with glossy-green foliage that turns a brilliant red and purple in the fall. Fragrant hawthorn-like white flowers appear in spring followed by lustrous black fruits (they are edible but bitter). 'Autumn Magic' is hardy to Zone 3 and its extreme hardiness and pest-free reputation make it an excellent choice for nursery production. It grows to 4 ft and suckers profusely so it can be used as a hedge plant, and is most effective when it's massed. Might be a good choice for a highway plant as it adapts well to many soil types. Propagation by softwood cuttings and tissue culture. A member of the rose family it grows well in culture on Woody Plant Medium and BA.

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***Rosa* 'Jan's Wedding'.** A Neil Adams' hybrid of *R.* 'Dornroschen' × *R.* 'Lichtknigin Lucia' with blooms of yellow, pink, and apricot which are born in huge clusters. Flowers are 2 to 3 in. wide, well-formed, and repeat throughout the summer. Landscape value as a specimen plant or in the shrub border. Hardy to at least -10F, Zone 5 to 9. 'Jan's Wedding' is propagated by softwood cuttings or tissue culture using Woody Plant Medium with BA.

***Syringa* × *laciniata* (cutleaf lilac).** This species is native to Turkestan and China and is an outstanding species. The lacy, fine-textured foliage is an unusual asset and quite striking. Small, pale lilac, fragrant flowers appear in May, born in 3-in.-long, loose panicles all along the stem. This very floriferous shrub lilac grows to 6 to 8 ft high and as wide. Hardy to at least Zone 4 to 8, this plant displays excellent heat tolerance, undemanding culture, and is free of pests. A member of the olive family this plant can be propagated by softwood cuttings or tissue culture. We culture on a Murashige and Skoog media with BA used in combination with 2iP.

***Halesia monticola* f. rosea.** The species is native to wooded slopes and streambanks of the south east coast. This form is a rare and choice pink form of the mountain silverbell. The pale pink bell-shaped flowers hang gracefully in clusters from the branches in April to early May. *Halesia monticola* f. rosea is best used in shrub and woodland borders set off by an evergreen background, it is used well as a companion to rhododendrons as it prefers acid soil. It grows into a large tree (to 50 ft) with a broad, rounded crown. Exceptionally pest resistant, it is hardy to Zone 4 to 8. Fall color is yellow-green. A member of the Styrax family it can be propagated by softwood cuttings and tissue culture. We tissue culture it on Woody Plant Medium with BA.

***Oxydendrum arboreum* 'Chameleon'.** 'Chameleon' is a selection made by Polly Hill. Sourwood is native to the east coast and is an all-season ornamental tree. Good plant habit, grows to 50 ft tall, a pyramidal tree with a rounded top and drooping branches. Flowers are white and urn-shaped (much like *Pieris*) blooming in June to July and practically covering the foliage. Flowers are followed by a brown dehiscent capsule persisting throughout the winter. Foliage is a lustrous dark-green changing to a combination of rich reds, purples, and yellows in fall, all on the same tree. 'Chameleon' should be used as a specimen tree in the landscape. Hardy to Zone 5 to 9. It can be propagated by softwood cuttings and tissue culture. A member of the Ericaceae family is can be micropropagated on Woody Plant Media with 2iP or Zeatin.

Finland Rhododendrons. Briggs Nursery is now growing seven selections from the breeding program at the University of Helsinki, Finland. These new rhododendrons have been developed by Peter Tigerstedt based on hardy material that had been naturally selected at the Mustilia Arboretum. The goal was to create winter-hardy cultivars that could tolerate temperatures below -31F. These hardy rhododendrons are recommended for landscape purposes, especially for USDA Zone 1 to 4. They grow well in containers under normal cultural practices for rhododendrons. As members of the Ericaceae family they can be propagated by cuttings, grafting, or tissue culture. We culture them on Woody Plant Medium with 2iP.

***Rhododendron* 'Peter Tigerstedt' (*R. brachycarpum* ssp. *tigerstedtii* × *R. catawbiense* `Album').** 'Peter Tigerstedt' has decorative, pure white flowers with

blood-red spotting in the upper corolla and curly margins. A vigorous, upright, and spreading plant it grows to 6 ft. Rhododendron hardiness rating of H1.

***Rhododendron* 'Haaga' (*R. brachycarpum* ssp. *tigerstedtii* × *R.* 'Doctor H.C. Dresselhuys').** The profuse flowers on 'Haaga' are pink. The plant habit is a well-branched and rounded. A vigorous plant growing to 5 to 7 ft. Rhododedron hardiness rating is H1.

Azalea 'Lemon Lights'. A new introduction from the University of Minnesota. Part of the Northern Lights series of hardy deciduous azaleas. 'Lemon Lights' comes from the same cross as 'Golden Lights' and 'Northern Hi-Lights' and was selected for its good yellow color and floriferous habit. Flowers appear in May and cover the shurb. Plants grow to 6 to 7 ft tall and wide, demonstrate good mildew resistance, and are hardy to -40F. Propagation is by cuttings or tissue culture, and like other members of the Ericaceae family we micropropagate it on Woody Plant Medium with 2iP or zeatin.

Desirable Characteristics of Propagation Media

Michelle L. Oliveira
Black Gold Inc., 19308 Hwy 99E, Hubbard, Oregon 97032

INTRODUCTION

The field of soilless media is undergoing a rapid technological change and I would like to examine our current use of media components and look ahead to the new possibilities for propagation media. We will focus on the physical, chemical, and biological characteristics of each medium component so you may have a clear understanding of why a particular blend of raw materials may work for your crops.

The propagation medium has three functions: (1) To hold the seedling or cutting in place during the rooting period, (2) To provide moisture for the cutting, and (3) To permit diffusion of air to the base of the cutting (Hartmann and Kester, 1990). In looking at a propagation medium for either seedlings or cuttings, we are usually seeking the proper blend of air porosity and water-holding capacity. If a grower is using a mist system to keep the relative humidity of the air around cuttings high, the medium must have a higher air-filled porosity. Indeed, many of the propagation manuals that specify an air-filled porosity of 15% to 20% were written for mist propagation systems (Handreck and Black, 1994. With the advent of fog systems and the subsequent effect of less water reaching the leaves, a higher moisture content may be desirable for maximum rooting. Seedlings require different degrees of air porosity and water retention depending on the size of the seed and the type of mist system or growth chamber used for germination. In addition to the physical characteristics, a grower needs to know the chemical nature of the media. More recently, emphasis has been on the biological characteristics of growing medium components. Keeping your own system in mind as we proceed, let's examine these characteristics of the most commonly used propagation medium components.

INORGANIC COMPONENTS

Sand was one of the first materials to be used in propagation due to its ready availability and low cost (Table 1). Sand is usually used in conjunction with other

blood-red spotting in the upper corolla and curly margins. A vigorous, upright, and spreading plant it grows to 6 ft. Rhododendron hardiness rating of H1.

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The propagation medium has three functions: (1) To hold the seedling or cutting in place during the rooting period, (2) To provide moisture for the cutting, and (3) To permit diffusion of air to the base of the cutting (Hartmann and Kester, 1990). In looking at a propagation medium for either seedlings or cuttings, we are usually seeking the proper blend of air porosity and water-holding capacity. If a grower is using a mist system to keep the relative humidity of the air around cuttings high, the medium must have a higher air-filled porosity. Indeed, many of the propagation manuals that specify an air-filled porosity of 15% to 20% were written for mist propagation systems (Handreck and Black, 1994. With the advent of fog systems and the subsequent effect of less water reaching the leaves, a higher moisture content may be desirable for maximum rooting. Seedlings require different degrees of air porosity and water retention depending on the size of the seed and the type of mist system or growth chamber used for germination. In addition to the physical characteristics, a grower needs to know the chemical nature of the media. More recently, emphasis has been on the biological characteristics of growing medium components. Keeping your own system in mind as we proceed, let's examine these characteristics of the most commonly used propagation medium components.

INORGANIC COMPONENTS

Sand was one of the first materials to be used in propagation due to its ready availability and low cost (Table 1). Sand is usually used in conjunction with other

organic components such as peat moss to increase the available water in the root zone. Although sand is defined by the U.S.D.A. system of soil classification as having a particle size of 0.05 to 2.0 mm, those in the medium to very coarse size ranges are preferable (0.25 to 2.0 mm) (Hartmann and Kester, 1990). The air-filled porosity percentage will depend on the size and shape of the sand particles. With a bulk density in the range of 1.3 g ml^{-1} sand does an excellent job of holding the cuttings in place during rooting. A neutral pH and low mineral nutrients are typical. Occasionally, a sand may be contaminated with calcium carbonate and can raise the pH of the medium (Landis et. al., 1990). We have also found that river sand which is commonly available in the Northwest can be contaminated with agricultural chemicals. In some instances, we have found low pathogen levels as well.

Perlite is perhaps the most commonly used aggregate component in rooting media today. It is an alumino-silicate mineral that is mined and then popped at high temperatures. Perlite has a closed cell structure that repels water and, therefore, is used to increase air porosity in a mix (Landis et al., 1990). It has a very low bulk density of 0.20 g ml^{-1} and is available in several particle sizes. The most common propagation grade of perlite has particles in the 3.0- to 3.2-mm size range, a water-holding capacity of 19% and an air-filled porosity of around 53%. There is also a very fine-textured grade commonly used for seedling mixes. One of the largest drawbacks to perlite is the tendency to crush if handled roughly or frequently. Once crushed, its ability to provide aeration is greatly reduced and the fines may actually clog a mix. Due to the low water retention of perlite, it is commonly mixed with peat moss, bark, or compost. A study carried out by Tilt and Bilderback (1987) showed a peat moss and perlite (1 : 1, v/v)blend had a total porosity of 85%, a water-holding capacity of 56% and air space of 29%. Due to the high temperatures during processing, perlite is sterile and it contains almost no plant nutrients. The cation exchange capacity (CEC) of perlite is very low and the pH is around 7.0.

Table 1. Comparison of inorganic components.

Component	pH	Bulk density	WHC	AFP
Sand	7.0	1.3	26%	10%
Perlite	7.0	0.2	19%	53%
Pumice	7.0	1.1	25%	30%
Vermiculite	7.0-7.5	0.11-0.15	39-52%	30-40%
Rockwool	6.0-6.2	N/A	60%	20%

WHC- water holding capacity
AFP- air-filled porosity
Bulk density is in g ml^{-1} on a dry weight basis.

Pumice, a volcanic rock mined in central Oregon and throughout the western U.S., is used regionally as a perlite replacement. It has a bulk density of 1.1 g ml^{-1} with air porosity between 30% to 34% and water-holding capacity of 25% to 26%. Pumice dries out faster than perlite due to the greater number of macropores. Watering practices must be adjusted if the grower is accustomed to using perlite in the

propagation mix and is changing to pumice. Pumice has the advantage of costing half as much as perlite in the regions where it is readily available. It comes in many grades and screenings suitable for nursery mixes. We find that for most nursery mixes a 3/8 in. screening without fines is the best all purpose grade. For rooting of cuttings, many nurseries prefer to keep the fines or "flour" in the pumice. The pH of pumice is in the neutral range, the CEC is very low and the rock is chemically inert. We have not found any evidence of pathogens or chemical contaminants in the years we have tested pumice at our plant. Being a volcanic rock, it is very stable and does not crush. However, it is heavier than perlite and when wet may be too heavy for many workers to handle. Growers have found that a peat moss and pumice (1 : 1, v/v) blend is an effective propagation mix for cuttings and a common planting mix consists of equal parts of bark, peat moss and pumice (1 : 1 : 1, by volume).

Vermiculite is another inorganic component frequently used for propagation blends, but has some significantly different properties. Vermiculite is an aluminum-magnesium-iron-silicate mineral, currently mined in Africa, Brazil, China, and some regions of the United States, and consists of thin plate-like sheets. It is expanded under temperatures up to 1000C that forces the mineral into a sponge-like structure with numerous pores. It is lightweight with a bulk density in the range of 0.11 to 0.15 g ml^{-1} (Landis et. al., 1990). The sponge structure creates a high water-holding capacity in the range of 39% to 52% depending on the grade or coarseness of the mineral. Air porosity varies between 30% and 40%. The plates contain many cation binding sites producing a high CEC. Vermiculite is sterile due to the high processing temperatures. It supplies magnesium and some potassium to a mix as it breaks down (Handreck and Black, 1994) and the pH is around neutral. The particles are physically unstable when wet and crush easily. In addition, it is more *expensive than any other raw material and the supply has been erratic in recent* years. However, if a grower wants a mix that is inherently sterile, a blend of perlite and vermiculite is the first choice.

Rockwool, widely used in Europe, has not met with wide acceptance in the Northwest although it is used by growers on the East Coast. Rockwool can be hydrophobic or hydrophilic and is usually blended to give a proper ratio of both types. Grodania manufactures a rockwool with 60% water-holding capacity and 20% air-filled porosity. The pH is slightly below neutral in the 6.0 to 6.2 range and the rockwool is sterile (Barletta, 1992).

ORGANIC COMPONENTS

The most common organic component (Table 2) used in propagation mixes is Canadian sphagnum peat moss. It is available in several grades with the majority of growers using a single-screened moss, typically referred to in the trade as "grower's grade". However, there is wide variation in the particle size from one producer to the next and even from one bale to the next. The distinctive and desirable features of sphagnum peat moss include a large amount of internal pore space capable of holding water and nutrients and a high buffering capacity to withstand rapid changes in pH and a low bulk density. The pH of sphagnum moss ranges from 3.0 to 4.0 which helps to balance the higher pH of inorganic components. Water-holding capacity is 50% to 60% by volume and air porosity is 25% to 30% (Conover and Poole, 1977). Peat moss is typically low in plant nutrients. Our tests have shown significant levels of beneficial microorganisms of *Trichoderma* and fluorescent

pseudomonads. Both have been suggested as antagonistic to certain root rots. Peat moss is familiar to most U.S. growers and the majority have adapted their nutrient and watering systems to a peat-based medium. When mixed with inorganic components, peat moss can aid in water and nutrient retention for cuttings or seedlings and possibly provide suppressive activity to root-rot development. Several drawbacks exist, however, including the hydrophobic nature of peat moss. This is usually overcome by adding a wetting agent. Additionally, peat bogs are environmentally sensitive and considerable pressure is being mounted to reduce or modify harvesting of the peat. Consequently, the price and availability may fluctuate in coming years.

In the 1970s and 80s, a group of researchers across the country looked at possible alternatives to peat. Some of the results of those studies were composted bark—pine, fir, and redwood. They found that under proper composting conditions, the finished bark was high in beneficial microorganisms that were naturally suppressive of root rots (Bilderback, 1992; Thomas, 1993). Since that time, many growers have incorporated bark into their growing or propagation media. Properly composted, bark has a pH in the range of 4.0 to 6.5 depending on the source. Water holding capacity can vary from 15% to 40%, depending on the degree of composting and the amount of fine particles. Air porosity will also vary for the same reason and may range from 30% to 50%. It is possible to buy composted bark from a wide number of suppliers in the U.S. Be certain to ask about their composting procedures and ask for a nutrient analysis and compost maturity test before trying it on your cuttings and plants. Possible phytotoxicity may occur with barks due to the monoterpenes present in some bark (Landis et al., 1990).

Table 2. Comparison of organic components.

Component	pH	Bulk density	WHC	AFP	CEC
Peat moss	3.0-4.0	0.03-0.14	50-60%	25-30%	100-120
Composted bark	4.0-6.5	0.25-0.30	15-40%	30-50%	140-210
Composts	6.0-8.0	0.20-0.40	varies	varies	varies
Coir fiber	5.3-6.4	0.16-0.25	60-70%	25-30%	95-100
Worm castings	6.5-8.0	0.55-0.60	50-60%	10-12%	N/A

WHC- water-holding capacity.
AFP- air-filled porosity.
Bulk density is in g ml^{-1} on a dry weight basis.
CEC is expressed as meq/100g.

Compost is one of the newer components on the market for use in growing media and quality can vary considerably. It may range from yard trimmings to municipal sewage sludge. National standards are not in place fully so this is a "buyer beware" situation. Know what the source of the compost was, the degree of compost maturity, and the available nutrients. Some composts are high in soluble salts while others can be low in all nutrients. In addition, ask for pathogen and environmental toxin tests. While composts may be used for growing media, it is not advisable at this time

to use them for propagation media without extensive testing in your nursery and consultation with your county extension agent.

Coir fiber is another recent introduction into the U.S. nursery industry. It has been used extensively in Australia and Europe in greenhouse and nursery operations. Coir fiber is the byproduct from the mesocarp of a coconut. After the long fibers are extracted for use in mattresses, brooms and other products, the finer particles are left behind and this is the part being used as a horticultural substrate. Coir has excellent physical properties. It does not repel water like peat moss and holds more water than many sphagnum peats due to its finer pore structure (Dyke, 1994). The pH of coir is somewhat higher than peat moss ranging from 5.3 to 6.4. However, the CEC is similar to peat. Total pore space is as high as 96% with large pores accounting for 16% which allows for good drainage (Handreck and Black, 1994) and bulk density falls between 0.16 to 0.25 g ml^{-1}. There is less overall shrinkage compared to bark or peat. If a grower decides to use coir in place of another organic component, remember to adjust watering practices or use less coir than one would use of peat moss. Additionally, coir requires more nitrogen initially due to the drawdown of nitrogen for microbial activity. No information is currently available on levels of beneficial microorganisms in coir. Due to the importation of the product from southeast Asia, it is at least as expensive as peat moss and, in some cases, more expensive.

The final organic component to look at today is earthworm castings. Worm castings arise from a process called vermicomposting and are becoming increasingly available as worms are used to process waste products. Castings have a relatively high pH from 6.5 to 8.0 and higher levels of potassium, calcium, and magnesium than peat moss or bark. They are biologically active with bacteria, actinomycetes, and fungi (Grapelli et. al., 1985). Grapelli et. al. (1985) looked at castings in propagation media. They pointed out that biological components, such as gibberellins, cytokinins, and auxins known to promote rooting, were present in worm castings. They found that castings greatly favored rooting percentages and the amount of root biomass (Grapelli et. al., 1985). Our company has always used wormcastings as a component in our retail mixes and our own studies have shown increased root and shoot growth in mixes with castings included. Ongoing studies at the U.S.D.A.-Agricultural Research Center in Corvallis, Oregon with castings suggest suppressive action against root rots (Linderman, 1995, personal communication). We have found the dense nature of castings limits their use to no more than 20% of a propagation medium.

The proper blend of media components will be specific to your propagation needs. Seedlings, cuttings and liner stock will all differ in their requirements for water-holding capacity and air porosity. The physical characteristics of the medium are critical to the future success of a plant's health, but, consider as well, the chemical and biological aspects. I predict that future media will be as carefully constructed for their biological properties as current media are for porosity. For those of you mixing your own media, I hope this will give you new insights into possible alternatives. For those growers purchasing propagation media already premixed, this should show you some of the future raw materials to look for from your supplier.

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How to Use Biological Control to Manage Propagation Pests

Robin L. Rosetta
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INTRODUCTION

Biological control is the suppression of pest populations by their natural enemies. This, of course, occurs naturally in our environment. It is quite a "bug eat bug" world out there. How do we utilize this occurrence to our benefit in our pest management programs? In order to successfully implement a biological control program in propagation systems, the pest management professional will need to hit the books. Applied biological control or 'biocontrol' is an information-intensive science and art. The science requires an intimate familiarity of both the pests and their natural enemies. The art of biocontrol is taking this information and transforming it into a practical and economical program suitable for a specific nursery location. In order to do this, biological control should be viewed in the broader context of integrated pest management (IPM).

IPM is a pest management strategy using multiple tactics to suppress a pest population below damaging levels. An IPM program includes several important aspects: pest identification, regular monitoring, action thresholds, and integrated

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IPM is a pest management strategy using multiple tactics to suppress a pest population below damaging levels. An IPM program includes several important aspects: pest identification, regular monitoring, action thresholds, and integrated

control tactics. Integrated controls include various tactics: cultural, physical, chemical, and biological.

GETTING STARTED

As with any new technique or skill, it is best to start small—limit the risk. Select one range, or crop, or even a few benches for your first attempt. If you're not currently monitoring, this is the first place to start. Dedicate time to scouting. It is too easy to skip the plant scouting when production is busy. Keep records. There is a wealth of information gained this way including cultivar sensitivity, timing of infestation, presence of beneficial organisms, and effectiveness of control measures. Scouting helps you to correct problems early increasing control options, such as spot applications, choice of lower toxicity chemicals, and problem elimination by roguing or pruning infested plants.

Correct pest identification is very important in biological control. Many natural enemies, especially the insect parasites, are very specialized. It may be necessary to identify the pest to the species level in order to choose the correct biological control agent. There are several good publications available (listed in the reference section) that will aid in identifying pests. County and state extension personnel and state nursery inspectors can facilitate pest identification as well.

Once the scouting program is well developed, begin eliminating pesticides that could impact the biocontrol agents you plan to release. In general, avoid long-residual, broad-spectrum insecticides such as pyrethroids. Explore the use of 'biorational' pesticides, such as insecticidal soap, horticultural oil, and botanical insecticides, e.g. neem products. Although many of these pesticides may be harmful to beneficials upon direct contact, they have limited residual activity, allowing beneficial agents to move into sprayed areas with minimal harmful impact. Of course, this applies to pests as well. Therefore, repeat applications may be necessary. There is limited information concerning pesticide compatibility with natural enemies. There are some charts available from insectaries, such as Applied Bionomics, the largest insectary in North America, or in the *Green Methods Catalog* from The Green Spot, a distributor for many insectaries.

After establishing a monitoring program and eliminating potentially harmful pesticide residues, the stage is set for implementation of biological control. Now the fun really begins. It is time to choose the biological control agent(s) for your pest complex.

TYPES OF BIOLOGICAL CONTROL AGENTS

There are three broad categories of biological control agents consisting of predators, parasites, and pathogens. Predators generally consume many insect or mite prey during their lifetime. They may be predatory as juveniles, or as adults, or both. Many are quite large such as lady beetles. They tend to move very quickly (a helpful trait if you must chase your dinner). Parasites, also known as parasitoids, are insect parasites of other insects. They lay their egg(s) on or inside another insect host. The egg then hatches and the larva consumes its host. Usually only one host is necessary for development of a parasitoid larva. The adult parasitoid continues the cycle. Many of the available parasitoids are very tiny wasps with extraordinary abilities to search out their hosts. Pathogens are the third category of biocontrol agents. Insect pathogens include fungi, bacteria, viruses, microsporidians, and parasitic nema-

todes. Most are applied as sprays or drenches and may have explicit requirements regarding humidity, temperature, or soil moisture. The most familiar pathogen to most growers is the bacteria, *Bacillus thuringiensis* var. *kurstaki*. This bacteria has a toxin that is released in the alkaline midgut of lepidopteran pests. There is a lot of interest in this area and quite a few new products are available or under development. The EPA is working to "fast-track" these pesticide registrations.

RELEASE STRATEGIES

There are three general release strategies in biological control: classical biological control, inoculative releases, and inundative releases. Classical biological control entails the importation and permanent establishment of natural enemies. This is usually conducted by state and federal agencies. A good example of this is the successful establishment of the parasite *Encarsia partenopea* for control of ash whitefly, *Siphoninus phillyreae*, in California. Inoculative releases consist of small releases of the natural enemy usually when pest populations are quite small. The desired end is that the introduced natural enemies will establish and reproduce, leaving the biocontrol agents and their progeny to suppress pest outbreaks. An example of this is the inoculation of the soil-dwelling predatory mite, *Hypoaspis miles*, onto greenhouse floors to suppress populations of fungus gnats. Inundative releases involve releases of large numbers of natural enemies to control a pest population as it nears damaging levels. This strategy is similar to our current pesticidal approach of chemical applications to control outbreaks. The application of Bt, *B. thuringiensis*, is an example of this type of release. The idea is to saturate susceptible plant material with the bacterial spores so they may be eaten by the pests. Repeated applications or releases are common. The large numbers of natural enemies and repeat applications may be expensive. In general, inundative releases are the least cost-efficient of the release methods.

SPECIFIC PEST CONTROL PROGRAMS

The following are some recommendations of biological control agents for several key propagation pests. The lists are not all inclusive and may change as more suitable candidates are discovered. Insectaries, like any other businesses, change their inventories as the market demands. Quality control varies greatly as do prices. It pays to shop around. *Suppliers of Beneficial Organisms in North America* is a very useful publication aptly described by its title. It is available for free from the California Department of Pesticide Regulation.

FUNGUS GNATS

Fungus gnats are small dipteran pests familiar to many who use yellow sticky cards in their monitoring program. The adults are generally considered nuisance pests. The larvae may cause direct damage and are implicated in the transmission of soil borne diseases, such as *Pythium* and *Fusarium*. Fungus gnats have several natural enemies including the predatory mite, *Hypoaspis miles*; parasitic nematodes, *Steinernema carpocapsae, S. feltiae, Heterorhabditis bacteriophora;* and the pathogen, *Bacillus thuringiensis* var. *israelensis*.

APHIDS

Aphids are key propagation pests due to their ability to cause direct damage, indirect damage in the form of honeydew and its associated black sooty mold, and their fast generation time. The most commonly encountered aphids in greenhouses tend to be the green peach aphid, *Myzus persicae*, and the cotton or melon aphid, *Aphis gossypii*. Biological control of aphids might include the parasitoids *Aphidius matricariae, A. colemani*, *Diaeretiella rapae;* the predatory midge, *Aphidoletes aphidimyza,* green lacewings *Chrysoperla carnea* or *C. rufilabris*, the predatory ladybug, *Hippodamia convergens,* and the pathogen *Beauveria bassiani.*

SCALE

Scale often occurs on cuttings from mother plants. There are two types of scale seen in propagation situations: hard scale and soft scale. Soft scale tends to be larger and produces honeydew while hard scale tends to be flatter and does not produce the honeydew. A good pictorial key is available from the California Department of Food and Agriculture. Natural enemies of scale include the predatory ladybugs*Rhyzobius lophanthae* and *Chilocorus nigritus*, and the parasitoid, *Metaphycus helvolus*.

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Cuttings, Clippings, and Miscellany

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Beginning in my youth with rose cuttings stuck under mason jars placed beneath large spreading junipers through a 5-year tour at Denver Botanic Gardens (DBG) where 1000-2000 species were regularly propagated each year, the propagation of plants has been an integral part of my studies, my avocation, and vocation.

Throughout the often unusual nature of these endeavors it became apparent, in retrospect, that plant propagation in the isolated Rocky Mountains was as different as its horticulture and that the progression of the best in horticulture in the Rocky Mountain region can be ascribed to a "can do" attitude when presented with an "it can't be done" project.

Every propagator here worth his/her salt has tried to root cuttings of the local *Juniperus communis* ssp. *alpina* (common juniper) to no avail, though most have succeeded in keeping the massively callused cuttings alive for over a year in a mist bed. One grower even resorted to force feeding the fruits to starved chickens in hopes that the resultant droppings might yield a few viable seedlings. Nearly everyone has given up on the ridiculous information often repeated in texts regarding the successful germination of *Arctostaphylos uva-ursi* (kinnikinnick) after burning pine duff atop a sown flat.

Ipomoea leptophylla (bush morning glory) "can't be grown from seed" unless you realize that recently harvested seed must first be after-ripened or subjected to scarification or a hot water treatment. *Eritrichium aretioides* (alpine forget-me-not) "can't be grown at all" until you realize that highly aerated soils and cool growing conditions are all that is needed. Success with the latter garnered me a lavishly appointed trip to speak to the American Rock Garden Society in Delaware where members were treated to several discourses on how attention to soil aeration could solve many of their specialized plant growing problems. Especially intriguing to them was learning that "sharp sand", a highly regarded soil amending substance, was decidedly inferior to spherically shaped sand.

Similarly, a renowned grower of these distinctive small plants was enlightened on how to grow the infamous *Erigeron chrysopsidis* var. *brevifolius* (Wallowa yellow fleabane), a species that had previously defied pot culture and one which this grower had resorted to growing in pure Turface. Attention to soil aeration means that one can grow all cactus in a peat-perlite soil mix and that getting *Echinocereus viridiflorus* (green hedgehog) to bloom in less than 9 months from sowing is no big deal.

The three broad-leaved evergreen manzanita (*Arctostaphylos*) species native to Colorado have been exploited to no avail, due, undoubtedly, to the lack of experience in propagating rhododendrons which generally do not perform well here. Local propagators still fail to comprehend the absolute need for sanitation in all growing matters and the need for highly aerated container soils. Treating the cuttings (the seed germinates no better than kinnikinnick) like they were the easily propagated privets or willows simply does not work well. The latest excuse for failing so miserably in rooting their cuttings is the discovery of the unique root mycorrhizae

associated with native stands. Unfortunately, even when soil from these stands is mixed with the cuttings, results are the same.

Castilleja (paintbrushes) is assigned to the "you can't grow them" society as well because they are "parasites" and they must parasitize sagebrushes (*Artemisia*). Actually, paintbrushes are hemi-parasitic plants which means they have the ability to germinate, grow, and reproduce without the benefit of another plant anywhere near them. Some species will parasitize sagebrushes (and probably any other plant as well) and, apparently, give up the ability to live on their own soon after. The "secrets" of their growth includes first noting their seed is surrounded by a reticulated network of dry material that inhibits water getting to the seed. Simply rubbing between thumb and palm rids the seed of this coating. While some species must first be moist-chilled for a period before sowing, others germinate without difficulty. Seedlings are tiny and unusually subject to damping-off diseases. Again, sanitation is the key to surmounting this. Copious light (24 h, if possible) and a regime of heavy fertilization with each watering will get the seedlings to the transplant stage with no problems. They can be transplanted singly or in twos since there is some evidence that they will parasitize each other, each benefitting from the experience.

Toys have played an important part in propagating new, unusual, or important plants. High-intensity discharge (HID) lamps, capable of producing 10,000 fc of illumination ran constantly at DBG as I learned that manzanitas grown beneath them could produce easily rooted cuttings in a matter of a few weeks and that *Mimulus lewisii* (Lewis monkey flower) could be grown seed to seed in less than 60 days. The hybridization potential of the latter is enormous. Increased branching, vastly hastened growth that was retained even after removal from beneath the lamps, and the vision of plants growing beneath them at night when all else was dark and quiet are but a few of the benefits that should endear their use to all growers.

Photoperiod lamps designed to run continuously during night hours or regulated to be "on" from only 10PM to 2PM allowed me to grow temperate-zoned woody plants during winter when merely increasing greenhouse temperatures was not enough. Aspens (*Populus tremuloides*) grown to 12 ft tall and *Juglans microcarpa* (littlenut walnut), among many others, were landscape ready the following spring from seeding.

If you can't see, taste, and feel it, then it can't have any effect on your plants—right? Wrong. Carbon dioxide generated inside the greenhouse during months when vents are closed has a dramatic effect on plant growth. What else would explain the growth and blooming of *Caesalpinia gilliesii* (Mexican bird of paradise) in 6 to 9 months from seed? Numerous papers have reported the gains to be realized from these generators but so few plant growers utilize them. Why?

Unorthodox tools and toys come in handy too. What implement would you use to propagate *Trifolium repens* 'Atropurpureum' (purple four-leaf clover) that was currently outside beneath 6 in. of snow and the air temperature was -20F? Why, a pick, of course. Armed with a map of its location in the garden, a section of it was picked out of the ground, thawed in the greenhouse, propagated via cuttings, and ready for display 3 weeks later.

Fraxinus anomala (single-leaf ash) in the one literature source found states that its seed is "impossible" to germinate. Actually, it germinates with ease after 3 months of moist-chilling and further, it was found that semi-hardwood cuttings of

2- to 3-month-old seedlings rooted with even greater ease. Unlike the seedlings' roots that are problematically taprooted, cutting roots are horizontal, branched, and much more attuned to pot culture. Clues to the possible success of this venture and its potential benefits to the vegetative propagation of ashes in general were derived from a master Japanese gardener who regularly rooted pine seedlings for eventual use in shallow bonsai pots.

The Mexican phloxes (*Phlox nana* ssp. *ensifolia* [syn. *P. mesoleuca*]) hit Denver in a very big way with their sprawling habit and large fluorescent blossoms. Unfortunately, the "impossible-to-root" label stuck to them meant that only specialists who managed to root a few could charge over $6.00 for each 2-1/4-in. pot success. Putting my toys to work, it soon was possible to root them by the thousands by growing stock plants under H.I.D. lamps and CO_2 continuously, fertilizing them constantly,and taking only very short cuttings of soft stems. Cuttings could be taken from cuttings, that rooted almost 100% in 2 to 3 weeks, each 3- to 4-week period after transplanting. Even leaf pieces rooted, though these did not form entire plants.

Where, in conclusion, would I recommend that a student apply his or her newly acquired skills? Botanic gardens are potentially extraordinary places to get your feet wet. Long before you learn that propagating, growing and studying plants is not their bottom line, you will be exposed quickly to a very large number of species and probably be working in areas where no one else knows how to really measure your productivity, efficiency, or knowledge—this is your time to learn and play.

Using Physiological and Anatomical Studies to Optimize the Environment for Rooting Cuttings

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INTRODUCTION

Landis (1993) grouped environmental factors affecting plant propagation into two groups: atmospheric and edaphic. The atmospheric environmental factors include: light, temperature, carbon dioxide, relative humidity, pathogens, insect pests, weeds, and cryptogams. The edaphic environmental factors include: water, mineral nutrients, pathogens, and insect and other pests. The biological agents in the environment may also be beneficial, such as mycorrhizae, root growth-promoting rhizobacteria, and biological-control agents.

If anatomical and morphological events are used to describe the process of adventitious root formation, then rooting occurs in four general stages: (1) dedifferentiation, (2) root initial formation, (3) root primordia formation, and (4) elongation of primordia leading to root system growth and development (Hartmann et al., 1990). Others have described rooting in two stages based on visible root morphology: root initiation (before roots are visible) and root development (after roots are visible). The optimum environment may be different for each stage of adventitious root formation. Physiological indicators of stress may be useful in determining the optimal environmental conditions for each stage of adventitious root formation.

Various physiological responses of cuttings appear to be linked to the anatomical developmental stages of adventitious root formation. Using photosynthetic rates as an example, studies of cuttings from various herbaceous and woody species have shown the coordination of a sudden increase in photosynthetic rates with the development of root primordia or visible root emergence (Davis, 1988; Davis and Potter, 1981; Feldman et al., 1989; Smalley et al., 1991; Svenson et al., 1995; von Schaesberg et al., 1993). Most of these same studies found a gradually declining photosynthetic rate until roots had formed (Davis, 1988; Davis and Potter, 1981; Feldman et al., 1989; Smalley et al., 1991), unless low light levels were used (Svenson et al., 1995). The declining rates of photosynthesis may be an indicator of accumulating stress on the photosynthetic mechanism, suggesting that the propagation light environment is not optimal. Reduced photosynthetic rates prior to root formation may also be related to leaf-water relations (Loach, 1988; Rein et al., 1991), hormone physiology (Smalley et al., 1991), or source-sink physiology (Feldman et al. 1989). Veierskov (1993) reported that *Hibiscus* cuttings root better when provided with a light intensity just above the light compensation point until roots begin to emerge, using higher light intensity to support root growth.

Similar physiological/anatomical links have been shown for stomatal conductance (Gay and Loach, 1977; Smalley et al., 1991; Svenson et al., 1995), transpiration (Smalley et al., 1991; von Schaesberg et al., 1993), leaf water potentials (Grange and Loach, 1985; Rein et al., 1991; Smalley et al., 1991), auxin sensitivity (Gaspar and Hofinger, 1988), and various other physiological responses. In general, cutting

physiological responses to the various stages of adventitious root formation suggest that at least two different environments are needed for optimal rooting of cuttings. Changes in mineral nutrient concentrations may also be linked to the anatomical development stages of adventitious roots (Blazich, 1988; Svenson and Davies, 1995).

The rooting response to heat (temperature) has also been linked to root initiation and development. For optimal root formation and subsequent root growth, Dykeman (1976) noted that the root formation stages have a different optimum temperature than the root growth stage. Dykeman proposed shifting the temperature regime during rooting, using higher temperatures for root initiation and formation, and cooler temperatures for subsequent root growth. Shifting the temperature environment supported the earliest rooting, the largest number of roots formed, and the highest root fresh weight of *Dendranthema* 'Bright Golden Princess Anne'.

Assuming that declining photosynthetic rates during the root formation stage (dedifferentiation, root initial formation, and root primordia formation) indicates that the photosynthetic system is under stress, then lower light levels may be required during this stage. Combining this observation with the observations for temperature reported by Dykeman, then the root formation stages should have lower light and higher temperatures, while the primordia elongation and root growth stage should have higher light and lower temperatures. This hypothesis was tested using poinsettia cuttings.

MATERIALS AND METHODS

Unrooted 'Lilo' poinsettia cuttings were obtained from a commercial vendor (shipped overnight). Basal stems of individual cuttings were stuck 1 in. into a blend of fully moistened sphagnum peat and perlite (1 : 1, v:v) contained in 2 1/4-inch rose pots. All cuttings were placed under mist pulsing at 5 sec every 10 min in a fiberglass-covered greenhouse with air temperatures set at 82/70F (day/night). Eight treatments were prepared using 73% shade cloth spread 3 ft above one end of a 6-ft wide by 40-ft-long mist bench and bottom-heat pads under half the mist bench (lengthwise). The design provided high (4000 fc) and low (1100 fc) light areas with or without bottom heat (78F substrate heated; 70F unheated). Treatments were: (1) low light and no bottom heat (low light control), (2) low light with bottom heat, (3) low light with bottom heat shifted to high light without bottom heat, (4) low light with bottom heat shifted to low light without bottom heat, (5) high light and no bottom heat (high light control), (6) high light with bottom heat, (7) high light with bottom heat shifted to low light without bottom heat, (8) high light with bottom heat shifted to high light without bottom heat. Sixty cuttings were used for each treatment. For shifting environments, cuttings were relocated to the appropriate location on the propagation bench after 8 days. After 16 days, mist was turned off. Use of movable screens would facilitate the shift in light environments for a commercial propagation system that would otherwise provide only one light level.

Ten cuttings within each treatment were randomly sampled 10, 12, 16, and 20 days after the cuttings were inserted into the medium, and the percentage of rooted cuttings was recorded. After 20 days, unsampled rooted cuttings were transplanted into 4-in. pots filled with the same substrate. Plants were grown on the same bench under 4000 fc of light (same air temperatures, no mist), and were fertilized daily with 150 ppm N using a commercial 20N-8P-16K liquid fertilizer. Ten plants were sampled 5 and 10 days after transplanting.

RESULTS AND DISCUSSION

All cuttings had rooted by day 20; however, percentage rooting differed among treatments before Day 20 (Table 1a). On Day 10 for both light levels, cuttings provided with a cool substrate had not rooted, but cuttings provided with a warm substrate had at least 10% rooting. On Day 12, cuttings provided with a warm-shifted-to-cool substrate had the highest rooting percentages, with cuttings provided low light having slightly higher rooting than cuttings given higher light. Cuttings provided with low-shifted-to-high light and warm-shifted-to-cool substrate had the highest percentage of rooted cuttings on Days 10, 12, and 16.

If cuttings provided high light and a cool or warm substrate are compared with cuttings provided low light, the cuttings given low light had higher percentages of rooting on Day 12, but not after Day 12. This appears to indicate that using lower light levels during the root formation stage helps the cuttings root faster, but may not necessarily increase the percentage of cuttings that will root.

In general, shifting poinsettia cuttings from a low to a high light level upon formation of root primordia supported faster rooting than use of low or high light throughout the rooting process. Increased rooting using lower light is consistent with the responses reported for*Hibiscus* (Veierskov, 1993; Grange and Loach, 1985), *Forsythia* (Grange and Loach, 1985), and *Mangifera* (von Schaesberg et al., 1993), and with recommendations of Loach (1988). Studies showing better rooting using higher light intensities (Moe and Anderson, 1988) may have measured growth responses related primarily to the primordia elongation and root growth stage. Shifting cuttings from a warm to a cooler substrate also supported faster rooting than use of cool or warm substrate throughout the rooting process. This response is consistent with the response for chrysanthemum reported by Dykeman (1976), and with recommendations of Preece, (1993). It may be important to use a warm substrate without using increased air temperatures to avoid carbohydrate losses from excessive respiration.

The influence of the rooting environment on the subsequent growth of rooted cuttings has not been extensively studied. Light and temperature manipulation during rooting influenced subsequent growth of rooted poinsettia cuttings (Table 1b). Rooted cuttings sampled at transplanting had similar shoot dry weights for all treatments. Cuttings rooted using low-shifted-to-high light, and warm-shifted-to-cooler substrate, had more shoot dry weight 5 and 10 days after transplanting. Using high substrate temperatures throughout the rooting process produced cuttings with less shoot weight 5 and 10 days after transplanting, compared to cuttings rooted with cool substrate or shifted from warm to cool substrate. For poinsettias, the beneficial effects of shifting the light environment and shifting the temperature environment acted synergistically, helping cuttings root faster and supporting faster growth after transplanting.

The ability to use lower light levels during the root formation stages would be helpful when using no-mist propagation systems such as fog or ultrasonic humidification systems. Lower light levels may be especially helpful with subirrigation propagation systems which have been shown to be superior to mist for rooting some cultivars, such as 'Franks Red' maples (Zhang and Graves, 1995).

The difficulty in implementing complicated controls when rooting cuttings on a large scale is the equipment cost associated with the different environmental needs of different species. More than one or two different environmental regimes may be

Table 1. Percentage rooting (a) and shoot dry weight after transplanting (b) for 'Lilo' poinsettia cuttings in response to shifting light and temperature environments during rooting. Root primordia formation began on Day 8.

(a) Percentage rooting

Light quantity (fc)		Temperature (F)		Rooted[1] (%)		
Day 1	Day 8	Day 1	Day 8	Day 10	Day 12	Day 16
4000	4000	70	70	0	20	80
4000	4000	78	78	10	40	80
4000	4000	78	70	10	60	90
4000	1100	78	70	10	60	80
1100	1100	70	70	0	40	80
1100	1100	78	78	10	60	80
1100	1100	78	70	10	70	90
1100	4000	78	70	20	80	100

[1] All cuttings were rooted by day 20.

(b) Shoot dry weight after transplanting

Light Quantity (fc)		Temperature (F)		Shoot dry weight (grams) Days after transplanting[1]	
Day 1	Day 8	Day 1	Day 8	5 days	10 days
4000	4000	70	70	1.0 d	1.7 c
4000	4000	78	78	0.8 e	1.6 cd
4000	4000	78	70	1.2 c	1.9 b
4000	1100	78	70	1.0 d	1.7 c
1100	1100	70	70	1.1 cd	1.7 c
1100	1100	78	78	0.9 de	1.5 d
1100	1100	78	70	1.3 bc	2.0 b
1100	4000	78	70	1.6 a	2.2 a

[1]There were no differences in shoot dry weight at transplanting; means within columns separated by Duncan's Multiple Range Test.

difficult for a propagator rooting a wide range of species under the same propagation system. When facilities provide an option, propagators may be able to enhance rooting by using cool air temperatures, warm rooting-substrate temperatures, and low light levels during the root formation stages, followed by cool rooting-substrate temperatures and higher light levels to support rapid root primordia elongation and root growth.

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"Propagation Practices" Question-Answer Period

Mona Meyers: I have a question for Jim Borland and Sven Svenson. As I understand it, light intensity during root formation during your respective studies seem to be at odds. One of you is advocating low light intensities and the other using HID lighting. Could you both comment on this? Is HID lighting that different from the lighting Sven Svenson is referring to?

Jim Borland: Actually, I was using that lighting for growing-on seedlings for the most part or for cuttings that were rooted.

Sven Svenson: The light intensity requirements for cuttings changes depending on the stage of root formation or development. There is a stage where higher light is required when roots are beginning to emerge from the cutting. I'm suggesting at the beginning is where lower light intensities may be beneficial. The quality of artificial lighting may be sufficiently different from shaded-natural lighting to warrant further study.

Anonymous: Can you comment further on the smoke treatments you briefly mentioned?

Martin Grantham: The first published paper was from Hannes Delonge on the Bruniaceae. They piped smoke into tented chambers containing whole flats of seeds. This treatment greatly increased germination. At this point they have chosen one particular feinbas shrub, *Paserina vulgaris*, to burn. They've also made connections with companies making "liquid smoke" to try and isolate the active ingredients.

Mike Babineau: A question for Sven Svenson. We have trouble with cuttings forming callus, but no roots. Did your research touch on that at all? Do you have anything to add whether the temperature or light affects that?

Sven Svenson: One of the species we worked with, *Photinia*, has a tendency to do that. On occasion the cutting will have a mass of callus on the base the size of a softball with no roots formed. We had some indication that soil temperature may play a role in this, but it's not a consistent response. It may have something to do with the physiological state of the cutting as it comes off the stock plant.

Mike Dyke: I want to add a few comments. First, on alternatives to peat. In Europe, there's pressure to reduce the use of peat. We have had very good results using coir fiber. On the aspects of biocontrol, very few nurseries in the U.K. are using biocontrol. However, those who are have used 15 to 20 predators. Once you start down the route of biocontrol you need to keep moving the times to keep ahead of the pests that come in. Finally, on the aspects of the environment for the rooting of cuttings, recent work at East Malling in the U.K. has suggested that combinations of low or high light levels combined with dry or wetness on the leaf can have huge effects on the rooting ability of various plants. A general guideline is the smaller the leaf the higher the light levels and the dryer the leaf likes to be.

Challenges Faced by an Arboretum Propagator

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To understand the challenges faced by the arboretum propagator, one must understand what an arboretum is and the mission it serves. Once this is understood, it will be clear that the propagation undertaken by an arboretum propagator is driven by very different goals than those of the commercial propagator. The goals that follow the mission are only part of the equation. Other challenges arise with the aging or maturing of the collections within the arboretum. This presentation will address the specific challenges I've faced as propagator at the Washington Park Arboretum, located in the city of Seattle.

BACKGROUND/DEFINITON

The Washington Park Arboretum, is located on a 200-acre site. The first plantings occurred in 1936, bringing many members of the collection to nearly 50 years old today. By definition, an arboretum is a living museum of woody plants for education, conservation, research, and display. For the Washington Park Arboretum, specifically, the mission is to utilize woody plant material that is suitable for the Pacific Northwest in fulfilling these goals. Of these mission goals, conservation or preservation of the living collections offers the greatest challenge to the propagator.

HOW IS PROPAGATION CHALLENGED IN THE ARBORETUM?

Preservation of Genetic Diversity. There are approximately 5000 different plants in the Arboretum collection. To maintain the strength and integrity of these collections new plants are acquired each year. For assurance of its identity as well as its origin, plant material is obtained from well-documented sources, whenever possible. And "wild-collected" seed from native populations is the primary choice.

Most new material is received as seed from the *Index Seminum*, a public garden, free-seed exchange program. Many taxa are obtained from exotic locations, such as South America, Asia, New Zealand,and Europe. Due to the fact that many of the taxa are uncommon, little or no information is written in the literature pertaining to the species sent. Therefore, propagation treatments are done mostly by trial and error, based upon whatever information might be found at the genera level.

Seed sent from the *Index* can vary widely as well. Some seed is fresh and well-identified and becomes a good performer. Other seed, however, is old (at least 2 years) and the quantity small (3 to 5 seeds per packet). This leaves little to no room for testing the seed and different treatment lots are greatly restricted.

The wide range of plant material that is handled is a challenge in propagation. The plant production program handles about 250 new seed accessions per year. When seed numbers permit, a range of treatments are tried on seeds where no information on propagation is found. Once germinated, seedlings are grown on in a fairly standard, uniform manner, unless specific information is found concerning the cultural requirements of the plant.

Preservation of the Collection. Conservation of the existing mature collections is focused primarily on one-of-a-kind, wild-collected accessions. Of these plants, those being suppressed by native plant growth or not thriving for some other reason are high on the list for renewal. Natural disasters (the winter storm of 1989-90 and the wind storm of 1991) as well as vandalism play a minor part.

Today in the Washington Park Arboretum, there exists a dominant native canopy of trees, consisting mostly of big-leaf maple and western red cedar. This suppressing overstory simply out competes many of the collection plants, limiting their growth or deforming their shape. There is also an old field nursery in existence that was planted more than 10 years ago. Most of the nursery "stock" is too large to move without a tree spade (and then, too difficult to get to), or else, it is too deformed from the close spacing of old nursery rows to make good collection specimens.

These conditions dictate a long list of collection plants in need of repropagation. Seed from these plants is usually out of the question, since it has most likely been hybridized by other plants in the surrounding area. Vegetative propagation is the preferred method, but not always a simple solution.

METHODS USED TO MEET THE CHALLENGE

The maturity of the specimens and the fact that most are also in a stressed state produce very little good vegetative parts for repropagation. Cuttings are tried on a scheduled basis according to time of year. If a plant is particularly difficult to root, extreme measures may be taken to reproduce it. Severe pruning measures are taken to induce new growth, if possible. This allows for more juvenile material to come on. If this method fails, or if this practice is too drastic, then other methods may be attempted.

Air-layering has been tried on *Poliothyrsis sinensis* , a deciduous tree from China, with success. For difficult-to-root evergreen oaks and magnolias, velcro strips and rooting hormone were applied to terminals during the growing season. Root nodules resulted and one magnolia rooted as a result; although, this practice was not very successful.

When all of these measures fail, a nursery specialist may be employed to propagate by grafting, as was done this past year with the Japanese Maple collection. As a final measure, when all attempts for repropagation fail, new plant material is obtained either via the *Index Seminum* or from a reputable nursery source.

THE ROLE OF RECORD KEEPING

Detailed records of all propagation activities are kept on BG-base, a botanical garden database widely used by public gardens throughout the U.S. as well as in parts of Europe.

Accession details, including information in regards to source are integrated between the arboretum records office and the plant production program, located at the Union Bay site of the Center for Urban Horticulture. The propagation records include details on treatments given, environmental conditions used, as well as the end results. These files are used for future reference in the plant production program itself as well as for reference to others who make inquiries on how to propagate these unfamiliar species.

ALTERNATE STRATEGIES

Role of the Nursery Manager. For the Washington Park Arboretum, plant distribution serves as a means of getting plant material off-site and into the market, as well as insuring the ongoing existence of the plants. Plant materials not readily available through the trade are distributed to commercial nursery managers upon formal request. A distribution program of surplus plants from the nursery are made available to various units of our support group, the Arboretum Foundation, as well as to other public institutions in the Seattle area. Information is kept on the materials sent out, in order that future reference can be made, in the case that all original plant material is lost from our collection. Arboretum policy allows for seeds or cuttings to be exchanged with sister institutions at no charge; whereas, nursery managers are asked to make a donation to help defray the costs of handling and shipping. The barter system has proven to be useful as well, wherein a nursery exchanges plants that are desired by us, in lieu of payment.

Networking. The challenges faced by the arboretum propagator can seem formidable at times. But, perhaps, life will become simpler in the future. Possibly, more associations between public institution and private industry will occur. These relationships may become more creative and could prove worthwhile for both sides.

Today, there are more native plant propagators/restoration ecologists who are striving to achieve the same goals of gene preservation as the arboretum propagator. Shared information on propagation techniques may work to benefit both.

New, improved ways of communication (World-Wide Web, bulletin boards, newsgroups, etc., located on the Internet) will make networking easier and faster. The isolated propagator, who works out of his greenhouse alone could become as extinct as the dinosaur.

Certainly, meetings of professional propagators involved in all types of propagation can open the door for new information to be exchanged and new ideas of methodology and networking to occur.

In conclusion, the challenges of propagation for the arboretum propagator are sometimes great and difficult to solve. Instead of profit-motive and high production yields, preservation of genetic diversity and location of new wild-collected sources become the main concern. For all of us who work in an arboretum, however, there is satisfaction gained in witnessing the renewal of old and the introduction of new plants into the garden. Seeing these results, makes meeting the challenges of propagation in an arboretum worthwhile and charges us up for the next round to come.

Rewriting of *Seeds of Woody Plants in the United States*

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INTRODUCTION

A team of scientists from the U.S.D.A. Forest Service is currently rewriting the classic publication, *Seeds of Woody Plants in the United States*. Originally published in 1974, Agriculture Handbook 450 (AH-450) replaced the older "Woody Plant Seed Manual" which had been out of print for many years (Table 1). The AH-450 handbook has long been the primary reference for foresters and horticulturists on the collecting, cleaning, testing, and storing of woody plant seeds. Nursery managers also use the popular reference for information on seed propagation. Unfortunately, although it has been reprinted five times, AH-450 is currently unavailable.

To fill this void, Timber Press published *Seeds of Woody Plants in North America* in 1992 (Table 1). Because there are no copyrights on government publications, the authors borrowed heavily from AH-450, but added 200 new genera and 1000 new literature citations. The vast majority of the new additions are native to Asia or are ornamentals, however, and most rate only a short paragraph or two. Another limitation is that the technical references for the majority of genera important to forestry, such as *Pinus*, *Picea*, and *Eucalyptus*, were not updated from that given in AH-450 (Bonner, 1993). Nevertheless, *Seeds of Woody Plants in North America* remains the best source of technical information for seed dealers and nursery managers growing forest and conservation species from seed.

FORMAT FOR THE NEW EDITION

The editorial team began planning the rewriting project back in 1993 and decided that the new edition of *Seeds of Woody Plants in the United States* would cover at least 290 genera of woody plants (Table 1). A good proportion of the new genera are subtropical and so the new edition may need to be published in two volumes. Like its predecessor, this book will be published as an Agriculture Handbook by the U.S. Department of Agriculture.

The rewriting project has proven to be a formidable challenge. Many of the original authors have retired and so other government scientists have graciously agreed to help write the sections on those genera. The entire 883 pages of AH-450 was scanned by computer into a word processing format and each author was provided with a disk of the original article. In addition, the Forest Service INFO-South library database was computer searched and a list of relevant articles was made available. Of course, much of the newest technical information has never been published and so seed processors and nurseries from across the United States were surveyed to see if they could provide any new operational techniques.

Besides the new genera of plants that will be added, we plan to increase the usability of the new edition in a couple of other important ways: the addition of more technical illustrations, and expansion of the general information chapters.

Table 1. Comparison of the chronology and features of the various publications.

Title	Publication Date	Publisher	Price	Photo Format	General Information Sections	Genera Covered
Woody Plant Seed Manual	1948	U.S.D.A., Misc. Pub. 654	$2.75 Out of print	Black and white	Yes - 5 chapters	126
Seeds of Woody Plants in the United States	1974 5 Reprints	U.S.D.A., Agr. Handbk. 450	$41.00 Out of print	Black and white w/ color plates	Yes - 8 chapters	188
Seeds of Woody Plants in North America	1992	Timber Press, Portland, OR	$49.95 available	Black and white	None	386 (many exotics)
Seeds of Woody Plants in the United States	1997-layout 1998-printing	U.S.D.A., Agr. Handbk. XXX	???	Color photos	Yes - 7 chapters	290 +

New Technical Illustrations. One of the outstanding features of AH-450 was the large number of detailed illustrations of seed anatomy and seedling development along with black-and-white photographs of fruits and seeds. In addition, a section of color photographs provided the reader with a good index of seed maturity for some of the species in which color is a criterion for ripeness. The use of color will be greatly expanded in the new addition as the cost of color printing has decreased substantially in the past few years. The editorial team has identified numerous high-quality color photos from personal collections and other government publications. These high-quality technical illustrations will greatly add to the usefulness of the new addition.

Expansion of General Information Chapters. One of the real benefits of the new edition of *Seeds of Woody Plants in the United States* to plant propagators is the inclusion of seven introductory chapters that will present comprehensive coverage of general seed and nursery topics: seed biology, harvesting and conditioning seeds, seed testing, storage, certification and seed exchange, nursery practices, genetic principles, and conservation. These chapters are an excellent way to present new technical information in one handy location.

As an example, there are new techniques to improve seed stratification. The traditional way to stratify woody plant seeds was to imbibe them in water at room temperature until they were at maximum moisture content, drain off the excess water, and put them in bags for the cold treatment (Bonner, 1974). Some people mixed the seeds with moist media, such as peat moss, and some just put the imbibed seeds into plastic bags ("naked stratification").

In recent years, however, new ideas have been emerging about stratification, primarily in terms of the moisture content of the seeds. The key point of this new technology was that seeds were stratified as usual, then redried to a lower moisture content (e.g., 35% for Douglas fir) and returned to cold storage. The benefits are that premature germination during stratification is largely prevented and germination rates are improved to the point that total germination can even be higher than with traditional treatments. Most of the early work on this "stratification-redry" technique was done on western conifers (Edwards, 1986).

The next improvement in the technique came from work on hardwood seed in Europe (Muller and Bonnet-Masimbert,1989) where they found that if proper seed moisture content was determined and controlled during stratification, full imbibition and subsequent drying was unnecessary. Seeds could be stratified at a moisture content that overcame dormancy yet prevented germination, and then cold stored for up to 5 years without loss of viability. These critical moisture contents were determined to be 30% for European beech, 27% to 30% for cherry, and 55% to 60% for European ash (Muller, 1993). Of primary interest to propagators, the seeds could be removed from storage and planted at any time without further treatment.

I.P.P.S. members will be particularly interested in new or improved seed propagation methods such as transplanting emergents—commonly known as "pricking out". Many seeds of forest and conservation species are too small or fragile to be direct seeded or planted as germinants. For example, the seeds of quaking aspen (*Populus tremuloides* Michx.) are very small with an average of over 3.5 million seeds per pound. The seeds also germinate within days, but the germinants are very susceptible to drying and damping-off. To propagate these sensitive seeds, growers fill shallow trays with a sterile peat moss/vermiculite growing medium and sow the

seeds by hand. The seeds are irrigated and placed into a greenhouse and are misted lightly until the young seedlings ("emergents") are well-established (Landis and Simonich, 1984). When the emergents reach the cotyledonary stage and begin to grow the first set of primary leaves, they are ready for transplanting to the growth containers or even bareroot seedbeds.

The traditional transplanting technique consists of working the emergents loose from the seed tray, making a dibble hole, placing the plant in the hole, and firming the soil or growing medium around the stem. Unfortunately, this procedure sometimes produces a "J-root" or kink in the seedling root that can reduce growth in the nursery and cause mechanical weakness or mortality after outplanting (Gordon and Hayes, 1995). To overcome this problem, growers have developed an innovative tool to make transplanting emergents much more successful. The tool has a sharpened probe with a v-notch in the tip. The top of the emergent is held by one hand and the bottom of the root is hooked with the notched tip of the transplanting tool. The root is pushed down into the soil or growing medium until the seedling is at the proper depth. Then, while still stabilizing the seedling, the hooked bottom of the root is cut off and the tool removed. This simple technique leaves the emergent transplanted without the possibility of a "J-root" or other deformation.

These and other new techniques will add greatly to the usefulness of the new edition of *Seeds of Woody Plants in the United States*.

ESTIMATED PUBLICATION DATE

The publication team hopes to have the final draft of the new edition ready for computer layout by 1997 and the final printing done by the following year. With the recent advances in computer technology, it may be possible to jointly publish *Seeds of Woody Plants in the United States* in an electronic version that would be available on compact disk or perhaps on the Forest Service Homepage over the World-Wide Web via the Internet.

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Worker Protection Standard: How It Affects Cutting Propagation

Raymond L. Pavitt
Astoria-Pacific, Inc., PO Box 830, Clackamas, Oregon 97015

The Worker Protection Standard (WPS) for agricultural pesticides, issued by the U.S. EPA in August, 1992, (40 CFR part 156 subpart K, and 40 CFR part 170) required labeling changes for many pesticide end-use products registered under section 3 or 24(c) of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). Among those end-use products are biological pesticides and, more specifically, plant growth regulators including rooting hormones.

Pesticide Regulation (PR) Notice 93-7 was issued to manufacturers on 20 April 1993, and outlined the requirements for meeting the labeling revisions required by WPS. Included in PR Notice 93-7 were the deadlines specified in WPS: After 21 April 1994, all products must bear the new WPS labeling when sold by the manufacturer. After 23 October 1995, all products must bear the new WPS labeling when distributed or sold by any person.

Pre-WPS approved labeling was simple for a rooting hormone; however, the accepted labeling under WPS included major new sections involving:

- Personal Protective equipment (PPE).
- Statement of practical treatment.
- Agricultural use requirements, including the restricted entry interval (REI).

Through various supplements, PR Notice 93-7 determined the following:

- The "toxicity category signal word" CAUTION was based upon the toxicity category number that applies to acute toxicity tests performed on the end-use product.
- The "chemical resistance category" was based upon the solvents used in the end-use product. In the case of Dip'N Grow®, the solvent is alcohol.
- "PPE" requirements were based upon both the toxicity category and the chemical resistance category.
- "REI" was based upon the WPS active ingredient list (5 April 1993) indicating indole-3-butyric acid (IBA), with a 12-hour REI and naphthaleneacetic acid (NAA), with a 24-h REI.

Personal protective equipment was specifically outlined in the WPS worksheet. Applicators and other handlers must wear: long-sleeved shirt and long pants;

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chemical-resistant gloves, such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, polyvinyl chloride, or viton; and shoes with socks.

The REI time periods were established by the EPA from the toxicity categories of tests performed upon the raw material. Unfortunately, the current eye irritation potential for NAA is toxicity category II causing this raw material to be classified as a 24-h REI. All other studies on NAA and IBA are toxicity category III which are classified as a 12-h REI. The end-use product is assigned an REI time equivalent to the worst case of any toxicity test of the raw material, even though it may only represent a fraction of 1% of the end-use product.

In the Federal Register of 11 January 1995, EPA published a draft policy statement on "reduced restricted entry intervals for certain pesticides". The final policy was published on 3 May 1995, and was presented to manufacturers as PR Notice 95-3 on 7 June 1995, with the following statement: EPA will permit registrants to reduce the worker protection standard (WPS) interim restricted entry intervals (REIs) from 12 to 4 h for certain low risk pesticides (Smith, 1995).

A list of active ingredients that are eligible for this reduction included IBA, but not NAA, since NAA is a 24-h REI active ingredient. For those rooting products that contain only IBA, the 4-hour option could be applied by the manufacturer. For rooting products such as Dip'N Grow that contain both IBA and NAA, PR Notice 95-3 was not an option.

NAA is accepted by many propagators as a beneficial companion to IBA in rooting compounds (Dirr and Heuser, 1987). Astoria-Pacific was very concerned about the 24-h REI and requested a meeting with the EPA in Washington D.C., to discuss product application practices for Dip'N Grow and to request regulatory relief for the nursery industry from the 24-hour REI. Following are the results of this meeting presented in an official EPA letter dated 10 August 1995:

"As discussed in our meeting, the 24-hour REI is triggered by the toxicity of the active ingredient, NAA. Any product, used for the commercial production of plants on farm, forest, nursery or greenhouse, is within the scope of the Worker Protection Standard (WPS). WPS, in turn, requires that any "in scope" product must bear a restricted entry interval (REI) statement on the product label. For these reasons, it is impossible to remove the REI statement from your product label. In our discussion of the pattern of use for your product, we spoke of a specific section of the Standard, specifically § 170.112 (b); this section outlines the exception for activities with no contact. For the practices conducted after application, specifically moving and transporting trays to the mist room and activities in the mist areas during the REI, you requested regulatory relief for the nursery industry. Your concerns have been addressed by the Interpretive Guidance Workgroup (IGW). The following discussion of the IGW guidance concerning movement of pots during the REI, entry under an REI for no-contact activities, etc., should provide the flexibility desired by the industry. The specific IGW questions and answers are enclosed with this letter."

The IGW guidance states that containers may be moved provided there is no contact with the treated area by workers. In the use patterns for Dip'N Grow, the bottom section of the cutting is treated, then submerged in rooting media; in this instance, the section of the stem that was dipped in the diluted product is the "treated area". After the cutting is placed in the rooting medium, subsequent movement of the tray would satisfy the "activities with no contact" condition. Moving a pot or flat of treated cuttings without contact to the pesticide-treated area would not be in

violation of the REI. The nursery workers moving the flats of cuttings from the treatment area to the mist rooms would still need to be notified, via central posting, as well as given posted (verbal is optional) warnings of the treatment to the cuttings.

The nursery industry may not have realized the full benefit of using the "no-contact" exception in their production practices. In regard to workers having to wear PPE during transport from the treatment area, into and about the misted areas during the REI, an unprotected worker (one wearing no personal protective equipment) may enter the treated area immediately after the application is finished as long as the "no-contact" conditions are satisfied. As long as no other REI is in effect, workers would not be required to wear PPE to transport flats of cuttings that have been treated with Dip'N Grow. During the REI for Dip'N Grow, workers may enter the mist area to adjust mist equipment, rearrange flats under the mist, etc., and do so with no limitations on the time spent in the mist area, **as long as no contact occurs with the treated area.** During the Dip'N Grow REI, should a flat or tray of treated cuttings be overturned during "no-contact" activities, nursery workers may not contact the treated cuttings, disturbed rooting media or tray(s) without wearing the reentry PPE. As a safety and compliance measure to handle spills of treated plant material during the REI, it is suggested that nursery workers have the reentry PPE readily available for use in or near the treatment area.

I hope that this guidance provides a clarity in terms of defining the "treated area", how the "no contact" exception is used for treatments to promote rooting, and the ability to enter and move flats of cuttings in the mist area during the REI. I hope that you will incorporate a general discussion of "no contact" activities in a new Dip'N Grow product information sheet. The nursery industry should be made aware that PPE is not required and entry into the mist areas are not restricted by WPS when rooting hormone is used and cuttings are placed in a mist area that does not have a REI in place from treatment with other products (Smith, 1995).

Needless to say, the nursery industry should be pleased with this guidance determination. We should remember however, that PPE is still required during dilution, mixing and use of the liquid rooting hormone.

ACKNOWLEDGMENTS

I would like to express my most sincere thanks to:

Janet L. Andersen, Acting Director, Biopesticides and Pollution Prevention Division, US EPA, Washington, DC, for her refreshing guidance of the BPPD and implementation of a common sense approach to regulatory affairs.

Bruce Lane, Research and Development Coordinator, Hines Nurseries, Irvine, CA, for his impressive photographs of the use pattern for Dip'N Grow that accompanied my request for this regulatory relief.

Donald F. Marek, Propagation Manager, Monrovia Nursery Company, Dayton, OR, for his outstanding step-by-step description of the use of Dip'N Grow in the cutting department, also sent with my request.

Judy A. Smith, Field Operations Division U.S. EPA, Washington, DC, for her rapid response to my request and her desire to understand rooting propagation and the nursery industry.

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"Propagation Challenges" Question-Answer Period

Mike Anderson: A question for Tom Landis. I bought the Timber Press manual 2 years ago and must admit don't use it very much because all the information is presented only in the metric form. How will the new manual handle that?

Tom Landis: We'll have both, metric first with English units after it in parentheses.

Dick Bir: When did you get this ruling?

Raymond Pavitt: The ruling was dated 10 August 1995.

Dick Birr: Have you written this up for any trade journals?

Raymond Pavitt: I have met with publishers of all the journals at recently held trade shows. The AAN "Alert" published excerpts of this last week. It will appear in other journals later.

Terry Finnerty: Can you comment about the growth of C-4 grasses in cool-season climates?

John Greenlee: The only C-4 grasses we grow on are tropical grasses like sugar cane and they are basically ornamentals. In cooler climates they will just be annuals or used as an annual in gardens.

Bruce Briggs: If some growers prefer to use Dip-N-Grow as a spray on the tops after the cuttings have been put in the greenhouse, what will appear on your label as a protection under the new law?

Raymond Pavitt: This is a difficult question to answer. Officially, Dip-N-Grow is only licensed by the EPA for cutting propagation by treating the cut bases. It is not legally authorized for spraying to the tops of cuttings. The label will only say for dipping the basal end of the cutting and placing in the medium.

Anonymous: Is Dip-N-Grow listed as a pesticide?

Raymond Pavitt: All growth regulators are listed as "pesticides" by the EPA since there is no separate category for them.

Ron Lapotin: Were you successful with any of the other growth regulator products used in the industry?

Raymond Pavitt: The ruling probably applies to any substance used to improve rooting of cuttings. Gibberellins may soon become declassified. Anything containing IBA and/or NAA is going to require the continuing registration and posting of the REI.

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The Pitfalls of Grafting

Richard F. Bush
Richard Bush's Nursery, 8051 S. Lone Elder Road, Canby, Oregon 97013

Pitfall 1: Translucent-white, 4-mil Plastic on Cold Frames. A couple of winters ago I covered my cold frames with translucent- white, 4-mil plastic. Before, I had always used clear plastic. I speed up callusing with a hot callus device and it is necessary to have a totally hermetic seal on the grafted area. I use laboratory parafilm to hold the graft tight and seal it at the same time. The grafts spend 2 weeks in the callus device, transplanted into 1-gal containers, and put into the cold frames in February. The translucent-white plastic apparently filters out the sun rays that degrade the parafilm and the plants were effectively girdled. It is not necessary to cut the parafilm when it is under clear plastic as the parafilm will degrade.

Pitfall 2: Hot Callus Device Temperature Pitfall. My hot callus device is outside with a poly covering to protect it from low temperatures. I placed a thermometer a couple stations from the thermostat. The heat wire broke just down from the thermometer so the only grafts getting callused were the dozen or so above the break in the heat unit. The only ones I checked had good grafts and good callusing. The other 340 had no heat and no healing since they are put in the tube with dormant rootstock and scion. The temperature was 40 to 50F.

Pitfall 3: Too Much Water. Some understocks are very fussy abouthow they are watered. True firs are a good example. A normal amount of irrigation on your other plants will cause stress and even death for those plants that do not like too much water.

Pitfall 4: Weevils. If you get some understock from someone new, be sure to bareroot a few and take a good look for weevils. You might graft them all and down the line the understock will start to die because it is girdled.

Pitfall 5: Labels. About 20 flats of bench-grafted conifers, rare, unusual, and new to me, had been grafted for a few months and it was time to take them out of the greenhouse. Due to the rarity of these plants each one had a flat pointed name tag in the pot. It was late in the day so they were put just outside the greenhouse on the ground. My hoe hands, all 25 of them (weeder geese) systematically removed all the name tags that evening.

More Pitfalls Without a Lot of Detail. If you graft a hardy cultivar with two needles on *Pinus contorta* and send it to a customer in Zone 4 or below it is sure to die. Make sure your understock is hardy in your marketplace. People who grow seedlings can tell you what area and hardiness they are from.

In bench grafting, if your understock has roots that are inactive and you graft it at this time, failure is likely. I like to see 1/4-in. white tips on the roots or indications of buds swelling.

When I receive scionwood in a brown bag by mail, taking 5 or 6 days to arrive, I am reluctant to bother grafting it. I like to cut scion wood for bench grafting around January. I immediatelydo a quick dip in one tablespoon benlate and 3 gal of water. I use paper towels. Get them thoroughly wet and then ring them out. Seal the towels and scion in a plastic bag and store at 36 to 40F.

Timing When Bench Grafting. If the understock roots are inactive, even if the scion is healthy and the graft was made technically correct, the chances for failure are good. Again, it is important to look for 1/4-in. white tips on the roots or indications of buds swelling.

Propagation Stock Orchard Management and Wood Selection of Fruit and Ornamental Plants

Jonathan La Forge
L.E. Cooke Co., 26333 Rd. 140, Visalia, California 93252

Propagation stock sources at L.E. Cooke Co. vary from purchased liners, seedlings, budwood, grafting wood, seed, tissue culture, and unrooted cuttings from seedsmen and commercial suppliers in the U.S., arboretums, and government repositories, to our own 60 acres of seed orchards, bud-scionwood orchards, 5 acres of cutting beds, and 20 acres of field division blocks and berry tipping beds. Because we practice a foundation stock plant program, L.E. Cooke also has Foundation screen houses, a registered mother block, and registered scion and seed tree blocks. These sources provide the 1300 cultivars in our production of 7 million trees per year and over 3500 cultivars in our total collection, many under evaluation from plant breeders and our own customers.

In any discussion of management of these sources, the use of their products controls the stock plant treatment.

Source	Harvest Time	Product
Berry-tipping beds	Mid fall	Rooted tips
Shrub-cutting beds	Winter	Hardwood cuttings
	Spring-summer	Softwood cuttings
Field division blocks	Fall	Division planters
Seed trees	Summer-fall	Seed for rootstocks, ornamentals
Cutting stock trees	Fall-winter	Hardwood cuttings
	Mid summer	Softwood cuttings scion/budwood trees
	Winter	Graftwood, bench-grafting scions, spring budwood
	Late spring	June budwood
	Summer	Summer-dormant budwood
	Fall	Fall budwood
Registered increase rows	All	All types, new clones
Screenhouse foundation virus-free trees		New mother blocks, budwood for new mother blocks

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Propagation stock sources at L.E. Cooke Co. vary from purchased liners, seedlings, budwood, grafting wood, seed, tissue culture, and unrooted cuttings from seedsmen and commercial suppliers in the U.S., arboretums, and government repositories, to our own 60 acres of seed orchards, bud-scionwood orchards, 5 acres of cutting beds, and 20 acres of field division blocks and berry tipping beds. Because we practice a foundation stock plant program, L.E. Cooke also has Foundation screen houses, a registered mother block, and registered scion and seed tree blocks. These sources provide the 1300 cultivars in our production of 7 million trees per year and over 3500 cultivars in our total collection, many under evaluation from plant breeders and our own customers.

In any discussion of management of these sources, the use of their products controls the stock plant treatment.

Source	Harvest Time	Product
Berry-tipping beds	Mid fall	Rooted tips
Shrub-cutting beds	Winter	Hardwood cuttings
	Spring-summer	Softwood cuttings
Field division blocks	Fall	Division planters
Seed trees	Summer-fall	Seed for rootstocks, ornamentals
Cutting stock trees	Fall-winter	Hardwood cuttings
	Mid summer	Softwood cuttings scion/budwood trees
	Winter	Graftwood, bench-grafting scions, spring budwood
	Late spring	June budwood
	Summer	Summer-dormant budwood
	Fall	Fall budwood
Registered increase rows	All	All types, new clones
Screenhouse foundation virus-free trees		New mother blocks, budwood for new mother blocks

NUTRITION

All cutting, scion, and budwood sources receive what we estimate to be their optimum fertilization in mid-March. Trees for June budding are fertilized at half-rate to help mature wood for early May budding. Medium-density plantings receive single applications of 120 lb per acre N, P, and K on legume and fescue orchard middles. Seed tree plantings are fertilized in fall and spring. Cutting blocks are on continual fertilization with irrigation and division and cane-tipping blocks are fertilized according to growth and temperature so they are at the correct size for division and tipping in the fall. Fertilization rates are not adjusted to size the wood. Dormant pruning and pinching of terminals are used to get the desired wood size.

PESTS AND DISEASE

Good pruning and diseased wood removal is important as is timely sprays for fire blight, various blossom blights, brown rot, and mildew. Pest control measures are primarily directed at dormant scale sprays and the occasional aphis infestation. Most notable in using an orchard cover of grasses and legumes is the absence of mites and lepidoptera pests due to the high number of predacious insects and the attractant of lush orchard floor growth. This is not true in our mother blocks, which must be kept weed free for potential vector control by state law. There, we have significant control costs.

VIRUS ELIMINATION AND REINFECTION CONTROLS

In California, there is a pome and stone fruit registration program for nurseries producing certified nursery stock. Funding for the program is via acreage fees. Also supporting the virus elimination and tree improvement is a California Department of Agriculture Assessment via a tree sales tax of 1% on most *Prunus*, pome, and nut tree sales. This assessment is allocated by the state through an Improvement Advisory Board that evaluates research proposals on virus and other crop limiting factors. It is through this board's program of virus elimination via heat treatment at Prosser and virus index program called the 10-Step program that L.E. Cooke Co. and other participating nurseries have used to eliminate virus and virus-like diseases from our stock plants. After treatment and testing at IR-2/NRSP-5, a U.S.D.A. Program located at the University of Washington-Prosser, these clones are returned to the participants. To maintain them in a virus-free state, we place these Foundation Plants in the same type of screen house that exists at Prosser. Since L.E. Cooke Co. has many varieties of fruit and flowering plants that are grown for specific climates, and we have the only foundation grade plants of these clones, we maintain them in our screen house. From this foundation screen house we are able to start new mother blocks at our nursery and provide wood for other nurseries that are starting new mother blocks of these clones.

Regular virus indexing of these foundation screenhouse plants on shirofugen and all of our C.D.F.A. mother blocks and registered blocks ensures control of vectored viruses. Annual ELISA (enzyme-linked immunosorbant assay) tissue testing is also done to detect infection by necrotic ringspot virus and prune dwarf virus. Having certified nursery trees also expedites export to foreign countries. But the main benefit and pay back is in the increase in bud-take percentage and tree vigor.

TREE IDENTIFICATION AND TAGGING

The importance of identification is critical if you are maintaining clones and following a virus-free protocol. If a graft-transferable virus is detected in a nursery crop then it is necessary to have good records that show the source of buds for the crop and the source tree of the buds of the parent tree of the crop. With this information it is possible to track and test the parent stock and find all infected stock for elimination from registration and prevent further use of infected stock plants. Tagging that assigns unique numbers to each stock plant and is used in the computer records for each individual plant is helpful in keeping track of each stock plant and its progeny for virus and budded stock growth checks. L.E. Cooke Co. uses laser-printed luggage tags that are laminated inside a 10-mil clear plastic pouch and tied to the stock plant with 20-mil green Miracle Garden Tie. The tags have the row, tree number, block number, tree name, planting date, and source printed on one side and the unique plant number in numerals and a three-of-nine bar code on the other side. Using the bar code has reduced our shirofugen index cost by 45% and increased the recording of data reliability by 95%.

Bar code is being tested for future use and should be very useful in budwood collection, budwood packaging, nursery row labeling, and data transfer to the office for inventory updating. Maintaining a cultivar as true to name implies that someone is checking that the cultivar is true to an original description and that those characteristics are the same in the plants that are selected to become the new mother/stock plants. Many things can influence change in the appearance of individual plants or populations of plants that are line bred to reduce variability. The interaction of the genotype with the environment is phenotypic variation that can change with environmental change. The responsibility of the propagator is to achieve a high rate of detection as possible of genotypic change or of "off-type" plants as possible. When a low rate of detection is present with a highly variable cultivar, the production of "off-type" stock is to be expected at a rate of the variation rate multiplied by the inverse of the detection rate. It is best to try to evaluate all new cultivars as they are received from the breeders and check them with a thorough description. All fruit plants should be fruited out and the characteristics checked before that individual plant is used as a stock plant. The progeny of the stock must be checked for trueness to type. This is the only way you can be sure a cultivar is being reproduced true to name and description. Many of the highly variable cultivars exhibit true-to-type mother plants, but have a high variability in the progeny. The cause of this variation is mutation in the genetic basis of the genotype and can be caused by many mutation-inducing factors that affect genetic material in the chromosomes (nuclear mutation) or affect cytoplasmic genes (point mutation). Multiplication of sets of chromosomes or polyploidy and translocations of chromosomes at specific loci can occur. Some of these are persistent at higher rates in some cultivars and must be carefully checked in expression to avoid unexpected performance that is not typical for the cultivar. A good example is bud failure in almond, *Prunus dulcis*. Another is the unstable mericlinal mutation exhibited in *Acer negundo 'Varieagatum'* progeny. Not all mutation is bad, many of the great fruit cultivars are bud sport mutations. But careful selection and diligent checking of stock plants is necessary to keep the best true-to-type cultivars and clones growing.

WOOD SELECTION AND CARE

Size of the required wood is determined by the understocks being budded and grafted. In short, the best size that fits is cut. To get wood that is the proper size and condition for grafting and budding is the difficult part. Some *Wisteria sinensis* and *W. floribunda* buds must be grown on fences or trellis to provide wood that is mature enough to bud and is the correct size. Some of the *P. cerasus* and *P. avium* cultivars require terminal tipping to produce small enough mature wood in the San Joaquin Valley of California. When the bud cutters cut a stock plant and it generally has wood that in their judgment is too small or too big they make a notation on the pruning book that is used at pruning time. One less bud per scaffold or one more bud per scaffold will be left for the next season to push. Some genera grow better budwood if they are only cut every other year for dormant and spring budding. These include *Cercis and Alnus* cultivars. Remove leaves as soon as possible for wood that will be used in a few days. Package by wrapping in damp newsprint, wrap in moistened burlap, then into plastic bags, and refrigerate at 34F. During shipment and longer storage I will omit the damp material and just wrap in plastic and refrigerate. For winter storage of fully dormant wood, it is essential to wrap in plastic quickly and to keep wood continually refrigerated at 33 to 36F or some wood will start to break dormancy very quickly (*Juglans*). The main cause of wood deterioration is dehydration; second is infection. Wood cutters must be trained to examine a plant the same way a doctor examines an athlete before an event. The cutters should know what the plant should look like and be familiar with the normal variation due to environmental factors, but be able to detect the slightest change from normal appearance. Standing at a distance from a group of plants and observing their color, reflection, branch habit, terminal coloring and general leaf characteristics will make variants more noticeable. On close inspection a look at leaf glands and stomata, exudates and pubescence, leaf shape and bark pattern are all clues to a good budwood cutter.

Study of diseased trees can improve recognition of disease much better than looking at pictures in books. Visits to disease gardens is helpful. Walking of nursery rows of bareroot stock to check for variants is a good lesson in the recognition of cultivars.

Bench Grafting, When Is the Best Time?

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INTRODUCTION

There are many factors to consider when grafting a wide range of hardy ornamental nursery stock. This paper will outline some of the factors that we at J. Frank Schmidt and Son consider when setting up our grafting calendar for the year.

TIMING

First, know the plants and quantities to produce for the year. Look at the "windows" or times of the year when each crop can be successfully propagated. These windows will vary greatly depending on the facilities available. Heated greenhouses or bottom heat may extend the windows for some crops, but not for others.

Some crops such as *Acer palmatum* have very large windows. They can be grafted successfully without heat between March and September, but using heat would allow you to graft in the winter months.

Other plants have very small windows. For example, I have seen *Fagus sylvatica* can be successfully grafted in the autumn, winter, and spring, but we can only successfully propagate them during two short intervals, late-January and late March.

If a new crop is to be added to production, we graft it at several times during the year to see when it grafts best. Often, it may take several years to find out when the best time is for our propagation methods. A plant may graft particularly well in the late summer or autumn; however, it may not overwinter well leaving you worse off than if you had waited until the following spring.

Once we know the windows available we then fit the grafting calendar together, at this time there are many other factors that come into play:

Available Facilities. Is greenhouse space available at the time we want to graft? Will we need to use a heated house or bottom heat?

Available Labor. What other work is being done at that time? Do we already have other crops to propagate? Perhaps there is a time this crop can be grafted when there is not so much other work to be done. One of our goals is to keep the labor curve as flat as possible so we do not require twice as many grafters one month as the next.

Scion Wood Availability. Summer may be a great time to graft *Acer palmatum*, but if we are short on scion wood for a particular cultivar we may have to throw too much of the softwood away and it would be better to wait until the spring.

Rootstocks. Are established rootstocks being used? Can the plants be grafted on bare-root dormant stocks?

Ease of Propagation. If the crop is difficult to propagate we may want a second chance. If it is easy, it may be possible to graft it during its last window for the year.

Table 1. Months of the year when the listed species can be grafted successfully in the greenhouse.

Crop	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Abies	X	X										X
Acer palmatum	X	X	X	X	X	X	X	X	X	X		
Carpinus	X	X	X	X						X	X	
Cedrus	X	X	X						X			
Cercis		X	X	X			X	X				
Cornus	X	X	X						X	X		
Fagus	X	X	X	X					X	X	X	
Ginkgo	X	X	X	X				X	X			
Hamamelis	X	X	X	X				X	X	X		
Larix	X	X										
Liriodendron		X	X						X	X		
Liquidambar		X	X					X	X			
Picea	X	X					X	X				X
Pinus	X	X									X	X
Wisteria	X	X	X	X								

METHODS

Once the time has been determined, the next thing to consider is the method. There are many variations of grafting and budding, but we use three in our greenhouse propagation:

1) Side veneer grafting: The scion is placed on the side of a rootstock that is later removed.

2) Whip grafting: The excess rootstock is removed at the time of grafting and the scion placed on top of the plant or the root.

3) Chip budding: A single bud shield is placed on the rootstock.

With many crops one method is much more successful than others. With other crops however, the difference may not be so great and other factors may influence the decision of which system to use.

Side Veneer Verses Whip Grafting. The side veneer graft is our default graft. It can be used for almost all crops and is easily learned. Whip grafting does not work on all crops; removing all the excess rootstock at the time of grafting will often kill the plant. It often takes a new grafter longer to learn. It does, however, have certain advantages over veneer grafting for some crops.

- Less rootstock preparation is required before grafting, the rootstock is simply cut off 3 or 4 in. above the pot.
- Heading back and thinning of the rootstock tops after grafting is not required.
- The scion will often grow faster in the spring because all the energy is going to the scion and not being shared with the remaining rootstock.

- Of the crops we grow, *Aesculus, Carpinus*, and *Fagus* are whip grafted.

Chip Budding. Chip budding is a common form of field propagation,but it can also be used in the greenhouse. It is especially useful for tree propagation where a single straight stem is required. It is easier to straighten one bud growing out the side of a rootstock than one of several buds growing out the side of a scion. Chip budding requires less scion wood since only one bud is used. It is also a faster operation than grafting.

The main crops we greenhouse chip bud are *Liquidambar* and *Ginkgo*.

Tying. After deciding what method to use we can decide on what tie to use. Options include: rubber strips, plastic chip bud tape, flagging tape, Max tape, and biodegradable tape.

What we use depends on our grafting environment and what works well in each case; more humid grafting environments will probably get very good results with rubber strips, drier environments may get better results with tape.

We tie all our deciduous plant grafts with some form of plastic tape. In the past we used chip bud tape for veneer grafts and stronger flagging tape for whip grafts. However, we now use the Medel grafting tape for all our deciduous plant grafting since it does not have to be tied at the time of grafting and, if applied properly, does not have to be cut off later.

While many growers get excellent results using rubber strips, we get better results with tape. We do, however, use rubber strips for our coniferous material. This allows the sap to run out between the rubber and not be trapped in the graft area.

Sealing. Whether grafts require sealing or not depends on the crop and the environment of the facilities. A more humid environment may make sealing unnecessary. However, if overhead irrigation is being used in conjunction with a plastic tie, sealing the top of the graft may be necessary to prevent water from running down inside the graft.

We seal the tops of all our deciduous plant veneer grafts since we use overhead irrigation and a plastic tape. However, we do not seal our coniferous plant veneer grafts.

ENVIRONMENT

Once grafted, the plant must be placed in a suitable environment. These can vary, from very simple poly greenhouses with no heat systems to more sophisticated greenhouses with ventilation and heating systems. The environment required will depend on the plant, time of year and method used.

Heating. Supplemental heat is generally required during the winter months, but by paying attention to timing and method its use can be limited. Bottom heat may be more expensive to install but may be more economical to run. Attention must be paid to how much heat is used and where. If the air temperature is too high the scion may break bud before it has callused to the rootstock.

We heat our propagation houses to between 40 and 45 F during the winter propagation months.

Ventilation. Ventilation and air circulation are most important when the scions begin to break bud. If the plants are still very close together, poor air circulation and

ventilation could quickly lead to the delicate new shoots rotting off.

Shading. Preventing too much heat build up in the spring is very important, while too much shade on cool overcast Spring days will retard growth and increase fungal attacks. Too little shade on sunny spring days may cause the emerging delicate foliage to burn or dry up. Depending on the crop and the day we will use shading of between 30% and 70%.

Tenting. Tenting is a widely used technique with new grafted plants. A thin 1-mil, clear polyethylene tent is put over the grafts, this has the effect of raising the humidity and the temperature without heating the whole house. It can be a particularly useful technique with autumn, winter, and spring grafting.

The poly is put over the grafted plants in the greenhouse. Shading will also be required on sunny days to prevent excessive heat build up. Even so, it will become very hot under the poly tent. What prevents the plants from burning is the 100% relative humidity. If the tent is not sealed properly and the humidity drops, the plants will burn.

Weaning the plants off the poly tent is very important. After callus formation has begun, weaning can begin by opening the tents in the cool mornings and closing them again for the hotter parts of the day. Weaning will take between 5 and 10 days depending on the crop.

We use tenting on almost all our crops grafted between October and April; the time tented will vary between 4 and 6 weeks depending on the crop.

Sex and the Single Plant: Seed Propagation: The Basics

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While there are many ways to propagate plants, some of which are very sophisticated, the increase of plants by seed is still a very common practice in the nursery industry. Seedage may be the only way to propagate the plant, is usually less expensive than other methods of propagation, produces plants for evaluation (pest resistance, aesthetics, etc.) and known characteristics, can be used for the production of understock, can be used as clonal propagation, and usually requires less space then other methods (Hartmann and Kester, 1975). However, seed-produced plants may show extreme variability, have a poorer root system, the sex of the plant will not be known, seed may have very low viability, or be unavailable (Macdonald, 1986).

Seed of most plants that have evolved in temperate zone climates have developed protective mechanisms that allow the plant to germinate under the most favorable conditions. This generally means the seed will germinate in the spring following the year or second year after the seed (fruit) ripens. There are a few of these mechanisms to consider and, unfortunately, in some cases there may be more than one mechanism in operation. By knowing the operational mechanisms that affect germination, the propagator may control these factors to affect germination in the most efficient manner and to the benefit of the propagator. Dormancy in plants and seed is the inability of the plant or plant part togrow and may be due to internal and/or external factors (Lang, 1987; Lang et al., 1987). The propagator may allow nature to take its course and have the seeds germinate in due time, or may elect to control the factors affecting germination to allow quicker, more orderly, and better germination. By controlling the factors of germination a more uniform crop may be achieved. Uniformity and predictability of seed germination is becoming a necessity for good grade count in production (Macdonald, 1986).

FACTORS NECESSARY FOR SEED GERMINATION

Seed must be viable. The elements that make a seed viable may be controlled by assuring these factors are in effect. This may be as simple as making sure the plants are pollinated. Separation of viable and non-viable seeds will assure a more uniform and predictable stand.

External Factors. The environmental factors that may affect germination include:

Light. Intensity and/or day length may be important to both germination and subsequent growth.

Oxygen. Needed for normal respiration.

Water. Needed for imbibition, germination processes, and subsequent growth.

Temperature. Many seeds have an optimum temperature for the germination process and for growth.

Any primary dormancy must be eliminated.

Seed germination is a complex interaction of many physical and chemical factors.

The germination process begins with the imbibition of water, elimination of primary dormancies, and along chain of events including enzyme synthesis, release of stored food, and an increase in respiration followed by the commencement of radicle/ embryo emergence.

FACTORS HINDERING GERMINATION

Internal Factors. These factors are normally physiological/chemical in nature:

Physiologically Dormant Embryo. Interaction of various hormones that are normally overcome by a chill period, the duration of which is dependent on the species. This type of dormancy may sometimes be overridden by the application (soaking) of the seeds in various gibberellins. Germination of light sensitive seeds may be enhanced under long days. Some seeds germinate better in the absence of light or under short days. Gibberellins may overcome the long daylight requirement of some seeds.

Rudimentary/Immature Embryo. The further development of an immature embryo is accomplished by warm-moist stratification generally for a period of 3 to 5 months.

Epicotyl Dormancy. Many plants species which have a rudimentary embryo can develop epicotyl dormancy once the embryo has been developed can be overcome by cold stratification. This usually takes 2 to 3 months. The species that have the underdeveloped embryo/epicotyl dormancy systems can be germinated in 6 to 8 months (usually) under ideal conditions, but take 2 to 3 years in nature.

Internal Inhibitors/Internal Resistance to Gaseous Exchange. These are not that common, but dormancies of this type are generally reduced only by cold stratification.

SEED COAT FACTORS

These factors may be either mechanical or chemical in nature.

Mechanical Resistance to Emergence. The first consideration in the germination of any seed is to get water into the seed. Processes which are used to diminish or remove seed coats impervious to water, gaseous exchange, and/or offer resistance to radicle emergence should be eliminated. The strategies which may be used to overcome mechanical seed coat factors and allow for water imbibition are:

Warm Stratification. This normally takes the place of the natural process where soil microbes will etch or erode the seed coat. It should be emphasized that a sterile stratification medium can not be used for this purpose.

Mechanically Wearing the Seed Coat. This is done to where water may penetrate. For small batches of large seed this can be done with a file, sand paper, or by nicking the seed with a sharp instrument. For larger batches an abrasive lined rotary drum may be used. Hot water may be used on some species to soften hard seed coats. Concentrated sulfuric acid can be used with extreme caution (Macdonald, 1986). Organic solvents may be used for dissolving waxy or water repellant outer layers.

Mechanical Resistance to Water Penetration And/or Gaseous Exchange. These seed coats are treated the same as the above.

Chemical inhibitors in the seed coat prevent the normal germination process—seed coat inhibitors have to be leached by soaking them in water or running water. Early maturing seed species and desert species fall into this category. These usuallywill not germinate until seed coat inhibitors are washed out by a heavy rain.

Other methods of enhancing and achieving good and uniform germination (Hartmann et al., 1990) are:

Soaking. Soaking the seeds in water for a period of time is a "pregermination" procedure that can give more uniform emergence (Anderson, 1987).

Osmotic Priming or Osmoconditioning. This process involves soaking the seeds in a high osmotic potential solution (either inorganic salts or polyethylene glycol) that starts the germination process, but does not allow radicle emergence. Seeds primed in this manner germinate more rapidly and with much greater uniformity (Geneve, et al., 1991).

Matriconditioning is surrounding the seed with a water-holding solid such as calcined clay or vermiculite. The matrix potential difference between the solid and the seed allows the seed to use this water. Germination is faster and more uniform.

Preconditioning the seed leads to more rapid and more uniform germination and would have applications in seedling production of annuals and perennials.

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Growing Fibrous-Rooted Oak Liners: A Methodical Approach can Yield Striking Results

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American oaks are distributed across every region of the country. Their bold structure helps define our forests and urban landscapes. Who can forget the sight of southern live oaks draped with spanish moss, or immense midwest specimens of bur oak with their timeless majesty? Their drought tolerance makes them a reliable source of food and shelter for wildlife. The durability and strength of oak lumber cut from vast eastern forests over the past 200 years helped build the strength of our nation. In his memoirs, John Charles Fremont wrote of seeing an oak woodland in northern California in March, 1844: "From the upland we descended into broad groves on the river, consisting of the evergreen, and a new species of white-oak...Among these was no brushwood; and the grassy surface gave to it the appearance of parks in an old settled country. We made an acorn meal at noon, and hurried on; the valley being gay with flowers and some of the banks being absolutely golden with California poppy...Here the grass was smooth and green, and the groves very open; the large old oaks throwing a broad shade among sunny spots."

Today, we are protective of the few remnants of these original oak forests of our heritage.

As nursery managers, we are just beginning to realize the market potential of this familiar genus of trees. In my recent informal survey of a half-dozen Oregon shade-tree growers, respondents indicated that oaks make up a consistent 10% to 12% of sales. Each grower intended to expand his offerings in this group of plants, prompted by inquiries from enthusiastic sales staff: "When are you going to get us more of these oaks?" There is also a solid trend toward greater selection that has increased demand for species such as chinkapin, chestnut, shingle, willow, and black oaks. Whether driven by increased awareness of their merits or the trend toward "natives" in the trade, it seems that oaks are increasingly popular.

Yet, there is a less sanguine aspect to the oak story. To many nursery managers, oaks remain a bit of an enigma. Personally, we appreciate them as landscape trees; we'd like to grow more of them. But how many of us might call to mind an oak seedling when the terms "carrot-rooted" or "dog-legged" are mentioned? No wonder we are uncertain how we feel about oaks. We've accepted higher-than-average costs and losses due to mediocre lining-out stock. It's hard to appreciate a group of trees that may take an extra year or two to finish and are still a source of adjustments later. Until recent years, oak liners have been propagated almost exclusively in field seedbeds. Nursery managers have had to accept oak liners that were of inconsistent root quality. "Oaks are tough plants", we have rationalized. "They'll make it. We'll root-prune them and cut the tops off so they throw up a good leader."

Why have we lowered our expectations when we purchase oak liners?

As nursery professionals, we need to re-examine traditionalnotions and accepted practices of oak propagation. Challenged to offer greater numbers and range in oak nursery stock, we must elevate our standards and grow liners that will flourish. We

cannot continue to offer plants we expect merely to survive. Would any of us try a restaurant that guaranteed its meals to be merely edible?

Recent advances in plug culture give us new opportunity to dramatically improve the root character of many tap-rooted nursery plants. Following is a brief summary of the propagation program we have developed over the past 7 to 8 years.

It is important to recall what happens when an acorn begins to germinate. Perhaps you have seen the nuts sprouting on the ground under white oaks in the autumn, or under the litter of red oaks in the spring. In either case, the root emerges from the seed well in advance of the shoot. So the germinating seed in the forest is already well-anchored into the soil several weeks before the shoot emerges to the light of day. Before the new shoot develops its first set of true leaves, the seedling is nourished by the seed leaves, or cotyledons. These cotyledons contain rich reserves of carbohydrate, protein, and oil. The large cotyledons provide the necessary energy and nutrients for oak seedlings to grow such a dominant primary root before it develops any shoot or true leaves.

Given the tendency for oak seedlings to develop taproots, it is essential to develop a well-thought-out plan for growing 1-year oak seedlings with fibrous roots.

The first, most important element of our strategy is to prune the primary root while there is no top. It is impossible to stress a seedling shoot which has not yet developed. By root-pruning the seedling before it has grown a shoot, we can avoid pruning it at any time again during the critical first year of its development. We air-prune the seedling's primary root by germinating the acorn in February in a "plug-tray" on the bench in a greenhouse. Growing Systems Inc. 73-cell trays work well for us: the conical individual cells measure only 2-1/2 in. deep by 1-1/2 in. across the top. Considering that some acorns are relatively large, you can imagine that we need to be creative when planting a big acorn like that of bur oak or chestnut oak. It is not necessary to bury the seeds if the flats are kept moist until the root grows into the soil mix.

Why do we choose such a small plug? Because it forces the root immediately down - there is little lateral room for the root to develop a "dog-leg". The shallow depth also insures that this young plant will be air-pruned very close to the soil surface. So its new, cultured root system will originate only a couple of inches below the crown. To achieve this air-pruning of taproots, it is critical that the flats not be left on the ground. An anchored flat is the result if flats are neglected and roots are allowed to grow out the bottom of the plugs into the ground.

It is possible to keep the seedling in this small plug for several months into the spring and early summer if prudent watering is practiced. The biggest risk of holding plugs for an extended time is that the vigorous liners may dry out from uneven hand watering or develop root disease from over watering. We find that irrigation booms are indispensable for even watering. A conservative water management program insures freedom from root diseases.

A cautionary note: merely pinching the primary root tip once is ineffective to induce the development of a fibrous root system in oak seedlings. The trimmed root usually forms a single new taproot at the point where the root was pinched. And it may become more crooked than a root left unpinched. So what is a grower to do?

We have found that a second critical step in growing 1-year oaks for maximum fibrous root development is to leave the seedlings in their plugs on the bench for at least 6 to 8 weeks after germination. During this time, we deny the air-pruned

taproot any opportunity to throw out a single new taproot. It responds by forming a substantial mass of callus that develops into new meristem tissue, forming numerous new small root-tips, or growing points. So, left in the plug for a few months, the young seedling develops the potential to grow many small fibrous roots using the same energy and vigor that it would normally have expended to develop a single taproot. Further, roots above the callus expand, filling the soil mix in the tiny plug. For handling purposes, the individual plugs can be removed without a frustrating loss of the soil mix.

Once a crop of seedlings is root-pruned and callused, the young liners can be shifted into larger pots or transplanted to beds outdoors. We find a ready market for 3/16-in. and 1/4-in. caliper transplants, so the great majority of our material is planted out into raised transplant beds of river-bottom sand in May and June.

It is useful to once again consider the natural scheme of things in the forest. We have all observed perfectly healthy old oaks and other trees growing in shallow soils or on rocky hillsides, green as grass in the worst of droughts. They successfully reproduced their kind and evolved in these conditions for eons before we ever came on the scene to consider how to propagate them with all of our fertilizer and irrigation technology and college degrees. Almost all plants survive in nature by forming symbiotic relationships with soil microorganisms. We can benefit by observing these soil organisms and applying them in nursery practice.

So the final key ingredient in our strategy to grow the best transplants possible is to inoculate our outdoor beds with spores of a mycorrhizal fungus that grows in association with oaks. After the first autumn rains, we simply collect the mushrooms from the ground under mature oak trees. Alternatively, we may collect them from established transplant beds in the nursery early in October. Although it's true that oaks can be overtaken by pathogenic fungi, we have never collected mushrooms except from under obviously healthy trees, so disease has never been a concern.

We homogenize the collected mushrooms with water in an old blender and mix the resulting slurry with about 20× its volume of sawdust. This inoculum is held in a woven poly sack for 6 months outdoors in a shaded spot. At transplanting, we sprinkle the sawdust inoculum lightly on raised transplant beds immediately before they are planted. Our observation is that transplants cultured for fibrous roots as described develop mycorrhizal roots quickly during the first growing season. We note the mantle of creamy-colored fungus mycelium on the feeder roots when we inventory in August, and at harvest. Inoculating the beds is especially beneficial if a grower has fumigated the soil being planted.

By using the naturally occurring fungus from under the trees which lends these oaks their durability and drought tolerance, we form a simple but complete propagation strategy. Great control is achieved over the germination process in the greenhouse while the seedlings are feeding off the stored energy and nutrients in the seed. But the wide-open spaces, full sunlight, and natural moisture buffer of the open field, coupled with the symbiotic mycorrhizal fungus, combine to yield a repeatable system for producing high-quality oak liners.

The benefits of these relatively simple propagation practices are enormous in terms of plant quality and profitability for ourselves and our customers.

We get much better use of valuable seeds in greenhouse propagation. The crows do not bother our germinating acorns under protective greenhouse cover. Neither

frost, heavy spring rains, nor weeds are a problem. Seedlings thrive in the warm greenhouse environment, effectively extending our growing season.

Transplanting is accomplished after the soil is warm in May and June when fields are easily worked, not wet. Availability of phosphorous is much better in warm soil due to greater microbial activity. The young transplants take off immediately.

We gain the capability to manage a crop for certain desirable caliper grades, based upon the controlled spacing of transplants in the row.

We find we can use fewer sprays for powdery mildew in susceptible white oaks when there is better air circulation around well-spaced transplants.

At inventory time, we easily calculate availability based upon a uniform stand of transplants.

During grading, there are fewer grades to sort compared with seedling-grown stock. Culls are few.

When customers open the box or take delivery, they comment "Wow, these oaks have some amazing roots!"

Garden center operators can re-pot these liners in late winter and early spring and sell them within the same spring. This means fewer plants to carry over at unreasonable expense through a hot summer season.

For customers who re-plant into field rows, the stand is uniform and transplants grow well from terminal buds in the spring. No labor is required to cut off half the taproot and most of the top so the liner can be planted with the expectation that it merely "survive" for a year while it recovers from abuse and major surgery. At least a year is shaved from the production cycle.

The beauty of this system lies in its fundamental simplicity. The focus from the beginning is upon development of maximum fibrous roots within one growing season, without any stress on the plant from root pruning. A well-grown, 1-year transplant is hard to beat in terms of plant value, considering delivered cost. It is like a loaded weapon: lots of power in a small package if it is handled properly.

Customers may be fooled or snowed once, but solid business is repeat business. Value in root systems must be the focus of that effort.

Evaluating Acid Scarification Effects on Dormant *Arctostaphylos nevadensis* Seeds

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Tetrazolium (TZ) staining was used to indicate embryo viability of dormant *Arctostaphylos nevadensis*seeds following acid scarification in concentrated sulfuric acid for 0 to 45 min. Embryo viability did not notably decrease even after 45 min in acid, although in a few seeds the endosperm tissues appeared slightly glassy and water-soaked around the micropylar opening where the acid had penetrated through the soft "micropyle plug". Other than penetrating the plug tissue, acid did not affect the seed coat even after 45 min. As in earlier trials, 25 min in acid was adequate time for the plug to be eroded, without any apparent damage to embryo or the endosperm. In most cases, viable embryos stained evenly in shades ranging from light pink to red, while most endosperm remained white or very light pink. Thus a glassy, water-soaked appearance of endosperm rather than TZ uptake may be the best indicator of over-treatment in acid. Seed coat thickness was not reliable as a guide in determining optimum acid scarification times in *A. nevadensis* seeds.

INTRODUCTION

Chemical scarification by soaking dormant seeds in concentrated sulfuric acid is recommended for many species of tree, shrub, and forb seed. Since the optimum treatment timing varies for different seed lots of the same species, the usual recommendation is to test a range of acid soaking times and then to observe the extent of thinning out or surface pitting of the testa by cutting and examining the seed coat. For some species, however, this may not provide an accurate assessment of the effects of scarification on inner seed tissues. For example, in seeds of *Arctostaphylos nevadensis*, the micropyle plug tissue is eroded well before the testa is affected (Schopmeyer, 1974). For this and many other species, additional and often lengthy stratification time is required to break endogenous dormancy. For A. *nevadensis*,even after scarification and lengthy stratification regimes, low germination rates (often 1% to 2%) are commonly reported (Carlson and Sharp, 1975). Schopmeyer (1974) reported varying success rates in other *Arctostaphylos* species by pretreating with acid for 3 to 15 h, followed by stratification to achieve up to 50% germination in*A. uva-ursi*. Others working with*A. nevadensis*,however, have found that acid soaking for 2 to 4 h degraded the seeds to mush, while shorter soaking times did not appreciably thin the seed coat or enhance germination (Colleen Archibald and Frank Callahan, personal communication).

Unfortunately, initial and post-treatment viabilities in some of the earlier studies were not reported. Knowing the viability and thus the maximum potential germination of a seed lot would be useful in evaluating the relative success of different treatments. Also, little is known about seed longevity for some wild shrub and forb

seeds either in controlled storage or natural habitat.

Fortunately, several methods of detecting viability in dormant seeds are available and in use in the seed-testing industry. Briefly, the basic methods include tetrazolium (TZ) staining to indicate enzyme activity and thus viability in hydrated seed tissues, root growth testing using a hydrogen peroxide presoak to initiate growth, incubation of excised embryos, and X-ray testing. Bonner et al. (1994) provide a brief outline of the methods, advantages and limitations of each type of test. X-ray analysis requires expensive equipment and training, but each of the other methods are readily adapted to small-scale, bench-top operations. Seed analysts familiar with the tests can often provide guidance in choosing and adapting the procedure best suited to a particular seed lot. Standardized procedures for some species are outlined in the International Seed Testing Association (ISTA) Rules Annexes (1985). Procedures for other species are continually added in the journals of professional seed analysts and testing associations. Vivrette (1995) recently described a technique of presoaking seeds in gibberellic acid (GA_3) to promote staining of tissues in deep dormancy that might respond slowly or not at all to TZ alone.

PROCEDURE

A study planned by the Plant Materials Center in 1993 and conducted at the Oregon State University Seed Lab determined that a 25-min soak in concentrated H_2SO_4 effectively eroded the micropyle plug without apparent damage to the embryonic tissues within. Tetrazolium viability testing of the seed lot before acid treatment showed 60% viability. However, viability tests were not repeated after acid treatments. We felt it would be useful to repeat the acid treatments, testing the seed after as well as prior to acid scarification.

In 1995, acid scarification and stratification procedures were repeated on *A. nevadensis* seed harvested in 1991 and 1993 from 1980-m elevation at Crater Lake National Park in Oregon. Air-dried seeds had been stored in the dark in cool, ambient air at 5 to 15C. Acid scarification was performed according to the methods outlined by King (1990). Acid treatment times ranged from 10 to 45 min. A 1% TZ solution was prepared according to the method in the ISTA (International Rules for Seed Testing Annexes, 1985). Seeds were bisected longitudinally to expose the embryonic axis and soaked in TZ stain for 24 h. Samples (n=25) of treated and stained seeds were examined by stereomicroscope to observe the extent of acid penetration and any effects on the viability of internal tissues. Stained seeds were stored in 85% lactic acid to preserve them for observation and photography. We also started several stratification regimes, varying the duration of both warm and cold periods. These seeds are due for germination checks in late fall of 1995.

OBSERVATIONS

Initial viability as measured by TZ staining for 24 h was estimated at 60% and 50% for the 1991 and 1993 lots, respectively. This estimate did not take into account seed that may have been in a state of deep dormancy because we did not pretreat seed in GA_3; in the case of coalesced units consisting of more than one nutlet, only one embryo was treated and observed. For purposes of this trial, seeds were counted as "normal" if the entire embryo was evenly stained from light pink to red. In most seeds, the endosperm did not stain. No instance of stained endosperm but non-staining embryos was encountered. Several embryos were so lightly stained they

were difficult to classify. In retrospect, the use of GA_3 might have enhanced the clarity of the results.

The most notable result was that even after 45 min in acid, nearly twice as long as the previously determined optimum time, little damage was observed to the endosperm and embryo of most treated seeds. Injury seen in a few of these seeds appeared as glassy or watery endosperm tissue at the micropylar end. Of these seeds, only three contained incompletely stained embryos and one of these abnormal embryos lacked staining at the cotyledon end rather than the radicle. While the small sample size of these preliminary tests and the presence of some lightly stained tissues precludes the use of statistical analysis, information from this trial indicates a window of time for effectively treating the seed without destroying internal seed tissues.

A question arises whether acid scarification is, in fact, advisable for this species. It is not known how long seed viability persists once the protective plug is eroded. The seed will have to fend off pathogenic organisms during the period of incubation to overcome endodormancy. To answer this question, TZ testing of non-germinating seeds is planned following stratification and greenhouse seedling emergence trials.

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"Seeds" Question-Answer Period

Anonymous: What can I use to distinguish between two populations of pistache seeds, one resulting from open pollinations among 25 genotypes and the other a closed-cross between two?

Ray Maleike: You may want to propagate from cuttings since pistache is capable of that.

Bob Buzzo: Mark, do you wait until the radicle emerges before you put them in the tray and then you don't cover the acorn?

Mark Krautmann: We cover the acorn with a rudimentary covering of soil mix; we don't use sand or anything fancy. We use the same soil as we use in the potting mix. Most of our oaks are pre-germinated.

Anonymous: Are the oak plugs planted mechanically or manually?

Mark Krautmann: It is all done mechanically. We use a custom-made transplanter.

Verl Holden: What acid concentration did you use for the *Arctostaphylos* treatment?

Joan Trindle: Ninety-eight percent sulfuric acid.

Verl Holden: Was that with constant agitation?

Joan Trindle: It was stirred gently the entire time.

James Kraemer: Have you grown out the seeds that were treated to see how the treatments affected seed germination?

Joan Trindle: They are just coming out of stratification this fall. I will try to germinate them and if they don't I will check their viability again using TZ.

John Shogren: What was the stratification treatment you used?

Joan Trindle: Two to 4 months of warm stratification followed by 3 to 7 months in cold stratification in a peat-perlite mixture at 40F.

Production Scheduling of Cuttings

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Monrovia Nursery Company was founded on a 10-acre site in Monrovia, California, in 1926 by Harry E. Rosedale. Today, the nursery produces approximately 42 million plants on 1300 acres using 1700 employees. Currently there are three locations, Azusa, and Visalia, California, and Dayton, Oregon, that ship throughout the United States, Canada and some foreign countries. We grow 1300 different taxa of shrubs, trees, perennials, vines, and topiaries all in a range of sizes creating multiple propagation techniques and finish dates.

Propagation at Monrovia Nursery includes 19 acres of greenhouse between Azusa and Dayton (Visalia at this time has no propagation facility) that produce 33 million rooted cuttings annually. The different methods of propagation include: rooted cuttings, tissue culture, seeds, division, grafting and air layering. Rooted cuttings comprise 90% of our production; seed approximately 7%; and tissue culture, dividing, grafting, and air layering at 3%.

I started my career at Monrovia Nursery in 1987 after completing a 10-week internship with the nursery. For the first 4 years I ran the liner division then became the assistant propagator and finally ended where I am today as propagation manager in the Oregon location. The nursery was approximately 360 acres back then and has grown since to 565 acres with 300 additional acres due to be completed within 3 years. With this type of rapid expansion, propagation has gone through many changes. It is my responsibility to propagate quality plants, on schedule, in the right quantities, and most importantly to make a profit for the nursery.

In the 1980s when the propagation department in Oregon began to produce cuttings, all plants were rooted in flats. Once the cuttings rooted they were transplanted into liner pots until they were of size to be canned into 1-gal containers. An index card file was kept that had all pertinent information, such as rooting hormone, cutting type, propagation soil type, mist requirements and any other key information. Once out of propagation, plant production followed a seasonal schedule, but no records were kept. It was a seller's market so if the timing was off on a particular item we would still be able to sell it.

In the 1990s things for the nursery began to change. We were getting bigger. With three locations, 1700 taxa in production, growing as many as five sizes, and labor becoming in short supply we had to prioritize our production through scheduling. In the past we relied on more seasonal schedules. It was a buyers' market and the competition was stiff. Our customers were managing their inventories by ordering smaller quantities more frequently. We realized we had to be able to grow plants better, faster, and cheaper. Our customers were indicating when they wanted their plants ready and what plants we should be growing. The scheduling of production to meet our customers' demand was necessary to stay competitive in the marketplace.

So how do you begin to get the nursery experience that is in everyone's head down on paper? We began by writing down crop times for the 1-, 2-, 5-, and 7-gal sizes. Once we got this together our sales force gave us projections on when our customers wanted their plants ready. We call these projections ready dates. Now we had the finishing times on crops and the ready dates. From this point we worked backwards

to adjust when a crop needed planting to be ready for sale. For example, if a 1-gal *Juniperus×media* 'Monlep' Mint Julep™ juniper was needed for March, 1996 sales, it needed to be planted from a liner into a 1-gal container in September 1994 (wait times during the winter months were factored in). The liner size takes 12 months to finish, they needed to be potted from rooted cuttings into liners in September 1993. The cuttings take 8 months to finish; they needed to be cut in January 1993.

While production was working on getting schedules finished for all sizes and taxa of plants, our computer needed programming to handle all of the information being generated. Once the programming was finished we were ready to input schedules with planting dates and ready dates into the computer. This process has taken 2 years and as we learn more about crop finishing times we are continuously adjusting schedules. Now we are able to print planting schedules by month for all sizes—that enables us to better calculate (juggle) our labor, material, space, and time requirements.

Labor is one of the factors that influences our propagation schedules. There are some things at the nursery that must be done on schedule, such as shipping (March through May), and winter protection (November and February.) In June, after our busy shipping season, we generally lose employees to other agricultural industries and during the winter months, from December 1 to February 15, our company policy allows employees to take up to 8 weeks unpaid leave. All of these factors influence our propagation schedules.

We are able to help our vendors in their effort to supply us with materials. The monthly schedules give us information, such as how many containers are needed, how much soil needs to be mixed, and how many canning machines will be used during the course of a month.

Space, next to labor, can be a stumbling block in keeping plants on schedule. If a crop is slow to finish, has disease problems, or isn't in demand by our customers space for new canning can get tight. Our propagation facility has 80 mist beds that turn over 4 times each year. I need approximately 300 mist beds per year to propagate cuttings on schedule. This number is increasing as the use of plug trays increases. Turning over our mist-bed space four times per year may not seem like a lot but consider our conifer crop sits in the mist for 4 to 6 months. The remaining 6 months, each bed is used 3 times. Our softwood cuttings root under mist and get moved out of mist in short order.

So, how does all this affect propagation? We had to look at ideal cutting times and see if these were in sync with our ready dates. In many cases we were pushing seasonal boundaries by balancing ready dates with labor, material, and space needs. Different propagation techniques, such as air layering, tissue culture, and taking cuttings at different times of the year were considered. We also looked at taking some shortcuts in the production cycle, such as direct sticking cuttings into liner pots, taking rooted cuttings into 1 gal, and more recently the use of plug trays on many crops. We found by using some of these shortcuts we were able to cut a year off some crop cycles.

CUTTING CALENDAR

■ March	Hardwood cuttings
■ April-September	Softwood cuttings
■ October	Rhododendron cuttings
■ November-February	Conifer cuttings

We typically prepare and stick cuttings year-round. Our production calendar year starts March 1 (Fig. 1). We are typically busy shipping plants this month and much of the labor force is pulling orders. Hardwoods are usually ready to cut the end of February or early March. We do very few cuttings of this type. Generally, hardwood cuttings supplement our softwood cutting crop. There are a few taxa we do as hardwoods, such as *Populus, Salix,* and *Prunus ×cistena.*

Our softwood season runs from April to September and is approximately 7 million cuttings. We prepare a cutting list that includes: stock code number, plant, month to cut, method, amount to cut, amount cut, liner net (this number indicates how many liners we intend to sell as liners,) 1-gal canning maximum (this is the total number of 1 gal we intend to produce for sales and shifting into larger sizes,) and 1 gal canning date or ready date. We keep this list on computer and update it with the cutting production numbers daily. We sort the list by month to cut and distribute to the respective growing areas that will be taking the cuttings. The growing areas coordinate taking the cuttings with our cutting manager. The list enables us to see if our cutting production is on schedule by looking at the total number of cuttings that have been completed for the month. If we are not on schedule, we look at possible reasons and determine how to get back on schedule. Possible reasons for being off schedule might be too little labor, our schedule might not be correct, the cutting wood may not be ready at the projected time, and space or materials limitations. A particular plant may have several entries on the softwood cutting list due to split schedules for the 1-gal sizes, sticking cuttings by different methods, or sticking cuttings for our other locations (Visalia or Azusa).

We have been rooting a large percentage of our cuttings into liner pots (or direct stick). Nearly 80% of the softwood cuttings are direct stick. Until recently, direct stick always meant individual liner pots. In our effort to mechanize the propagation end of the business, we are using plug trays. We are currently doing 75% of our softwood cuttings in plug trays. This not only saves the labor to put pots into flats for direct stick, but also saves labor to grade plants before they go to 1-gal canning. Each time the softwood cutting list is updated, we total the "amount cut" column and compare it with the "amount to cut" column; that gives us an overall picture of our production for that particular cutting season.

Another list we print gives our cutting crew and supervisors important information they need to prepare the cuttings. This list includes the stock code number, plant, month to cut, method, rooting %, hormone, soil type, and key plant (a key plant means our sales staff has put a priority on this plant which helps our supervisors and crew make decisions on prioritizing production.) Both cutting lists are a part of a spreadsheet program in our computer. The supervisor can select what information she/he needs.

Softwood cuttings usually finish mid to late September just in time for our rhododendron cuttings. Our rhododendrons in the field are pruned in June and grow out by September for us to get cutting wood. We produce approximately 750,000 rhododendron cuttings annually. In the 1980s we stuck all of our rhododendron cuttings into flats containing 60% peat moss and 40% perlite. We would transplant into 4-in. liner pots. This process would take 2 years to get a liner ready for 1-gal canning. Often we found we were overgrowing our rhododendron liners. We started to directstick rhododendrons into liner pots in the 1990s. By doing this, we can cut 1 year off our schedule. We direct stick the rhododendron cuttings in October and

they are ready to can into 1-gal in June the following year. By direct sticking our rhododendrons into liners, space in the mist house can be a problem. We went from getting 40,000 cuttings into 1 mist bed to 22,000. By shifting some of the September softwood cutting production to August we were able to come up with enough space to get our rhododendrons into mist beds. Another problem was the coordination of cutting wood. The pruning of the stock plants has to be done on time and the crew selecting the cutting wood must be trained about what ideal cuttings are.

By the end of October the mist house is fairly empty, except for the rhododendron cuttings; we are ready for our conifer cuttings. We produce approximately 6 million conifer cuttings annually. In the past all of the conifer cutting crop was stuck into flats. Over the last 3 years we've been experimenting with direct stick conifers and, more recently, with plug trays. Direct stick and plugs use nearly 4 times more space for rooting than if the cuttings are stuck into flats. Again, with direct stick and plug production we can cut nearly 1 year off our production schedule. The cutting lists for both the rhododendron and conifer cuttings are identical to the softwood cutting list.

At Monrovia Nursery we started scheduling production 5 years ago in an attempt to better serve our customers. Our production scheduling is gradually evolving as we learn more about particular crops and crop timing. As growers and managers at Monrovia Nursery we are constantly learning and gaining knowledge as experts. Our goal is to produce a quality product in a timely manner and produce a profit. We are striving to reach that goal every day.

Controlling the Propagation Environment with a Computer

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I have been around the nursery business for 27 years having been groomed by my father. As a kid one of the first jobs I had was stripping the leaves on azalea cuttings after school and on weekends. I have been at the nursery full-time for 14 years, starting in ornamentals production, from propagation to sales.

I have always been interested in doing things the easy way. As kids, my brother Rick and I worked in the nursery. One job we hated was cleaning wood flats after liners were transplanted from them. Broken and rotten flats were discarded so we didn't have to clean them. One day we decided to break some newer flats and discard them, the only problem was, we got caught. Our dad made us repair them and it was a lesson well-learned.

In May of 1979, our nursery experienced a fire in our propagation house. Our dad always told us if there was ever a fire in a greenhouse, turn on the sprinklers and get out. I went in to turn the sprinklers on and there was no water. The electric line to the pump had broken and that was what started the fire. The greenhouses contained rooted azalea cuttings, ready to be transplanted to the liner stage. It was a total loss. I tell this story because I was there a few minutes after the fire started and felt helpless, I had no control over this environment.

In 1989, we started using a computer environment control system. We built a range of Stuppy Greenhouses with gutter vents and wanted computer-controlled vents. The system turned out to be a flop. We did not do enough research on computers. It was not predictable. It would open vents when it was freezing outside, turn off the heat, and caused many other problems. It was eventually replaced.

Rick and I did not give up even though our dad had seen enough of computers for awhile. He was ready to go back to thermostats for control. Then a computer company made us an offer we could not refuse. They offered us the equipment for 6 months on a trial basis; all we had to do was install it. It worked so well in the first 2 months that we ordered more equipment to do more ranges.

The first success we encountered was in humidity control. The azalea crop we were growing was an early one and had to grow during the winter. We always had trouble in double poly houses with condensation dripping on the foliage. This caused distorted leaves, little or no growth, and disease problems. With the computer we were able to lower the humidity allowing the plants to grow. Our dad hated to see fans drawing in cold air from outside and reheating it, but this method really lowered our humidity. We figured if we gained more #1 grade plants it would be worth the extra cost for the energy. Our energy bill increased by about 15% or $6000. We gained about $500 per house in quality of plants × 30 houses = $9000 gain per crop cycle. We were sold on the value of computer use in greenhouses.

Some major reasons to computerize the greenhouse environment:

1) Accuracy is the major benefit of computerizing. In a propagation house, water

is a critical factor, misting cuttings using light level rather than time is preferred. The computer will adjust the mist frequency as the weather changes, i.e., if you have a bright sunny day and the mist is averaging 10 min apart and suddenly clouds come in for 1 or 2 h, the mist frequency will be adjusted automatically. With time clocks someone would have to be adjusting them continuously. My point is to mist the plant when it needs it, not when the time clock says it is time to mist. Think about how you mist your cuttings. Are they really getting the water they want and need or are they getting what the grower thinks he wants to give them? It is hard to get growers to adjust a time clock several times a day, so they tend to apply too much water to cover themselves when it gets hot in the greenhouse.

2) Troubleshooting is an area where I use our computer a lot. One morning I was called to the propagation house. Under the benches it was 85F when normally we run 68F. The first thing I did was check the graph on the computer. The climate temperature was right, but the air under the benches was too hot. I then looked at the energy curtain, it was fully opened, but the computer showed it should be closed. I found out that one of the guys left the curtain in manual open position and forgot to change it back to automatic. On another occasion I found out that our heating pipe in one greenhouse range was too small. The plants in this range were always small and we could not figure out why. By graphing the climate temperature and heat target, I was able to guarantee that when it was below 35F outside, the house would drop below the heating target. As soon as the sun would come out, it would come back to temperature. By recording this I was able to raise the temperature on the boiler and also put different plants in this house. Without redoing the whole heating system we were able to adjust and get by with the system we had. My point is, a person cannot live in a greenhouse 24 h a day. With the use of a computer, you are able to record what happens in the greenhouse 24 h a day. Think about times when something was not growing right, were you able to find out what was wrong and were you able to correct it? A computer makes this task easier.

3) Another benefit to computerization is archiving. Archiving enters a record on the hard disk every night at midnight of all the days events. It can be used to track high and low temperatures, what equipment was running and several other things. One time I used the archiving records to set the light level on the shade curtain. I went back and looked at the highest light level for the season and worked down from that level. It sped up the process greatly because I had a starting point from which to work. It can also be used to graph how many times the mist ran in the propagation house, which is useful to use as a reference.

The major concern with computers is finding one you can trust and then trusting it will work for you. Questions always run through your mind, am I going to ruin a whole batch of cuttings or range of plants? You wonder this if you don't fully understand the settings you have set and how the computer is going to operate to achieve those settings. I suggest if you are looking at a computer, sit down and spend time up front to fully understand the system, so you can take full advantage of it and make yourself a better manager.

One final thought, a computer will never replace the human element of propagation, it only makes it easier. Our dad always taught us to never trust a machine, always keep an eye on it to make sure it is working.

A Unique Approach to Mass Propagation

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Assistant Propagator, Bailey Nurseries Inc., 9855 NW Pike Rd., Yamhill, Oregon 97148

At Bailey Nurseries, West Coast Division, we are faced with propagation challenges that mandate a "unique approach to mass propagation". We are asked to propagate over 420 different taxa of woody plants, collect and stick 3-1/2 million softwood cuttings, and accomplish this task inside a very short window of time. We normally start around May 15 and end around August 15. This means we will stick approximately 45,000 cuttings per day. We stick 1 million hardy shrub roses of 90 different cultivars, 2 million shrubs of 200 taxa, 1/2 million trees of 100 taxa, and 30 taxa of vines. This obviously requires a great deal of scheduling, planning, orchestrating, managing, and communicating. Attention to detail, patience, and good humor hold it all together.

The system we use was in large part developed by Mr. Jim McConnell, long time I.P.P.S. member and propagation manager at Yamhill for the past 15 years. It is his knowledge and insight that has allowed our program to grow and evolve into what it has become today.

The vast majority of our cuttings come from our own fields and containers. This practice ensures that our sources maintain their juvenility, a factor that we feel is partly responsible for consistently high rooting percentages. With the exception of our virus-indexed material, very little comes from stock blocks. We maintain two full-time cutting crews of 10 to 15 people, one at our Sauvie Island location and one at Yamhill. We attempt to make the desired cutting in the field at the time they are taken. By minimizing the number of times cuttings have to be handled we speed up the process of getting them into the greenhouse. We also receive unfinished cutting material taken from plants that are limbed up, pruned, or cut back. This material is then processed into usable cuttings. As with all propagation, timing is critical, so a considerable amount of time is spent in the fieldsdeciding when particular plants are ready to cut. Cultural practices are reviewed with farm foremen to ensure that our best cuttings are not left laying on the ground behind a pruning crew.

The cutting crews take, prepare, and count the cuttings, place them in plastic boxes with drain holes, label them with date, plant name, source, count, and keep them wet until they can get to the cooler. Our ultimate goal is to get the cuttings from the field to the greenhouse as quickly as possible. While it is most ideal to stick cuttings within a day or two of being taken, realistically it can easily be 7 days before some are actually stuck. As long as the cuttings are kept moist and cold, we notice little adverse effects associated with waiting.

Using our cooler as a staging area for the cuttings and always being mindful of processing the oldest cuttings first, we determine the order plants will be handled, the appropriate rate and type of rooting hormone (IBA, KIBA, or Wood's Rooting Hormone) to be used, and the order they will be planted. While it is not always practical, we try to keep "like rooting" plants together in the greenhouses. It's definitely worth the effort when it comes to Greenhouse management. Another criteria for grouping plants in the greenhouse is whether or not they are scheduled to be dug dormant. If they are to remain in the greenhouse for early summer field

planting or containerizing we attempt to keep them together. This practice minimizes the amount of greenhouse space that is tied up into June. It is essential for us to have as many houses as possible available for the beginning of the season.

We propagate in hoop houses, 30 ft × 148 ft, in ground beds of pumice. We currently have 38 greenhouses totaling about 4-1/2 acres under poly. All of our houses are equipped with mechanical irrigators manufactured by Growing Systems. We feel it is the mechanical boom that is the key element of our system allowing us to propagate such a diverse group of plants. It is not uncommon for us to have 30 to 40 different crops in the same greenhouse, each requiring a different misting regimen. We have continued to use the Growing Systems booms because of its relatively simple design and ease of maintenance. It is also our belief that one system is easier to manage than a mixture.

Prior to planting, all of our houses are fumigated, rototilled, and watered. We utilize a 55% shade cloth to keep the house cool while the crew is working and leave it on the newly stuck house for up to 3 days after finishing. This provides the plants a low stress time to acclimate to the new environment. To facilitate the planting of our cuttings into the greenhouses quickly, we utilize two sticking crews for most of the summer. We have one crew made up of local high school and college students that work mid-June until mid August, and one crew from the Nursery labor pool that will be with us from start to finish. A crew consists of 8 stickers and one person to water-in, count, and keep the crew supplied with cuttings. There are two people per bed, 4 beds per house. The crew starts at the end of the house closest to the irrigation boom and plant evenly across. Keeping the plants in even blocks across the house allows the grower a way, through the use of actuator switches on the boom, to skip over fast rooting plants while maintaining the mist on the slower rooting varieties.

Our greenhouses are monitored sun-up to sun-down, 7 days a week, all summer. Misting frequency is totally dependent on the weather. Because we close the greenhouse doors during the rooting process, it is not uncommon on hot days to run the mist continuously. Ideally, the mist is set according to the weather conditions to provide the least amount of water possible to maintain the turgidity of the cuttings. Keeping the cuttings from wilting without making them too wet is the biggest challenge for the greenhouse monitors. Frequency of misting is more important than quantity of mist. The general rule of thumb is "just enough" but "not too much". It is critical that the greenhouse monitor walk through every house, as often as possible, to inspect all of the crops in the houses. High temperatures combined with high relative humidity results in fast rooting. The flip side of the coin is, high temperatures combined with inadequate moisture result in large brown spots in the greenhouse. These are not desirable. One advantage we have is consistently cool, calm nights. This allows us to open the doors of all the houses at night. No matter how much water you have to use during the heat of the day, this gives the plants a chance to "dry down". The real advantage here is the virtual non-use of fungicides.

As the plants root, they are slowly weaned from the mist. Misting frequency is gradually reduced until it is no longer needed. It is during this weaning process that our fertilization program is started. When the majority of the cuttings in the house have initiated roots, we feed the entire house a starter fertilizer (4N-16P-3.2K-2.1S) in liquid form directly through the boom at about 200 ppm N. We use a portable injector of simple design, for our "starter" solution. It is easy to use and was relatively inexpensive to build. We follow 10 days later with a growth fertilizer (8N-4P-8K-

5.4S) in liquid form, at 400 ppm N, and then every 10 days until the house has had three applications of the growth solution. We have a central injector we use for the 2 : 1 : 2 so we can fertilize two houses at the same time, making scheduling easier. Because our goal is to be finished fertilizing by the 31st of August, some of the cuttings in the "late stuck" houses do not get the full treatment. These houses all get at least one application of the "starter" followed by 0N-30P-30K sometime in Sept./ Oct. to help with hardening off and over wintering. In the spring, we will continue the fertilizer schedule for the crops that are overwintered in the greenhouse, until a total of three applications of the 2 : 1 : 2 is provided.

The obvious result of an intensive fertilization program is increased growth. This in turn requires more maintenance. We maintain uniform size and shape through the use of a mowing system. A Honda mower was chosen for its ability to remove the cut debris. By selecting cutting heights, we can either have short, multi-branched shrubs or tall single-stemmed tree liners. Our goal is to have large caliber liners, with fibrous root systems of uniform size.

Pesticide use is minimal, usually spot applications when needed. Our two worst pests are aphids and spider mites. Solo backpacks are used for spot sprays and a 50-gal sprayer is available for whole-house treatments. When we do spray, every attempt is made to comply with the federal "Worker Protection Standards".

We make use of a computer-aided inventory system, custom designed for our use. It is absolutely essential that we have a reliable method of tracking the plant material. This becomes very apparent at digging, grading, storing, and shipping time. Final destinations for our rooted cuttings include our own West coast dormant and green plantings, Minnesota plantings with a small percentage destined for sales. Cuttings that are dug dormant are graded, root-pruned, if appropriate, counted into lots of 100, labeled, and "jelly-roll" wrapped. They are then either stored frozen in our cooler or sent back to Minnesota for planting or for sales.

In conclusion, let me reiterate that our system has been developed based on our own unique needs to meet our goal of producing the best possible liner material for an incredibly diverse range of woody plants.

"Cuttings" Question-Answer Period

Margorie Sweeney: Where do you get your cuttings from?

Chris Santana: Almost everything is from stock in the field.

Robert Abe: What fungicides do you use as a cutting dip?

Chris Santana: We use several different rooting hormones, such as Dip-N-Grow, Hormodin, and Hormex. We steam pasteurize our beds between crops. We use small quantities of Subdue on an "as needed" basis.

Anonymous: How do you use ozone? Have you noticed an improvement in rooting from ozone-treated cuttings?

Tom Fessler: We use a little swimming pool ozonator. Cuttings are dipped in an ozone-rich solution. We have noticed improved rooting and are very pleased with the ozone-treatment techniques.

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Bruce Briggs: Is your computer system measuring or monitoring when to apply water to your gallon-size plants?

Tom Fessler: Our computer is capable of doing that, but we haven't programmed it to do that yet.

John LaForge: What medium do you use inside your greenhouses?

Randy Murphy: It's all pumice in the ground beds and is 10 in. deep with two drain lines under each bed.

Divide and Conquer: Propagation of Herbaceous and Tree Peonies

Richard W. Rogers
Caprice Farm Nursery, 15425 SW Pleasant Hill Rd., Sherwood, Oregon 97140

INTRODUCTION

If there is a critical moment in the propagation of herbaceous peonies (*Paeonia*), it comes at the very moment you attempt to divide a mature plant. All of your dreams for commercial success hinge on that decisive cut. Like the diamond cutter in the TV ad perched on the back seat of a moving car, the next stroke will determine if you'll walk away with two, five-caret stones or a lot of worthless chips.

In the next few moments, I will share with you how this operation is performed at Caprice Farm Nursery. Whether for walk-in customers who will closely inspect our peonies on-site or for our mail-order clients who rely largely on our reputation, we endeavor to provide our customers with healthy, well-grown plants of the highest quality.

HERBACEOUS PEONIES

Let's begin with a caution. Avoid using older plants since by the fifth year the clumps will have grown too big and too heavy to lift without damage to man or peony. I start with a well-watered 3- to 4-year-old plant. I cut the foliage to within 4 in. of the ground. Next, imagine a circle 32 in. in diameter (or 16 in. out from the crown). Using a garden spade and following that circle, dig down the full length of the shovel face, producing an inverted cone of root mass and soil. Supporting the cone with both hand and spade, lift the root mass free of the hole, being careful not to break the brittle roots.

Now off to the work station. Wash the clump, completely freeing it of all clinging soil. Left in place, the weight of this soil is enough to produce unacceptable levels of breakage.

Here's where your money is made or lost. Examine the clump carefully. Count the eyes and find where the main roots connect to the crown. The "eyes" or buds are similar in appearance to those found on the common potato. When done, you'll want three to five eyes supported by a root system at least 8 in. in length.

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In choosing a cutting device put emphasis on comfort and controllability. Some workers prefer a knife. I'm happier with a #4 or #6 FELCO clipper.

After I have determined where my best divisions are to be found, I make my first cut. Gently pull on one side of the root allowing the blade to shear through cleanly. Sometimes this shear cut must be made in several small steps. It depends on root size and toughness. After all retail-size divisions (divisions with three to five eyes each) are cut, they should be trimmed of all small thread-like rootlets. This trimming promotes faster growth and healthier plants. Any broken or rotten roots are also trimmed off at this point. I then plant back all the smaller pieces—these may take additional years to reach digging size.

Hybrid cultivars are different from *Paeonia lactiflora* in that the eyes tend to cluster on thinner necks which makes dividing more difficult and consequently produces lower yields. It is this lower yield that accounts for the higher price of most hybrid peonies.

TREE PEONIES

This may sound trivial, but it is extremely difficult to keep cutting instruments used in grafting clean and sharp. With each cut, a purple, starchy, hard-to-remove residue builds up on the blade's sides and edge. Moreover, I believe that this residue may come to harbor an infectious contaminant. Since razor blades are very cheap, I use a fresh single-edge razor blade for each graft.

I start in early-August with a 2- to 4-in. scion from the mother stock with at least one bud. The second component is a herbaceous *P. lactiflora* root 8 to 10 in. long and from 3/4 to 1 in. thick. In turn, I make a cleft graft on both, line up the cambium, and wrap securely with grafting tape. This newly grafted unit is packed into a plastic lined crate containing barely moist peat moss. I keep the new graft at approximately 80F for 2 to 4 weeks until the grafted elements have knitted together. It is then planted in a trench of well-worked soil with the top of the scion 4 to 5 in. below the soil line.

Al Rogers, the senior partner at Caprice Farm Nursery, has written a very comprehensive book on *Peonies*. Published by Timber Press and just off the presses, peonies, covers plant propagation as well as worlds of other peony-related matters. It is the first major work on the subject to be produced in 78 years.

Methods of Propagation for Aquatic Plants

James K. Purcell
Jim's Water Gardening, 90760 N. Prairie Rd., Eugene, Oregon 97402

People not familiar with aquatic plants are sometimes intimidated by the prospect of cultivating and propagating them. Aquatic plants, unfamiliarity notwithstanding, are very easy—often annoyingly easy—to grow and propagate.

Basically, plants require light and nutrients (including water) to grow. Aquatics have an advantage over many plants in that by growing in water they have unlimited access to water, which is also a very efficient transporter of other nutrients. The primary limiting factor in the growth of aquatics then becomes growing space with sunlight. The best way for an aquatic species to survive is to secure as much available growing space with sunlight as possible. The aquatics best adapted to survive under these conditions are those that can grow and multiply quickly—very quickly, because many species of aquatics are using the same survival strategy. For example, if grown in optimum conditions, a single water hyacinth (*Eichhornia crassipes*) can multiply to over 1 million plants through division in a single growing season of only 5 months. While that is an extreme example, *Azolla* (a small floating plant) is capable of doubling every day.

Many aquatics go through drastic seasonal fluctuations and climactic cycles, and as a result are very adaptable to various water levels and water chemistries. Of course, there are little growing tricks and some species can be difficult to work with out of their natural environment. In general, though, aquatics are very easy to propagate, and with many species the real trick is to not be engulfed by them.

For convenience, I will classify aquatic plants into four groups according to their growth habit:

- Water lilies (genus *Nymphaea)* and lily-like aquatics
- Marginal aquatics, also referred to as "uprights"
- Floating aquatics
- Submerged oxygenating aquatics

Water Lilies and Lilylike Aquatics. These include both hardy and tropical water lilies, lotus (Nelumbo), Nymphoides (which look like small water lilies), water poppy (*Hydrocleys nymphoides),* and water hawthorne (*Aponogeton distachyus*). These plants are characterized by having roots that anchor the plant in an earth bottom, leaf stems extending from the soil through water anywhere from several inches to several feet deep, and leaves floating on the water surface. Lotus are placed in this group in spite of the fact that in shallow water their mature leaves do grow in an emersed state (up out of the water). Water lilies are the best known of the aquatics and usually form the foundation of pond plantings. By the way, water lilies are not actually a lily according to taxonomy.

Hardy water lilies in cultivation are hybrids of several species from temperate climates and will generally overwinter outdoors unprotected. Named cultivars are propagated by division. The rhizomes grow horizontally in the soil and new growing points develop along the rhizome. This is the same way a typical *Iris* multiplies. These divisions are separated and repotted with sufficient rhizome to support the new growing point. Division is best done while the plant is in active growth from

April through July. A typical plant may yield 3 to 7 divisions per growing season. Water lilies may also be propagated by seed, but this is not normally done, as desirable named cultivars cannot be produced true from seed.

Tropical water lilies in cultivation are hybrids of several dozen species from tropical climates, and will generally not overwinter outdoors unprotected in the United States except in the southern Zones 9 and 10. They are generally more spectacular than hardies, blooming more and later in the season. Their blooms stand up well out of the water and color choices include blues and purples, which are unavailable in the hardy water lilies.

Tropical lilies are divided into either day or night bloomers. Both day- and night-blooming tropicals are propagated by division from the dormant tuber. In the spring the tuber sprouts, sending up a slender growing point that becomes a small water lily. When this new lily has several small floating leaves, gently sever it from the tuber and plant. The tuber will send up another growing point and by repeating the process of separation you can typically generate 4 to 7 plants before the tuber is exhausted. Night bloomers may generate 10 or more.

Some day-blooming tropical lilies have another ability called viviparity. Viviparous varieties grow a new plant, which we call pups, out of the sinus node in the leaf. In some varieties these pups will form not only leaves and roots, but may bloom as well while still on the leaf. Viviparous varieties vary in their degree of viviparity. The most viviparous lilies can produce dozens of pups in a single season.

Lotus (*Nelumbo*) are magnificent plants which can overwinter outside down to Zone 4 so long as the tubers are in water deep enough to not freeze solid. They produce large numbers of banana-like tubers that should be divided in spring just before active growth begins. A single, established lotus plant can send out a runner extending 30 ft or more in a single season and this runner will form many overwintering tubers.

The *Nymphoides* and the water poppy are closely related to water lilies, but are smaller and have slightly different growth habits. Most send out runners like a strawberry plant, which root new plants. One, the water snowflake (*Nymphoides cristata),* is viviparous, growing a new plant out of every leaf.

Water hawthorne is a beautiful lilylike aquatic with long narrow leaves and small, white, vanilla-scented blooms. It grows freely from seed and may become a pest in an earth-bottom pond. Native to Africa, it grows and blooms in the spring and fall, coming up very early and lasting into winter. In the summer, it goes dormant, mimicking Africa where the shallow ponds dry up completely and bake in the hot summer sun. This adaptation to its harsh native environment gives us a delightful little plant up and blooming both earlier and later than most other aquatics.

Marginal Aquatics. These are plants that root into soil and grow with their leaves up out of the shallow water around the edge of water features. They may grow in damp soil or in up to about a foot of water. Taller marginals can adapt to deeper water than shorter marginals. Some are best suited for the bog garden, while others may survive in as much as 2 ft of water.

Marginal aquatics may also be classified as temperate or tropical. Marginals include water iris, cattail, pickerel, papyrus (*Cyperus papyrus*), and variegated giant reed (see *Schoenoplectus lacustris* ssp. *tabernaemontani* cvs.). Most of these multiply by division, just like terrestrial plants. Some may be efficiently propagated by seed, such as papyrus and marsh marigold (*Caltha palustris)*, but most multiply so

quickly by division that it is the preferred method of propagation. Some, like the iris and pickerel (*Potederia cordata*), have a horizontal rhizome that develop new growing points. Many, such as cattail and pennywort (*Hydrocotyle*), send out a complex of runners which quickly produce a stand of plants. Some, like marsh marigold, form clumps which may be divided. Marble queen sword plant forms plantlets on flower stalks.

Floating Aquatics. These plants may be either temperate or tropical, but are most often tropical, as this growth habit does not provide as much protection from cold temperatures. They grow on the surface of the water, with leaves floating or raised slightly above the surface, and roots hanging down suspended in the water or occasionally rooted if in shallow water. Many have flotation devices built into the leaf or stem structure. Floaters are the fastest growing of aquatics, and include water hyacinths, *Azolla*, duckweed, frogbit (*Hydrocharis*), and water lettuce (*Pistia*). Typical reproduction is by division and most will send out runners like a strawberry plant. Smaller floaters, such as *Azolla*, form a carpet on the water and a plant 1/2 in. across can be broken apart to form 25 or more tiny plants. These small floaters quickly cover the surface and can be among the worst of aquatic weeds. On the other hand, they provide shade and food for fish and compete with algae for light and nutrients.

Submerged Oxygenating Aquatics. This group of plants grow completely under the water. Some, like the genus *Vallisneria* and dwarf sagittaria (*Sagittaria subulata*), root strongly into the soil bottom and multiply by sending out runners. Others, such as *Elodea* (syn. *Anacharis*) and *Cabomba*, root weakly if at all and quickly fill up the area between the bottom and surface of the pond. They are limited only by available light and nutrients and are easily propagated by stem cuttings.

Submerged plants are often referred to as oxygenators even though all aquatics, and all photosynthesizing plants for that matter, produce a surplus of oxygen. The term oxygenator is used because submerged plants release all their surplus oxygen under water and, therefore, raise the oxygen content of the water during daylight hours. This benefits many organisms in the ecosystem which require oxygen. The other benefits of submerged aquatics include competing with algae for light and nutrients and food for fish.

This has been a brief and basic overview of propagation of aquatic plants. Anyone who has experience with the propagation of a variety of terrestrial plants can quickly and easily adapt to the growing of aquatics. The main differences are in dealing with utilizing various water levels to assist in propagation and in recognizing and coping with the lower oxygen content of soil when saturated with water. The lower oxygen content of the soil encourages anaerobic conditions potentially harmful to the plant when it is most vulnerable, such as during dormancy or when newly divided and planted. The use of fresh soil, oxygenated water, and warm temperatures to encourage fast growth are some of the means used to cope with this potential problem. Organic fertilizers are best avoided (a time honored mistake in water gardening, where traditional literature still heavily endorses organics) for the most part because they require oxygen to decompose and steal oxygen from a system already deficient in it. Organics can most successfully be used in limited situations by growers who understand the biochemical process and can successfully manipulate it.

The culture of aquatic plants naturally requires the construction of special growing beds and special attention to their cultural requirements. Large-scale commercial growers have found it does not fit in easily with their overall program and it remains a specialty market. In order to address that market properly, it is important to provide a wide variety of aquatics for the consumer and to facilitate the availability and proper use of other pond products, such as liners, pumps, filters, etc. Extra attention is required to provide sufficient customer support.

However, you do not have to be a commercial grower of aquatic plants to appreciate them. I became interested in aquatics because they were fun. If you enjoy plants, you will enjoy aquatics. If you have been in terrestrial horticulture for some years, the differences are just great enough to pique your interest.

Terra Plug® Production

Gina M. Falcetti
Summersun Greenhouse Company, 4100 East College Way, Mount Vernon, Washington 98273

Terra Plugs® (U.S. Patent 5331908) are field-grown perennial plugs produced by a patented process developed several years ago by Carl Loeb and Bruce Gibson, the owner and general manager of Summersun Greenhouse Company. The nursery had been a large producer of bedding plants, baskets, and poinsettias and was interested in expanding into the perennial market. The search for an efficient and labor-saving way to produce field-grown perennials led to the concept of planting perennials directly into the field in 3-in. bottomless pots. The initial production crop was 500,000 plants and this year there are 2.7 million plants in the field. Currently we are growing 176 taxa, 40% of which are vegetatively propagated.

Propagation begins in the greenhouses at Mount Vernon, Washington in early April. Cutting material is taken from both container and field stock beds at the perennial farm. The first crops are those items requiring superior drainage or on which losses are fairly high, such as *Phlox subulata* or *Dianthus*. These are stuck in 200 cells in 100% perlite. By early May we are cutting and sticking an average of 40,000 cuttings daily, most directly to the 3-in. bottomless pot. Cuttings are placed on heated floors and mist or fungicides are applied by robots. We use the same 18-in. × 18-in. flat used throughout the nursery. Our spacer insert holds 30 plants and allows ample room for growth without overcrowding. We set the same spacer into a cardboard insert for storage and shipping.

Seeds are sown into 288-cell plug trays on one of three seed-sowing machines. They are moved into a sweat chamber for 2 to 5 days and then either to the greenhouse or to the freezer for stratification. Once established, the plugs are transplanted into the 3-in. pots and grown in the greenhouse for 4 to 6 weeks. When roots are visible at the bottom of the pot the plants are sufficiently established to withstand field conditions. At this point they are graded, racked, and trucked to the perennial farm.

Three to four weeks prior to planting, the fields are treated with Vapam for weed and disease control. Planting begins mid June and continues until early August, with an average of 100,000 pots planted daily. Terra Plugs® are planted in raised beds that are made with a Struik rotovator and hiller that has been customized to

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Propagation begins in the greenhouses at Mount Vernon, Washington in early April. Cutting material is taken from both container and field stock beds at the perennial farm. The first crops are those items requiring superior drainage or on which losses are fairly high, such as *Phlox subulata* or *Dianthus*. These are stuck in 200 cells in 100% perlite. By early May we are cutting and sticking an average of 40,000 cuttings daily, most directly to the 3-in. bottomless pot. Cuttings are placed on heated floors and mist or fungicides are applied by robots. We use the same 18-in. × 18-in. flat used throughout the nursery. Our spacer insert holds 30 plants and allows ample room for growth without overcrowding. We set the same spacer into a cardboard insert for storage and shipping.

Seeds are sown into 288-cell plug trays on one of three seed-sowing machines. They are moved into a sweat chamber for 2 to 5 days and then either to the greenhouse or to the freezer for stratification. Once established, the plugs are transplanted into the 3-in. pots and grown in the greenhouse for 4 to 6 weeks. When roots are visible at the bottom of the pot the plants are sufficiently established to withstand field conditions. At this point they are graded, racked, and trucked to the perennial farm.

Three to four weeks prior to planting, the fields are treated with Vapam for weed and disease control. Planting begins mid June and continues until early August, with an average of 100,000 pots planted daily. Terra Plugs® are planted in raised beds that are made with a Struik rotovator and hiller that has been customized to

inject Chapin™ drip tape into the hills as they are being formed. A specially designed dibbler follows behind the hiller.

Racks of plants are brought to the field and loaded onto the planter. Plants are fed to each of 4 planters below by a co-worker riding above on the trailer. Pots are set into the hills just flush with the soil surface. An irrigation crew follows behind and connects the drip tube to the lay-flat irrigation hose that feeds it. This subirrigation system is extremely efficient. The entire 110 acres can be watered in a single day, if necessary. A 750-gal-per-min pump draws water from a slough at the back of the property and filters out particles.

Fertilizer is applied regularly at 200 ppm through the drip tubes beginning 2 or 3 weeks after planting. Initially, we use Peter's Excel 21N-5P-20K, which is an ammonium nitrate-based all-purpose feed. In early autumn we switch to a calcium nitrate-based fertilizer 15.5N-0P-0K to prepare plants for dormancy.

Within days of being planted, Terra Plugs® are well-rooted into the hills. Throughout the growing season they are continually inspected for trueness to type and uniformity and culled as necessary. We mow and hand shear many varieties to encourage basal branching. Frequent shearing is especially important with *Phlox subulata* and *Dianthus* to produce a compact crown.

Beginning in mid December, plants are harvested from the field. This is accomplished by a piecework crew of 12 men and two pick-up crews of three men each. Roots are cut off flush with the pot and the plants are then placed in flats, racked, and transported to the barn for processing.

The majority of the plants are processed using two custom-made carousel trimmers. Plants are placed into rotating cups on the carousel and passed through sets of flail blades that can be adjusted to trim to different heights and widths. As they come off the machine, plants are placed into the spacer trays and cardboard shipping insert. They are re-inspected visually, labeled, and stacked on pallets to be transported to the freezer. All plants that go dormant are frozen at 28F prior to shipment. Evergreen plants, such as *Iberis* and taxa that do not store well, are harvested fresh and pre-cooled prior to shipment. We ship from January through May throughout the United States and Canada.

The end result of this process is a large, field-grown crown with the handling characteristics of a plug. Transplant losses are low and uniformity is excellent. Summersun produces 350,000 1-gal perennials annually from Terra Plugs® at our facility in Aurora, Oregon. We plant beginning in late February directly outdoors and begin selling the first pots in mid April. With the possible exception of a few of the later-breaking types, such as *Ceratostigma* or *Platycodon*, finished product can be produced in 6 to 8 weeks from transplanting. The larger crowns produce many more flowering stems and much more reliable blooms than containers started from smaller greenhouse-grown plugs. The Terra Plug® concept has made it possible for us to produce superior containers in a short period of time and it gives our customers an opportunity to add or expand a perennial program into an already busy production schedule without sacrificing valuable greenhouse space.

"Perennials" Question-Answer Period

Anonymous: Can you recommend some peony cultivars that will grow in warmer areas?

Rick Rogers: Get early-blooming singles and semi-doubles in the Japanese types. Tree peonies work well in California. Stay away from the late-blooming doubles. They will not be luxuriant in the Bay Area, but they will grow.

Kristin Yanker-Hansen: Does shallow planting help in providing the cold temperature treatment peonies need to bloom?

Rick Rogers: The shallow planting will help. Peonies need 400-900 h of sub-40F temperatures.

Joan Trindle: What kind of water quality issues do you face in your propagation and are any of the plants you work with candidates for some of the wetland/pond treatment facilities?

Jim Purcell: Absolutely. I am pondering putting in a septic system with a lagoon that actually replaces a septic system. Water hyacinths are routinely used in tropical countries and some of the warmer climates of this country, at least experimentally, for reducing the BODs in water and then using the plants as a mulch or livestock *fodder*.

Terry Finnerty: What regulations are in place, if any, to protect from the possible danger of spread of your plant materials?

Jim Purcell: The grower and shipper have the responsibility to know what restrictions may apply anywhere they ship.

Hannah Mathers: How are the insectivorous plants propagated?

Jim Purcell: They are propagated by division, but we are not propagating any of those at this time.

Carole Barnett: What medium do you use in the plugs?

Gina Falcetti: It's Ball #3 mix.

Anonymous: What fungicides are you using?

Gina Falcetti: Banrot is used as a preventative. In the case of *Dianthus* and *Phlox*, we use Chipco or Daconil to prevent *Alternaria*.

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Plant Propagators to the Rescue!

Gary A. Ritchie
Weyerhaeuser Company, The George R. Staebler Forest Resources Research Center, Centralia, Washington 98531

INTRODUCTION

Ladies and gentlemen, I am honored to have been asked to keynote this excellent I.P.P.S. meeting and extend my sincere gratitude to the meeting organizers for having invited me to come.

The organizing committee asked me to conclude this convention with an upbeat review of some of the many important contributions plant propagators make to the service of humankind. In response to this request, I have selected the title "Plant Propagators to the Rescue" and have chosen three case studies in which plant propagators have played a key role in solving a significant social problem. Two of these cases involve my own employer, Weyerhaeuser Company, while one involves the government of a communist country. Two are from here in the Pacific Northwest (PNW), one comes from the Peoples' Republic of China. Two involve forest trees, one involves medicinal plants. Two involve vegetative propagation systems, while one involves seed-based propagation. I was personally involved in two of these cases and completely uninvolved in the other. These choices are drawn directly from my own background in forestry in the PNW and all are subjects of my own personal interest.

CASE 1: TAXOL: RESCUING THE PACIFIC YEW

"I can think of no greater gift to mankind than the domestication of a wild plant" Thomas Jefferson.

Ovarian cancer is a particularly frightening disease. Because its symptoms often do not appear until it is too late for treatment, ovarian cancer kills about 12,000 American women every year. A ray of hope in the fight against ovarian cancer has arisen out of an extensive screening of natural plant products carried out by the National Cancer Institute (NCI) back in the 1960s. Of tens of thousands of natural products screened for activity against cancer, one called "taxol", a substance from the bark of the Pacific yew (*Taxus brevifolia*), showed considerable promise in tests against certain cancer types, especially those associated with ovarian cancer. The mode of action of taxol was found to be unique among cancer-fighting drugs and it promised to be a powerful new weapon.

Full-scale clinical testing of taxol began in 1981. These early trials showed great promise and more taxol was needed to continue further testing. Expensive and difficult to obtain, limited taxol supplies became a serious impediment to further evaluation of the drug. In addition, concern was mounting about the ability of the natural populations of Pacific yew trees to sustain this level of exploitation. Although the yew is neither threatened nor endangered, neither is it considered to be abundant. Furthermore, bark removal kills the tree and the trees are very slow growing.

In January, 1987, Dr. Nicholas Wheeler, a forest geneticist at Weyerhaeuser's Western Forestry Research Center, Centralia Washington, received a phone call from Dr. Gordon Cragg of the NCI. The NCI needed taxol to continue clinical testing

and wondered if Weyerhaeuser could supply 27,000 kg of Pacific yew bark. Dr. Wheeler's response was that we had very little Pacific yew on our ownership and that there were serious concerns about extensive bark harvesting and its impact on populations of this native tree species. Why not instead, he suggested, grow the plant as a short rotation nursery crop strictly for taxol production? But no one had ever done this before.

Plant Propagators to the Rescue! A Weyerhaeuser taxol team was formed, agreements were entered into between Weyerhaeuser, the NCI, and Bristol-Myers Squibb (B-MS) a large pharmaceutical company which had earned the government right to market taxol. The agreement was for Weyerhaeuser to develop, within 3 years, a propagation and cultivation system aimed at producing taxol biomass on a short rotation in a nursery. B-MS would be the customer for the crop.

There were many unknowns:

1) Can slow-growing yew plants be intensively cultivated in a seedling conifer nursery and would these small plants produce taxol?

2) How would we propagate Pacific yew: from seeds? from cuttings? where would we get the cuttings?

3) Is the Pacific yew the only species containing taxol?

4) Is taxol present in other tissues besides bark? If not, how would we remove the bark from small seedlings?

5) How would taxol content in the biomass respond to seasonal cycles and cultural practices?

6) What opportunities might there be for genetic improvement, then cloning high-yielding strains?

To shorten a very long and exciting story: after 3 years of painstaking propagation and cultivation research and operational experience, answers are beginning to emerge. This is what we now know: Yews grow extremely well in some of our bareroot nurseries, but not so well in others. This seems to reflect the absence or presence of certain essential mycorrhizal species. Seed propagation is very difficult, but a container-based cutting propagation system has been developed and is very effective. Virtually all species of *Taxus* contain taxol, and it is present in virtually all tissues of the plant except the wood. Some species (or cultivars) contain more taxol than others, and it is distributed among tissues differently in different cultivars. Season and cultural regime significantly affect taxol content. Bareroot nursery rotations of from 3 to 4 years can result in economic yields of taxol-containing biomass. There is a great deal of natural variation in taxol content among species and strains, hence there is much opportunity for genetic improvement.

Our first full-scale commercial harvest of taxol-containing biomass was carried out throughout our nursery system during the summer of 1995 in which close to 11 million 3- to 4-year-old yew plants were harvested.

We believe that a nursery-based production system for taxol biomass has the potential for meeting present and future world demands for this drug, which is now being shown to be effective against other cancer types, such as breast, lung, and head and neck tumors. This can be done with no impact on native populations of Pacific yew.

CHINA: RESCUING THE ANCIENT CLONES

"Planting cuttings of the fir along the roads; enjoying the cool air in the moonlight of the future" Zhu Xi, Song Dynasty, China.

We modern propagators may believe that we are at the cutting edge with our rooting techniques, but at least 1000 years ago, in what today is the Peoples' Republic of China, people were apparently rooting cuttings by the millions. Someone, somewhere back in antiquity, had observed that when Chinese fir (*Cunninghamia lanceolata* [Lamb.] Hook.) trees are cut down and the site is burned, the tree produces "fire" sprouts from below the ground around the cut stump. If these are removed and stuck directly into the ground they will root and grow into a new tree a genetically perfect replica of the mother tree from which it came. They also learned that if suckers from only the largest and most vigorous trees were taken, they would tend to produce large and vigorous trees.

After a forest was harvested, people would seek out the largest stumps, collect cutting wood from them, and stick the best cuttings into the ground in groups around the original stumps. These groups were actually clones and a few of them were truly spectacular in their growth traits. Some of the exceptional clones were repropagated countless times over many centuries. Cloning became the backbone of Chinese forestry. It is reported that yield of some of the best clones was six times greater than that of wild forests (1170 m^3 ha^{-1} versus 193.5 m^3 ha^{-1} at 39 years) (Li, 1992).

Up until the 1950s this practice was carried out over hundreds of thousands of hectares across 14 provinces in southern China. Often the trees were interplanted with other crops in an early version of what we today call "agro-forestry". Sometimes they were planted in mixes with other species, but most often they were planted in mosaics of small mono-clonal blocks.

After 1950, however, China came under strong influence of the Soviet Union and unorthodox views of Soviet geneticists were forced upon Chinese agriculture and forestry. It was asserted, without basis in science, that vegetative propagation and cloning was eroding the genetic quality of the forests. Hence, the practice was discontinued. During the 1960s, 1970s, and 1980s nearly all reforestation in China was accomplished with seed and most of the priceless ancient clones were abandoned and lost forever.

Plant Propagators to the Rescue! Recently, Professor Minge Li, forest geneticist from the Central China Agricultural University, and his colleagues have recognized the folly, indeed tragedy, of this course of action. They have mounted an effort to return to the traditional methods of clonal propagation of Chinese fir throughout southern China. Through extraordinary efforts, they are recovering some of the priceless old clones and returning them to production. They are developing innovative methods of restoring juvenility to some of these trees that have matured over time. This technique involves burying twigs beneath the soil and harvesting the shoots that emerge. This practice apparently rejuvenates them and they can then be used to reestablish stock blocks of some of the valuable clones.

In 1991, over 60 million Chinese fir cuttings were rooted and planted throughout China (Ritchie, 1994).

MOUNT ST. HELENS; RESCUING THE TREE FARM

"I think it would be wonderfully exciting to witness the eruption of one of our Cascade volcanoes during our lifetime." Dr. Dixy Lee Ray, former Governor, State of Washington, 1980.

Exciting, indeed! When Mount St. Helens erupted on May 18, 1980, it not only blew away the top of the mountain itself, but along with it went 221 homes, 12 bridges,

27 km of railroad track, hundreds of kilometers of roads, about 5000 black-tailed deer, 1500 elk, millions of smaller animals and birds, and 56 human souls (Winjum, 1984). Losses to Weyerhaeuser Company, apart from forest trees, consisted of 12 logging sites and 10 rock pit operations; about 650 km of roads and bridges; and three non-resident logging camps containing maintenance shops, equipment, transfer stations, 39 rail cars, and 63,000 m^3 of decked logs (Winjum, 1984).

In all, approximately 61,000 ha of forest were destroyed, on both public and privately owned land. The greatest forest loss was that incurred by Weyerhaeuser Company—about 27,000 ha, or approximately 14% of the SW Washington Tree Farm. This included about 15,000 ha of highly valuable merchantable timber. In addition, about 10,000 ha of young plantations ranging from 1 to 35 years in age were completely destroyed (Winjum, 1984).

What to do? It was immediately apparent that Weyerhaeuser had sustained losses of monumental proportions and that management plans for the tree farm, indeed for the entire region, needed to be immediately and substantially changed. It was also clear that the recovery effort would require very close coordination and communication among corporate management, tree farm operations, seedling propagators, and various research groups within the company. Regenerating the area was in every way a new challenge. A review of the scientific literature revealed that such an operation had no precedent; hence, no one could be certain that successful reforestation was even possible.

The first small regeneration trial was conducted on 16 June using about 1000 each of bareroot Douglas-fir (*Pseudotsuga menziesii*) and container noble fir (*Abies procera*) seedlings. This early trial revealed several serious problems. In the first place, the St. Helens ash was completely devoid of plant nutrients; consequently, the ash had to be scalped before planting so that seedling roots were in contact with the mineral soil. Scalping, in turn, led to stem girdling by weevils (*Stremnius* spp.), that tended to concentrate in the scalping holes. This problem was subsequently solved by planting large diameter stock. In the second place, the ash cover provided an extremely harsh microclimate that resulted in severe seedling stress and loss of vigor. In the third place, the areas in which the ash was deepest were highly prone to surface erosion.

Plant Propagators to the Rescue! These early research trials generated sufficient information that operational plans could be made for subsequent large-scale reforestation activities. These plans called for reestablishment of plantations on about 18,000 ha between 1981 and 1985. The general strategy was to regenerate first the lands posing the least difficulty (those containing shallow ash, modest amounts of debris), while at the same time continuing research on regeneration of the deep-ash sites, site preparing the debris-laden areas and propagating the millions of required seedlings and transplants. There was a need as well to identify attributes of seedlings capable of surviving in this harsh moonscape.

Full-scale operational reforestation began in February 1981, with seedlings grown at Weyerhaeuser's Mima Forest Nursery near Olympia, Washington. This nursery, one of the largest on the west coast, has an annual production of about 23 million bareroot seedlings, mostly Douglas-fir. Lifting operations are conducted in December, January, and February; then stock is stored in freezers at -1C, where it remains in a dormant condition until it is field-planted.

The easiest sites to replant were plantations 1 to 10 years old that were relatively free of heavy ash and debris. These were hand-planted with shovels, the ash layer was scalped and small drainage channels were cut to enable water to drain out of (rather than into) the planting holes. During this first year, seedling supplies were low and stock from adjacent seed zones had to be used. About 2000 ha were regenerated in this manner.

Plantations between 10 and 20 years old were more difficult to work with because they were too dense to plant and were impossible to control burn since the ground was covered with ash and would not support fire. Hence, these young dead trees had to be felled first or crushed before burning. Some slash burns in these areas were larger than 600 ha.

Ash depths of more than 20 cm posed another serious problem. Hand scalping was not feasible in this material because of the ash's excessive weight and planter fatigue. The only method that proved successful was to prepare these sites with a tractor-mounted V-blade. About 1,000 ha were prepared and planted in this way. Unfortunately, scalping with a V-blade was feasible only on ground with less than a 30% slope. Power augers were tried on steeper slopes, but were only marginally successful.

Very deep ash (20 to 30 cm) posed serious problems. An initial approach employed direct planting in the ash, with subsequent addition of various fertilizer treatments. These trials were not successful.

Planting in 1982 focused on two types of ground: low-elevation, shallow ash sites (about 1500 ha) and middle- to high-elevation, deeper ash sites (about 2000 ha). The low-elevation sites were planted with Douglas-fir. Little or no site preparation was needed because there had already been extensive salvage logging on these areas. Seedling survival averaged 88%. Douglas-fir and noble fir stock was planted on mid- to high-elevation sites, respectively, with good success. Although this stock suffered winter desiccation aggravated by lack of vegetation on the barren, ash-covered landscapes, survival did approach 90%. A tribute to excellent stock production technology.

Subsequent activities reached a peak in 1983, when about 5000 ha were regenerated. By 1984, 2+1 Douglas-fir and noble fir transplants from the same seed zone (which had been ordered immediately after the eruption) became available. This stock was planted on some 3400 ha in 1984 and on an additional 1600 ha in 1985. Black cottonwood (*Populus balsamifera* ssp. *trichocarpa* syn. *P. trichocarpa*) was planted along riparian zones and mud flows and lodgepole pine (*Pinus contorta* [Dougl]) on exposed ridges.

By the end of 1985 the project was essentially completed. In all, about 18,000 ha of new plantations were established during this period. This required about 17 million bareroot Douglas-fir and noble fir seedlings. Seedling survival in most of these areas has been better than 85%. Of the remaining 9000 ha about 7000 ha were traded to the U.S. Government for inclusion in the Mount St. Helens National Monument. A satisfactory method of regenerating the remaining deep-ash and mud-flow areas has not yet been found and these areas, comprising about 2000 ha, will remain unplanted for the foreseeable future.

I invite, indeed encourage, each of you to make the easy drive up to the St. Helens National Monument while you are here in the Portland area. As you drive along this spectacular highway from Silver Lake, past the new C.W. Bingham Learning

Center, to the Visitors Center at the National Monument, virtually all of the young forests you will pass through along the way resulted from the propagation and planting effort I just described. These well-stocked forests, now 12 to 14 years old, contain trees approaching 10 m in height and will soon be in need of thinning. They teem with elk and other wildlife, the streams support healthy populations of Coho salmon and steelhead (Rochelle, et al., 1992). The rapid and successful establishment of these magnificent young forests is a tribute to the skill and efforts of many dedicated people especially plant propagators!

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POSTER SESSIONS

Controlled-Release Urea Fertilizers Affect the Growth and Quality of Selected Foliage Plants

P.K. Murakami and F.D. Rauch
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Three formulations of an encapsulated urea product and one sulfur-coated urea were evaluated at 0 to 4 times the recommended rate on *Chamaedorea elegans*, *C. seifrizii*, *Chrysalidocarpus lutescens*, *Spathiphyllum* 'Tasson', and *Rhapis excelsa* against a standard controlled-release fertilizer at equal N rates. Each plant species responded differently to the fertilizer sources. *Chamaedorea seifrizii* and *S.* 'Tasson' did not exhibit preferences for fertilizer sources from top-growth measurements. *Chamaedorea elegans*, *C. lutescens*, and *R. excelsa* growth measurements indicate that fertilizer source affected growth and quality of the plants. The general recommendation for foliage plant production is an equal ratio of ammoniacal to nitrate nitrogen sources. Economically, this ratio makes the fertilizer more expensive than other traditional fertilizers. The use of a controlled-release urea fertilizer has the benefit of being a cheaper source of N and would lower the cost of production, but results on the selected foliage plants indicate that the fertilizer composition is important in plant production.

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Nitrogen Fertigation of Apple Nursery Stock: Effects of Application Rate and Cutoff Timing on Nursery Stock Size, Dormancy Development, Natural Defoliation, Freezing Tolerance, and Spring Regrowth

Steve Castagnoli, Leslie Fuchigami, and Timothy Righetti
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Eugene Mielke
Oregon State University, Mid-Columbia Agricultural Research and Extension Center, Hood River, Oregon.

Malus 'Gala' and 'Fuji' nursery stock were grown under different nitrogen (N) fertilization regimes with two rates and three application cutoff dates in factorial treatment combinations. Nursery caliper size was increased by higher N rate and later N cutoff timing. The onset of dormancy was delayed by the high N rate. Natural defoliation was delayed by later N cutoff date. Mid-winter hardiness was reduced by the high N rate with no effect of N application cutoff timing. Spring budbreak was advanced by the high N rate in all except the first cutoff treatment and delayed by earlier application cutoff. Tree size after 10 weeks of regrowth in spring of the year following N application was increased by higher N rate and later cutoff date. Nitrogen rate and application cutoff timing are both important factors in improving apple nursery stock quality and performance in the orchard.

Chemical and Manual Defoliation of Apple Nursery Stock: Effects of Defoliation Timing on Defoliation Efficacy and Nursery Stock Quality

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Department of Horticulture and Landscape Architecture, Washington State University, Pullman, Washington

Eugene Mielke
Oregon State University, Mid-Columbia Agricultural Research and Extension Center, Hood River, Oregon

Malus 'Braeburn', 'Fuji', and 'Gala' nursery stock were manually defoliated on one of five dates, chemically defoliated with one of three spray application timings, or naturally defoliated. Among the chemical treatments, the earliest application timing was most effective in promoting early defoliation. Nursery stock caliper size was affected by manual defoliation treatment, increasing with later defoliation date. There were no

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Malus 'Braeburn', 'Fuji', and 'Gala' nursery stock were manually defoliated on one of five dates, chemically defoliated with one of three spray application timings, or naturally defoliated. Among the chemical treatments, the earliest application timing was most effective in promoting early defoliation. Nursery stock caliper size was affected by manual defoliation treatment, increasing with later defoliation date. There were no

significant differences in caliper size among the three chemical defoliation treatments. Of all defoliation treatments, only the first manual defoliation treatment resulted in nursery stem caliper lower than that of the spring dug treatment.

New shoot growth in the following year, was greater with later defoliation date. Conversely, earlier chemical treatment resulted in higher new shoot growth. The amount of stem damage appears to be dependent on cultivar and defoliation treatment and timing. The relationship between dormancy development and stem damage associated with early manual and chemical defoliation, however, is not clear. These results indicate that nursery production practices can significantly impact nursery stock quality and performance of trees in the orchard.

Tie-off Layering of Hazelnut

David C. Smith
Hazelnut Breeding Program, Horticulture Department, Oregon State University, 4017 ALS, Corvallis, Oregon 97331

Hazelnuts (*Corylus avellana* L.) have traditionally been propagated for commercial orchards in Oregon by simple layerage, wherein a year-old shoot from the mother plant is bent into a U-shape and is inserted into a slot opened in the ground with a shovel. Several of the specialty hazelnut nurseries in Oregon are now using a system of mound layering locally called tie-off layering. Current season's shoots are girdled with hog ring staples and sprayed with a rooting hormone. Sawdust is then placed around the shoots to a depth of 8 in. These nurseries have concluded that the tie-off method produces more saleable trees per stool that are more heavily rooted and straighter stemmed than trees propagated using simple layerage.

Cytokinins and Donor Plants Affect Regenerative Capacity of American Elm Leaves

Mary W. George and Robert R. Tripepi
Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, Idaho 83844-2339

Adventitious shoots have been induced to form on leaf explants of American elm (*Ulmus americana* L.) with thidiazuron (TDZ) in the medium, but the effects of other cytokinins, donor plants, and basal media were unknown. The goal of this study was to examine factors that influence the regenerative capacity of American elm leaves. Excised leaves from 2-year-old seedlings were surface sterilized, and 1-cm^2 sections were taken from the midrib portion of the leaves. Three to six seedlings were used as donor plants in various experiments. Zero, 7.5, 15, or 22.5 μM of benzyladenine (BA), TDZ, kinetin, zeatin, or 2-isopentenylaminopurine (2iP) were added to Driver Kuniyuki Walnut (DKW) medium. Basal medium (DKW or Murashige and Skoog [MS]) effects on shoot regeneration were also examined. Leaves placed on DKW media with BA or TDZ formed adventitious shoots, with TDZ inducing up to 100% regeneration. Donor plant also affected the efficiency of shoot regeneration, with

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certain seedlings having 1.5 to 7 times more explants forming shoots compared to other plants. Leaf explants from donor plants with the highest regenerative capacity had a higher percentage of regeneration on DKW than MS medium. Explants from productive donor plants should be placed on DKW medium supplemented with TDZ to improve shoot regeneration efficiency from American elm leaves.

Evaluating Pulp and Paper Sludge as a Substitute for Peat Moss in Container Media

Robert R. Tripepi, M.W. George and A.G. Campbell
Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, Idaho 83844-2339

Pulp and paper sludge is a byproduct of paper production, yet this fibrous material may be suitable as an alternative amendment for peat moss in container media. Newsprint mill sludge was composted 6 weeks and cured before use. One-year-old seedlings of lilac (*Syringa vulgaris* L.) and amur maple (*Acer tataricum* ssp. *ginnala* syn. *A. ginnala*) as well as rooted cuttings of cistena plum (*Prunus* ×*cistena* Hansen) were planted in 3-liter pots containing a bark : sand (2 : 1, v/v) mix, 25% or 50% peat-amended media, or 25% or 50% sludge-amended media. After 14 weeks outdoors, shoot dry weight and changes in plant height were measured. All species planted in sludge-amended media grew as well as those potted in peat-amended or the bark : sand media. In fact, some species grew best in sludge-amended media. Lilac seedlings planted in 25% sludge produced almost double the amount of shoot dry weight and were 80% taller than plants in the bark and sand mix or 25% peat. Maple plants grown in 50% sludge produced over 100% or 35% more shoot dry weight than those grown in 25% or 50% peat-amended media, respectively. Plum cuttings potted in 25% sludge grew at least 53% taller than plants grown in either peat-amended medium. These results indicate that composted newsprint sludge can be used as a peat moss substitute in a container medium for the landscape plants tested.

Alaskan Natives: More Potential for Ornamental Nursery Crops

Terry Finnerty and Dave Wattenbarger
University of Idaho Cooperative Extension System, Sandypoint, Idaho 83864-0867

James Kraemer
Silver Springs Nursery, Moyie Springs, Idaho

The purpose of this project was to:

- Collect native Alaskan species.
- Develop the propagation techniques for these selected species as potential new introductions in the Idaho nursery industry.
- Include some species in the small fruit breeding and demonstration trials at the University of Idaho-Sandpoint Research and Extension Center in Sandpoint, Idaho.

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This project has been conducted as part of a cooperative effort between the University of Idaho-College of Agriculture, Idaho nursery growers, the Idaho Department of Agriculture, and the Stillinger Foundation. Major collection areas were: the Interior (Fairbanks, Delta, Denali Park, etc.), the Yukon River, above the Arctic Circle (Brooks Range, Prudhoe Bay, etc.), the Kenai Peninsula, Cook Inlet, and the Copper River Delta. Habitat types included alpine and arctic tundra, glacial and river outwash, spruce bogs, and boreal forest. Approximately 150 plants were collected and pressed for inclusion in the Alaska section of the University of Idaho Herbarium, and approximately 30 different species of trees, shrubs, and herbaceous perennials were collected for potential use as nursery or fruit crops. The following species were presented in the poster presentation, but more species are currently being examined: *Arctostaphylos uva-ursi* var. *uva-ursi, Empetrum nigrum, Iris setosa* ssp. *interior, Loiseleuria procumbens, Rhododendron lapponicum, Rubus arcticus* ssp.*acaulis, Salix alexensis, Vaccinium uliginosum*ssp. *alpinum, Vaccinium vitis-idaea,* and *Viburnum edule.* There is much potential for expanding product inventory by introducing what are native species in some areas (Alaska) as exotics in other areas (Idaho) with similar environmental and climatic conditions. This work is only the preliminary stage of a long process to develop some of the more desirable native Alaskan species as new products for the commercial nursery industry. In addition to initial propagation procedures, various cultural conditions including watering, fertilizing, temperature, lighting, and different propagation media will all need to be tested to optimize production of each species. The final stage of development will be examining how well the plant grows on a natural landscape in a non-native environment. These stages will take time, but the process has begun, and hopefully can continue as public and private institutions seek to improve the future of the nursery industry.

Correction: *Vaccinium uliginosum* ssp. *alpinum* was confused with another species that is not included in this poster. It was collected but not propagated. The error was not recognized until the poster was near completion.

Oregon Association of Nurserymen's Plastic Recycling Program

Walter Suttle
Monrovia Nursery Co., 13455 SE Lafayette Hwy., Dayton, Oregon 97114

Ron Lapotin
Oregon Garden Products, 3150 SE Minter Bridge Rd., Hillsboro, Oregon 97123

A program to recycle broken plastic pots, flats, and plug trays was initiated by the Oregon Association of Nurserymen in February 1995. Plastics accepted must be made of polyethylene (recycling symbol 2), polypropylene (recycling symbol 5), or polystyrene (recycling symbol 6). To participate, the plastics must be free of soil, separated by resin type, and delivered to 1 of 3 cooperating plastic consolidators in the Willammette Valley. The consolidators bale and ship the material to reprocessors for manufacturing into resin pellets or plastic lumber.

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New Zealand Named Lavender Cultivars: The Advantages and Disadvantages

Virginia McNaughton
c/ R. H. Button, Longstaff Road, Christchurch

INTRODUCTION

Lavender! It is probably one of the most versatile herbs to grace our gardens. New Zealand has proved an ideal climate for growing many different lavenders, with the exception of extremely cold areas, as some species are frost tender. A revived interest in ornamental planting, cottage gardens, and formal gardens has led to an increase in breeding of lavenders for the domestic market.

I would like to mention some of the New Zealand named cultivars which, either because of their distinguishing characteristics have become popular, or probably will become popular with the public.

NEW ZEALAND CULTIVARS

Section Stoechas. Some of these plants have characteristics similar to *Lavandula stoechas* ssp. *stoechas* and some to *L. stoechas* ssp. *pedunculata*.

***Lavandula* 'Evelyn Cadzow'**. A very attractive low-growing (20 to 30 cm) shrub, quite bushy in habit with one of its most distinguishing features being its bright green foliage. The flower spikes are 10 to 20 mm long excluding the sterile bracts.

Their shape is round and plump and the 12-, to 14-mm sterile bracts are reddish purple in colour (71A with a little 77A, RHS colour charts) and very striking. Fertile bracts are reddish-purple and green and corollas a very dark purple. Peduncles vary from 2 to 8 cm in length. Overall the plant looks like a miniature version of *L. stoechas* ssp. *pedunculata*, except that the foliage and spikes make a wonderful contrast and create a striking appearance which is very popular with the public.

***Lavandula* 'Marshwood'.** A very large, upright-growing shrub that can easily reach 80 cm at maturity. It gives a bold appearance and is suitable for mass plantings, borders, etc. The foliage is greyish-green and the peduncles are long (13 to 15 cm) and noticeably hairy, particularly under the spikes. The sterile bracts are 2 to 5 cm long (77A - 77B, RHS colour charts) corollas are dark purple and fertile bracts green tinged with burgundy-purple. The overall spikes are quite long and impressive but the sterile bracts do fade in colour with age.

***Lavandula* 'Helmsdale'**. The habit of this plant is more bushy with medium to long peduncles and greyish-green foliage making it a very attractive hedging plant (50 to 60 cm). The flower spikes give the overall impression of being burgundy in colour although the fertile bracts are actually green with purple tips. The sterile bracts are an attractive burgundy colour.

***Lavandula* 'Plum'.** For such an uninteresting name, this medium sized plant compensates by being attractive in all areas. In flower it reaches 50 cm and will produce abundant spikes throughout the growing season. The spikes are composed of dark purple corollas which contrast significantly with the reddish-purple sterile

bracts (72A, RHS colour charts). The growth habit is bushy and the foliage is delicate with leaves much shorter in length than most of the other cultivars. However, the plant is very robust and is also a favourite with those who see it.

***Lavandula* 'Avonview'.** A rather striking plant displaying vigorous upright growth, easily reaching 60 cm in height in a short space of time. One of its most distinguishing features is its long, broad sterile bracts (77A with touch of 80A, RHS colours charts), and large impressive spikes. The corollas are dark purple and the fertile bracts are purple with a splash of green up the centre. Peduncles are long.

***Lavandula* 'Pippa'.** An unusual plant in that the spikes tend to change colour as they age. At night the flower heads can also tend to look a little luminescent as well. The growth habit is upright and vigorous, easily reaching 60 cm. The sterile bracts are purple (79B - D, RHS colour charts) with dark purple corollas and green fertile bracts tinged with reddish veining.

***Lavandula* 'Pippa White'.** A spectacular flowering plant of sprawling habit which tends to attract much attention and has a tendency to become a conversation piece in the garden. The peduncles are 6 to 8 cm long and noticeably hairy. Spikes are long with many being over 7 cm in length, with purple corollas and green fertile bracts. The sterile bracts are a creamy-white with green and yellow veining. Foliage is greenish-grey.

***Lavandula* 'Pukehou'.** Foliage is greyish-green and the growth habit is bushy. The peduncle length varies between 6 to 14 cm with medium-length spikes with purple fertile bracts, dark purple corollas and long attractive purple sterile bracts (83C - 83D, RHS colour charts).

***Lavandula* 'Willowbridge White'.** This plant is more like *L. stoechas* ssp. *stoechas* in form and habit. The most noticeable difference being the flower spikes which combine dark purple corollas with white sterile bracts. 'Willowbridge White' is currently being tested through Plant Variety Rights in New Zealand.

Section Spica. These are just a few of the plants available on the New Zealand market.

***Lavandula angustifolia* 'Blue Mountain'**. A striking grey foliaged plant, 50 to 60 cm in height with medium-length spikes. Corollas are a deep violet (dark 88A, RHS colour charts) and calyces are also very dark (86A with a tinge of blue, RHS colour charts) giving the flower heads an overall dark violet appearance. A most attractive plant which lends itself to many uses, its primary ones being more as a foliage plant and cut flower rather than for oil. It is probably one of the most appropriate lavenders in this group to be used as hedging because of its vigorous compact growth habit.

***Lavandula angustifolia* 'Avice Hill'**. A grey-foliaged plant which, although slower growing when young, forms a lovely compact bush at maturity. One of the features of this plant is its unusual scent, which is very sweet and slightly different from some other lavenders in this group. It also has a tendency to flower all summer, producing masses of heads for a *L. angustifolia* cultivar. Flower spikes are very uniform with large violet corollas (88A - 88B, RHS colour charts), dark violet and green calyces (86A, RHS colour charts) and broad green fertile bracts.

***Lavandula angustifolia* 'Pacific Blue'.** This plant was grown initially by Crop and Food Research to assess its oil-producing qualities. Formerly known as *L. angustifolia* '565/6' it has been given a new lease of life as 'Pacific Blue'. Foliage is greyish-green and the bright blue spikes are medium to long. Flower heads are suitable for cutting.

***L.* ×*intermedia* 'Impress Purple'.** Also grown by Crop and Food Research to assess oil-producing qualities and formerly known as *L.* ×*intermedia* '41/70'. The habit of the plant is bushy with grey foliage and long, frequently branched peduncles which have a tendency to sprawl. Spikes are short to medium length with large violet corollas (88A, RHS colour charts) and lighter coloured calyces. Long bracteoles are present and fertile bracts are also long and narrow. Overall the spikes have quite a dark appearance for a lavandin and they make attractive cut flowers. The scent is camphoraceous. This plant is sometimes mistakenly sold under the name *L.* ×*intermedia* 'Arabian Night'.

Most of these plants are reasonably frost hardy (depending on where they are grown) and are all suitable ornamental plants.

There is, however, a cautionary note with this tale and one which I am sure you have all heard before, since it does not just apply to lavenders.

Lavender is a highly promiscuous plant and tends to hybridise freely within sections with intersectional crosses being rare. In latter times, people excited by the prospect of selling something "new" on the market have been giving names to such seedlings without knowing the full story. Many similar, if not the same seedlings, will arise spontaneously in different gardens and are often brought to me for comparison. Because of this, I feel we need to be careful about what we are naming and be very selective in this process. The public will soon tire of similar plants on the market! Such a situation has not only created confusion amongst the public but also amongst the nurserymen and further complicates an already confused genus.

One example of this are two subspecies of *L. stoechas* which, in my opinion, should never have been released onto the market. These are *L. stoechas* ssp. *sampaioana* and *L. stoechas* ssp. *luisieri*, the naming of which for some reason has been mixed up at the source level. It may take some time to unravel the problem, by which time further damage will have been created by releasing these plants in New Zealand. Once on the open market, these plants can be distributed world wide which will ultimately lead to further confusion at a species level. At present there is a genetic analysis being made to determine the difference in lavenders from the Iberian Peninsula and I would prefer to wait until such research was complete before seeing such plants widely available.

However, in the meantime, I have no doubt that new cultivars will continue to appear on the market especially as New Zealand has the ideal climate and a wide genetic base from which to choose. The decision of naming new cultivars will be left to the discerning nurseryman and the Plant Variety Rights Office and as long as some of the above mentioned points are kept in mind, then the future of lavender breeding in New Zealand is a promising one.

The Commercial Application of *Trichoderma* (Beneficial Fungi) in New Zealand Horticulture

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INTRODUCTION

The*Trichoderma* species is one of a small group of beneficial fungi being successfully utilised on a commercial scale for biological control of other fungi. This microorganism has now been registered as a biofungicide in many countries including France, U.K., Belgium, Switzerland, Sweden, Chile, New Zealand (N.Z.), and U.S.A. In its natural environment *Trichoderma* is a resident of the litter and woody plant debris in humus or associated with plant matter in the soil. It acts as a mycoparasite or saprophyte to establish a niche for itself, often at the expense of other fungi which it may use as an alternative source of nutrients. It has been clearly demonstrated actively parasitising basidiomycete fungi including *Rhizoctonia solani* (Lewis and Papavizas, 1980), *Armillaria mellea* and *Chondrostereum purpureum* (Papavizas 1985). *Trichoderma*'s biocontrol properties were probably first observed inadvertently in 1914 controlling boot lace fungus, *A. mellea,* after soil fumigation with carbon disulfide. However, not until 1951 was this control demonstrated to be due to enhanced mycoparasitism of the pathogen by *Trichoderma* (Bliss, 1951). Although extensively studied for many decades *Trichoderma* was not registered for commercial use until the 1980s.

Trichoderma has a number of unique properties which have led to its successful commercialisation. Firstly, it is extremely safe with no recorded adverse reactions through a half century of investigations and uses. The strains used commercially will not grow above 33C and, therefore, present no hazard to humans and livestock.

Secondly, it has a wide range of useful antagonistic and parasitic activity towards other fungi, many of which can be harmful pathogens. *Trichoderma* controls the growth of many opportunistic wood-infecting, decay fungi as well as many soil resident fungi causing seedling wilt and damping off diseases. Thirdly, and perhaps most importantly, *Trichoderma* has immunising and protective qualities when resident in a host. It has an ability to survive long term within the host without causing damage to it while imparting a sort of "vaccination" effect which discourages other infecting microorganisms. This property has led to *Trichoderma* being called an immunising commensal (Ricard, 1977). Other examples of common commensal organisms include the nitrogen-fixing bacteria in legume roots and the mycorrhizal fungi associated with many plantation tree roots, both of which assist with nutrient uptake. Once introduced into a woody plant *Trichoderma* can remain active within it for many years offering protection against a range of other microorganisms (Ricard and Highley, 1988).

Trichoderma's parasitic properties towards *C. purpureum*, the fungus causing silverleaf disease, are well described in the literature (Papavizas, 1985; Ricard and Highley, 1988). *Trichoderma* has been shown to actively parasitise the growing *C. purpureum* by wrapping itself around the mycelium, eventually strangling growth and extracting the cellular contents. Ultrastructural observation has confirmed the skeletal acytoplasmic nature of parasitised mycelium (Chet et al., 1981). This process is usually fatal to *C. purpureum* and most often leads to silverleaf disease control in the host plant. Similar parasitic mechanisms have been described for *R. solani* and other fungi. Other mechanisms of biocontrol by *Trichoderma* are less well understood. Some strains of *Trichoderma* have been shown to produce metabolites (antibiotics) with fungicidal activity (Papavizas, 1985).

Much of the work on *Trichoderma* as a commercial biocontrol agent for silverleaf disease in stone fruit trees was performed during the 1970s at the Long Ashton Research Station in England. This work culminated in a registration with the British Pesticides Authority for silverleaf control in 1979. At this time comprehensive research was also performed on various safety and toxicological aspects of the organism to ensure its safety in general horticultural use. One such study showed the LD 50 (lethal dose in mg/kg body weight where 50% of laboratory animals will survive) of *Trichoderma* was less than that of common salt NaCl (Ricard, 1977).

When resident in a host, *Trichoderma* actively inhibits the growth of many other fungi, and while not necessarily destroying them may discourage infection by occupation of the host niche. Among these are the wood-infecting fungi causing diseases, such as, collar rot, *Phytophthora cactorum*; European canker, *Nectria galligena*; and the root-infecting boot lace fungus, *A. mellea* (Fig. 1A). Field results in New Zealand demonstrate that protection of host plants with *Trichoderma* is much more effective than attempts to cure heavily infected plants.

Figure 1A, wood fungi *Trichoderma* is probably more suited to soil colonisation than woody plant colonisation.

Extensive research over two decades into the biocontrol of soil pathogens has been conducted by Papavizas' group at the Beltsville Agricultural Research Station in Maryland, U.S.A. (Papavizas, 1985; Papavizas and Lumsden, 1980). With its extremely rapid growth and copious production of spores *Trichoderma* species quickly colonise the substrata of soils especially after chemical or heat sterilisation treatments. Many strains of the organism, of which there may be over 200, can be isolated from soil in nearly all parts of the world. These growth characteristics have been utilised by incorporating *Trichoderma* and its close relation *Gliocladium virens* into potting mixes and glasshouse soils to minimise problems with wilting and damping off of seedlings caused by fungi, such as, *R. solani*, *Fusarium*, and *Pythium* species (Fig. 1B).

Figure 1B, soil fungi dark bars represent growth on nutrient media plates of various wood infecting fungi (A) and soil-borne fungi (B) unchallenged by *Trichoderma*. Light bars represent growth when challenged with *Trichoderma* under identical conditions. Glasshouse and field trial results from a number of countries suggest there may be significant benefit for some commercial crops by incorporating *Trichoderma* into soil. Recent work conducted at Littlehampton Research Centre in England demonstrated dramatic growth improvement with commercial flower seedlings grown in this way. The suggested mode of action for the *Trichoderma* was that it may have been acting as an adjunct to nutrient uptake. *Trichoderma*'s disease

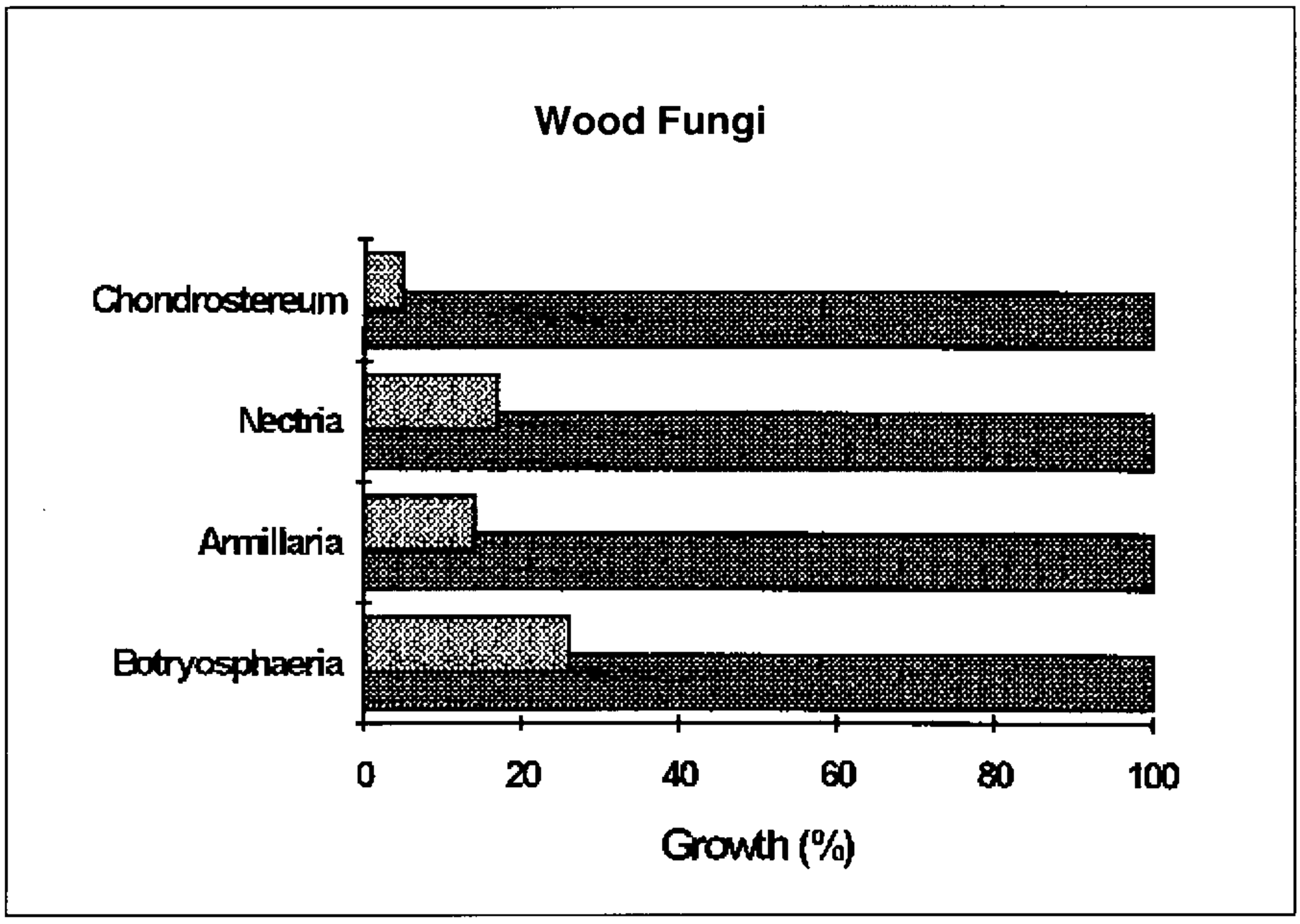

Figure 1A.

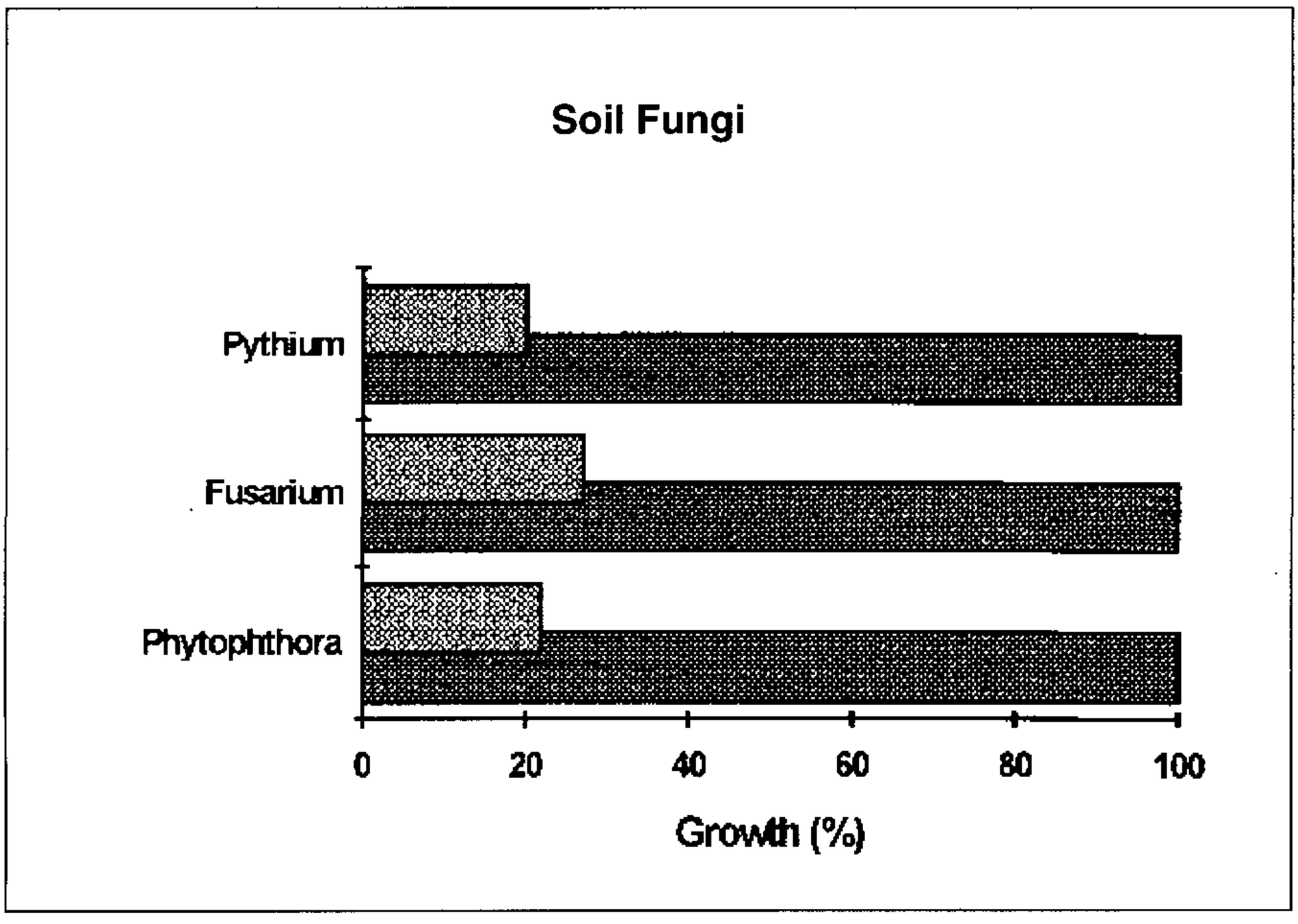

Figure 1B.

protection properties alone would have been unlikely to account for the increased growth observed. Similar results have been obtained in a number of commercial crops in N.Z. Agrimm's *Trichoderma* soil-conditioning pellets (Trichopel) have demonstrated significant growth enhancement and plant health benefits.

Agrimm Technologies product range is now being tested in extended field trials for efficacy against wood-infecting pathogenic fungi such as *P. cactorum* collar rot in various crops as well as *Eutypa lata* and *Botryosphaeria stevensii* dead and dying arm in grapevines.

As an example, Trichoject treatment (10-ml injection) of grape vines infected with *B. stevensii* resulted in clearance of symptoms from 31/45 (69%) of treated vines on assessment the following season (Table 1), which further increased to 90% two seasons after treatment (data not shown). Excellent results in the control of these diseases demonstrated to date in New Zealand are expected to allow Agrimm to both extend its product label claims and crop applications in the near future.

Table 1. Treatment of *Botryosphaeria stevensii* infected grapevines.

Treatment (10 ml)	No. vines	Disease symptoms grade 0	1-2	3-5	Mean + s.d.
Trichoject	45	31	12	2	0.5 + 0.9 a*
Trichoject/chemical**	52	8	39	5	1.3 + 0.8 b
Control	52	0	24	28	2.5 + 1.1 c

* Significant difference by Student's t test ($p<0.001$).
** 5ml + 5 ml injection.

Trichopel, a soil-conditioning pellet containing *Trichoderma*, has enabled *Trichoderma* to be placed around plant roots in a form which enables the beneficial fungus to become established in direct contact with the growing root of the plant for the overall benefit of plant health and vigour. Extensive field trials with Trichopel over the past two seasons have shown excellent growth and health improvement in a range of crops, such as, flower bulbs and tubers, tomatoes, strawberries, as well as nursery plants including N.Z. natives and various ornamental trees and shrubs.

As an example, when Trichopel-G (the G is used to denote growing formulation) was added at 200 g m^{-2} to the planting bed of *Sandersonia* tubers, significant live weight gains over untreated control tubers were recorded (Table 2.). These gains were significantly greater when the pellet was closely associated with the tubers (zone) compared with it mixed through the media (mix). Weight gains of up to 35% (data not shown) were recorded from Trichopel treatments in this trial.

Table 2. Trichopel effect on *Sandersonia* tuber weights.

Treatment	Number[2]	Mean wt. (g)	Std. deviation	Significance (p)[1] T v C	Significance (p)[1] M v Z
Mix-200g	6 × 50	8.78	0.63	0.19 ns	-
Zone-200g	6 × 50	10.19	1.26	0.01 s	0.01 s
Control	6 × 50	8.51	0.35	-	-

[1] Significant(s)by Students t Test ($p<0.05$) - individual means. T v C = Test v Control, M v Z = Mix v Zone.
[2] Weights from 6 groups of 50 tubers were recorded.

Attention is currently being focused on the propagation phase of at-risk crops where vulnerability is highest and conditions for *Trichoderma* establishment are most favourable. *Trichoderma* conveniently thrives in temperatures, moisture levels, and a soil/media pH which are most suited to optimum plant growth and development. When Trichopel is introduced, the *Trichoderma* will grow on the nutritive support pellet and if it is sustained by woody plant debris or other humus-type material in the soil/media, will grow rapidly and become established throughout the local environment, eventually producing spores. Trichopel is best applied in close proximity to developing roots of germinating seeds or rooted cuttings. This is easily achieved by broadcasting a layer of Trichopel pellets into the propagation tray immediately below the seed sowing bed or at the final depth of cutting insertion. Pumice propagation media may not sustain the *Trichoderma* beyond the period afforded by the carrier food source, by then it must have become rhizosphere competent in order to maintain beneficial effects.

CONCLUSIONS.

Further applications of the Trichopel technology developed by Agrimm are under evaluation and include the production of a prototype pellet for use in fine turf and a potting mix seeder additive. It is anticipated that the experience gained from current production and use of Trichopel can be utilised to produce cost-effective means of delivering and establishing *Trichoderma* into these and other areas for the benefit of the end user.

Utilising *Trichoderma* as a biocontrol agent does require a sympathetic crop management strategy. Eradicant fungicide additions, powder or drench, to potting media or soil, unless of compatible status, must be avoided or *Trichoderma* will be compromised. However, regular foliar applied fungicide and pesticide treatments targeted at the aerial parts of the plant are unlikely to effect *Trichoderma* resident in the medium/soil next to the plant roots.

Trichoderma's beneficial qualities and effects, together with the further potential for nutritive benefits giving improved vigour and seed germination, should stimu-

late the growers interest in further evaluating various Trichopel formulations. Many horticulturists will favour the concept of using *Trichoderma* as part of their crop management strategy. Those that do so will not only enhance crop health and vigour, but, will also be contributing to a more sustainable and environmentally sensitive crop production. After all, most of us wish to be part of the solution and not a contributor to future problems.

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The Conventional Tube

Jan Velvin
Lyndale Nurseries Auckland Ltd., P.O.Box 81-022, Whenuapai, Auckland

INTRODUCTION

This paper was initiated by the question: "Why does Lyndale Nurseries Auckland Limited use the tubes we do" ?

1) My first reaction to this question was—my very experienced partner Noelyn said to use them!
2) My second thought was, it is the industry norm!

The rest of the exercise has been quite enlightening as I have worked my way through the question—but why and what is a liner nursery such as Lyndale trying to achieve? As a liner grower we are aiming to produce a quality-graded, individual, small plant that is healthy, well rooted, well shaped, and gives the greatest possible potential for quality growth to the customer when growing on this plant.

Obviously there are influences on this exercise.

EXTERNAL INFLUENCES

- Timing of cutting material and seed availability.
- The marketing time frame—when does the customer require this unit?
- The growing environment.
- Trucking costs and space.
- Quality and grading—our customers do not just require one but up to 5000 plants which all look and behave the same.

INTERNAL INFLUENCES IN THE NURSERY

- Production efficiency.
- Production costs.
- Growing conditions required, what can we provide.
- Ease of handling our product by individuals. Or, to borrow a more eloquent quote on growing in containers:

"The cuttings or seeds should be planted in a marketable container, grown in this marketable container to a marketable size in the required time frame under conditions that are suitable for the plant".....and I have to add—or at a price that our customers are prepared to pay.

So what is involved?

1) Root the cutting.
2) Pot the cutting.
3) Sell the cutting.

Simple isn't it? We believe that in using the tubes shown we have found the most suitable and cost-effective marketable unit for our present production system.

OPERATION

Let's look at the operation of our liner nursery. Lyndale Nurseries Auckland Limited is a specialist propagation unit which produces over 2 million units per year. This

production encompasses approximately 1000 taxa, mainly of trees and shrubs.

Obviously for a nursery such as this to remain economic, uniformity in production methods throughout the range of plants grown, even to the point of compromise where possible, is essential. At Lyndale our seeds, cuttings, and micro-propagated units are all initially set in hygiene trays, misted or fogged, then weaned. All units are strictly graded during making and setting. When the cuttings are well rooted the trays are then taken to the potting shed and potted into individual tubes (Fig. 1)

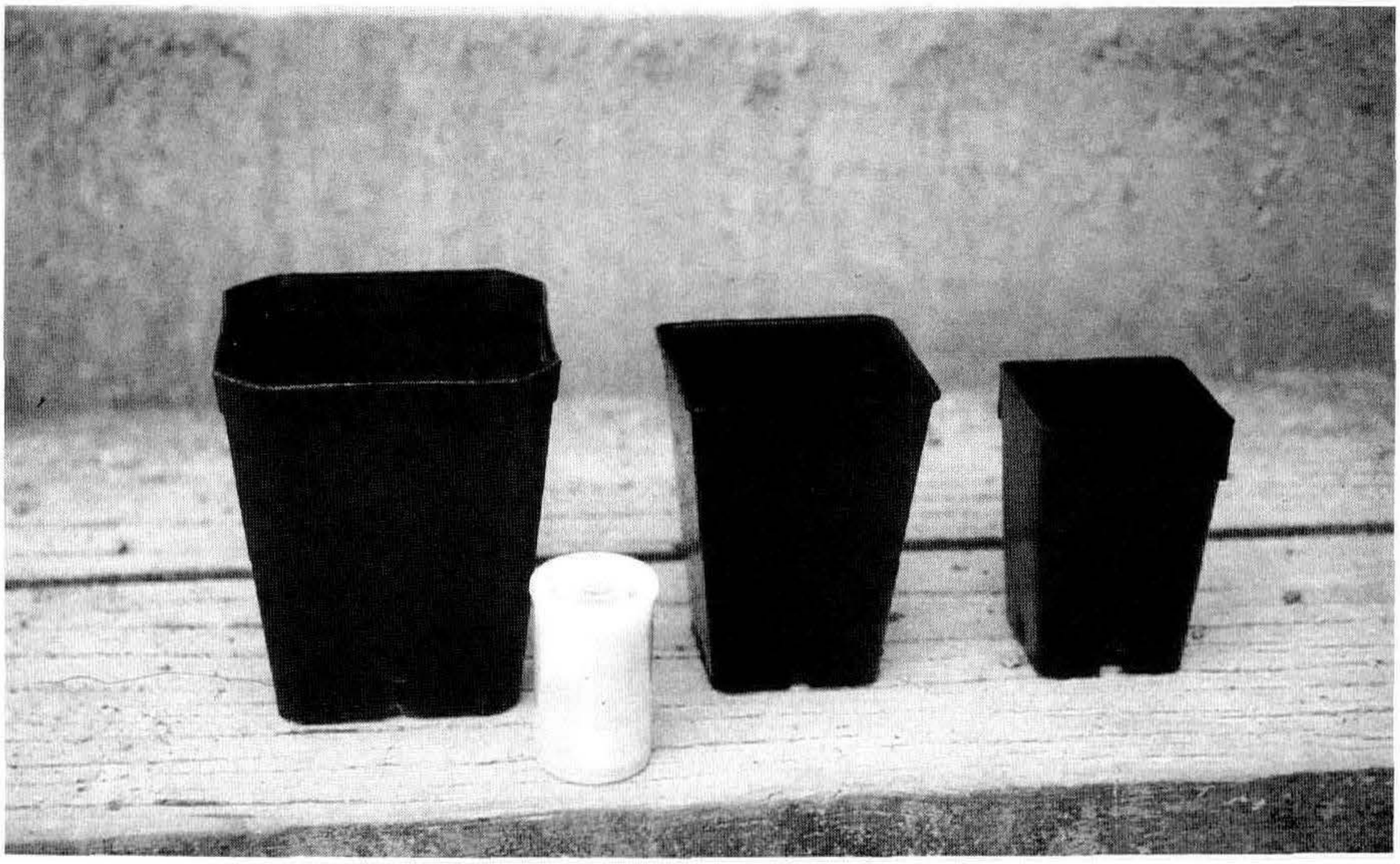

Figure 1. Range of tubes used at Lyndale.

The two questions still remain: 1) Why a plastic tube? 2) Why an individual unit? Let's consider the choice of the tube.

- It is reusable.
- Resists deterioration and decay.
- It is easily cleaned.
- It does not inhibit plant growth; adversely affect temperature, or promote disease.
- It has excellent drainage capabilities.
- It is a size and shape that can be handled easily and efficiently by an individual in commercial numbers, i.e., trays of 54, 35, or 20.
- It can be freighted economically but is strong enough to retain its shape while freighting.
- The plant is easily removed for potting.
- The sizes used can be potted directly into the pot sizes which are the nursery norm. No further growing-on is required.
- Cost is able to be accommodated into the final price of the unit.
- Supply is excellent.

- The size and shape will comfortably accommodate the 4 to 12 months root growth we require without disfiguration or repotting the plant.

Why the individual unit? One very good reason—quality and uniformity is the number one requirement from our customers! Grading, therefore, is the most essential part of our operation from collecting cutting material to dispatch. Our customers expect plants within the batch received to be consistently the same and do not want to pay freight on empty units or receive uneven batches of plants. This is what Lyndale Nurseries is endeavoring to achieve.

Rootrainers: A Nurseryman's Perspective

Lee Gilbert
Morgans Road Nursery, Blenheim

INTRODUCTION

Morgans Road Nursery in Blenheim, specializes very much in Rootrainers for almost all of its approximately 300,000 annual stem production. The product range is quite diverse with *Eucalyptus, Cupressus, Acacia*, and other commercial type species grown in a small (Hilson) Rootrainer. An increasing range of New Zealand natives, a smaller range of exotic amenity species, and a selection of perennials and garden plants are grown in a large (Tinus) Rootrainer. The Rootrainer system has been around for a considerable time, being first patented in New Zealand some 18 years ago. The patent has since expired opening up production to a larger number of manufacturers.

Whilst the system carries the label of Rootrainer, the root-training principle is certainly not limited to this system. The principle is incorporated in many container types now in use, though some manufacturers do not have a good understanding of the principles involved. The use of this root-training principle, I believe, is most important and will see the phasing out of some container types. There are a number of different methods to attain root training. These include, as in Rootrainers, the use of sharp ridges (sharpness being the critical element) over which the soft emerging tips of the roots will not cross. Others are the use of gaps in the growing container (as in sideslit trays) and the use of root-permeable material (as in paper pots). A common feature of these systems is the use of air pruning to limit root length and promote additional root formation. In Rootrainers this is facilitated by packing them in wire frames which hold them off the ground to allow a space of dry air underneath. Most of my plants are grown on concrete pads which aid this process.

I chose Rootrainers because at the time I perceived them to be ahead of other systems available. Whilst there is more choice now they are still a strong competitor in the market place.

THE STRENGTHS AND WEAKNESSES OF ROOTRAINERS

The root-training principle has wide and strengthening recognition. The emphasis on root development is a strength not fully appreciated by the public.

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The hinged nature of the container allows both grower and buyer to check on root development though the hinges of the Rootrainer tend to be a structural weak point.

A cavity takes up very little surface area compared to its depth.

This is a strength in that it:

- Allows for intensive use of growing area in the nursery.
- Allows for the ability to be freighted economically.
- Allows for an adequate root depth which aids establishment in the field.
- Allows for economical though adequate use of potting media.

It is a weakness in that it:

- Means that top watering is difficult making flood pads a virtual necessity for efficient system use.
- Allows little space for stem and branch development. This can largely be overcome but requires intensive management to do so in some instances.
- Comes up against a common public perception that "bigger is better".
- Is difficult to insert rooted cuttings in such a narrow area.

The limited life of the container is perhaps not environmentally sensitive. But for mail order systems, where recycling and in particular container deposits are difficult, it is ideal in that we do not particularly care if the container does not come back. The downside is that it often rules out the recycling option should it otherwise be available.

Having four cavities in a book aids storage and holding, but is retailer unfriendly and gives rise to root migration between cavities. Recent discussion with the manufacturers should lead to the elimination of this latter problem.

The Rootrainer hinging system, whilst allowing monitoring of root development, means the container can open if not tightly stacked and expose the roots to the air. This is a problem to the nurseryman and retailer alike.

PRICE

At a bulk user price of 11¢ a cavity, giving due regard to the flimsiness of its nature, in comparison with 10-cm tubes, the cavity could appear to be expensive. It is my understanding that this is also being addressed, at least to larger users.

The capital structure to efficiently use the root-trainer system is dedicated, particularly if wire frames are included. The strength is that this dedication (or specialization) is the very thing that allows for efficiency. The weakness is that it can make diversification difficult and wasteful.

The manufacturers are New Zealand based which allows for dialogue on product.

They do, however, have a much larger product range than Rootrainers so there does appear to be a tendency to downgrade the priority of manufacture. Customer service increased dramatically when the patent expired allowing competition.

I personally see continued strong use of the larger Rootrainer but alternative systems will decrease the use of smaller cavities.

The different container systems you are hearing of this morning all have strengths and weaknesses, none more so than the ability of the nurseryman to use them. A well-grown plant in a given container will always be superior to a poorly grown plant regardless of the container used. The message is—"know about and learn to use your chosen system well."

The Use of Paperpots for Growing Revegetation Species

Randall H. Maloney
Kapiti Nurseries, P.O. Box 285, Paraparaumu

In late 1993 our nursery was requested to propagate 30,000 native grasses, sedges, and rushes for planting around the margins of two lakes created during a land development project.

Part of the land development was adjacent to palustrine wetlands and, in particular, was in close proximity to a protected scientific wetland reserve. The landscaper engaged to undertake the revegetation and planting programme insisted that two main criteria must be met when the plants were to be supplied.

Firstly, the plants must be propagated from endemic species to maintain the genetic purity of existing vegetation and secondly, the plants were to be supplied either bare-rooted or in biodegradable containers to allay any possibilities during planting of plastics entering into the new or existing waterways and wetlands.

Of the 32 species selected, it was decided that only two species, *Phormium tenax* and *Cortaderia toetoe* would be propagated and provided bare-rooted, the balance of plants, being mainly species of *Carex, Juncus, Isolepis, Baumea,* and *Scirpus*, were to be container grown. A growing medium of granulated bark, peat, medium-grade pumice, and organic wetland substrate (13 : 4 : 2 : 1, by volume) was chosen. During excavation of one of the lakes, considerable organic wetland substrate was excavated and a small portion of this was incorporated into the medium. Because of the growing medium and the second criteria mentioned, it was decided that the plants would be grown in paperpots which had only been introduced into New Zealand a few years earlier. The paperpots chosen had a diameter of 4.9 cm and a height of 7.5 cm and were glued together with watersoluble glue in a sexangular form of 130 pots per batch. Each batch was stretched open and placed in a plastic tray and removable side clips held the stretched batch open and in place. As all plants were propagated by division of mother plants (ex situ), which were grown from seeds collected locally from plants growing naturally (in situ), the pots were only filled halfway before the divisions were inserted and then topped up and firmed down.

The divisions all had healthy fibrous roots and the minimum amount was retained and the top growth trimmed back very hard leaving in most cases only 2 or 3 cm of top growth showing.

The trays were then placed under shade (50%) in a growing shed that was maintained at 24C. Automatic overhead irrigation controlled by an electric "leaf" was used. The trays were laid down on wooden slats 2 cm thick, which rested on plastic sheeting, that allowed 1 cm of water before it was designed to overflow. The concept of open-bottom pots, resting on slats partially immersed, was mainly to promote the root growth of these wetland species down into the water, but also to observe root growth, so that if necessary, root pruning could be done. The glue holding the pots together soon dissolved and allowed individual pots to be lifted for inspection. Decomposition of the paperpots began to show after 3 months and at 6 months most of the cellulose paper had decomposed, leaving a net of synthetic fibres

from which strong fibrous roots were showing. Top growth had been monitored and in some cases shearing was necessary. As no fertilisers were added during the mixing of the growing medium, an application of foliar fertiliser was applied after 3 months and again just prior to removal from the nursery. After 6 months all plants were removed from shade and hardened off for a 6-week period prior to dispatch and planting out on the sites.

We had some concern that the net of fibre left after the decomposition of the paperpot did not decay biologically but by means of physiologic factors. We decided that bacteria present in the wetlands would assist in the fibres being humified with time and that the plants roots themselves would hold the fibre net in place. The net was flexible enough to expand and allow large rhizomes, such as, those of *Baumea juncea*, to spread and colonise.

We did not believe that damping off would prove to be a problem so no Terrazole™ was added to the growing medium at mixing. Had we been propagating these species by seed germination and considering the addition of the organic wetland substrate then Terrazole™ or similar product would have been a necessity. No fungal diseases were detected on any of the species and only normal routine spraying was carried out to prevent any insect problems from occurring.

A granular topdressing was applied one week prior to moving the plants out of the shade and all species responded with strong growth flushes both foliar and at their roots.

CONCLUSION

For this particular propagation and growing programme, there was need to implement a container system specifically requested by a client, owing to the potential environmental hazards that might be caused by accidental discarding of nonbiodegradable plant containers at the planting-out stage. With hindsight, we will in future similar programmes be using a paperpot that decomposes in a shorter period of time, to reduce the need to root prune and top shear to only once during lateral root growth. We believe that this form of biodegradable container is ideal to grow the types of revegetation plants mentioned and for direct planting into sensitive ecosystems, such as, this planting site.

Side-Slit Cell Trays: The Ford Report

Adrian Ford
Fords Nurseries Ltd., Hilderthorpe, North Otago

Our goal was to produce 5 million forestry seedlings per year in Rootrainers. Nothing on this scale had been attempted before within forest nurseries in New Zealand. So while we had no previous experience within New Zealand to go by, equally we had no preconceived ideas to influence our production methods apart from the precept that Rootrainers would be the container to use. This, at the time, was considered the container most suited to forestry's demands that seedlings grown in containers should have absolutely no root deformation that would, at some later date, impact on the stability of the tree.

Rootrainers had largely filled this requirement for the relatively small-scale production of forestry seedlings in containers at that time.

However, when consideration was given to much larger production runs, we realised that the production system had to be totally integrated in some flow-through concept, and that everything had to revolve and evolve around the container used.

Filling/seeding systems, handling systems, and greenhouse/headhouse layout were all subservient to the type of tray used. It was very obvious to us that Rootrainers were not suitable. Fortunately, we had experimented a year earlier with the new side-slit tray and, to our knowledge, this was the only container which could approach the Rootrainer for minimising root deformation. However, there were other factors to consider, such as, suitability for automated filling and seeding, suitability to handling systems, ease of handling both manual and mechanical, preparation for filling/seeding, ease of storage/stacking (7 million cells can take up a lot of room), ease of washing, economic life, cost, and efficient use of greenhouse space.

In all these respects the side-slit tray seemed superior. The decision to use this type of tray was the first major planning decision made. All the other production systems were selected to complement the tray type. This was, to some degree, made easy by the fact that we are dealing with one species in large numbers, all of one age, on a long-term contract.

While there are several configurations and cell sizes of the side-slit tray available, our choice was for the "81" tray of 100-cc cell size, giving 546 cells per m^2 or effectively 450 cells per m^2 over the whole greenhouse. All other configurations of side-slit trays that we have trialed have proved equally as effective as the "81".

There is no doubt in our minds that experience gained during overseas travel in North America, Canada, and Scandinavia gave us the understanding and knowledge, that enabled our success in gaining a contract of such size as to allow the setting up of such a production facility. The cost of that experience was negligible compared with the cost and returns of the project. I am convinced that while New Zealanders may be the best yachties, the second best rugby footballers, and the best producers of bare-root forestry seedlings, we can still learn an awful lot from overseas experts and practitioners.

Side-slit trays have been developed in Scandinavia where containerised production of forestry seedlings has been standard practice for a long time. Growers there

are very, very skilled at that type of production. The tray's flat, square configuration, based on an agreed industry standard, lends itself very well to automated filling and seeding, is well suited to various types of handling systems, is comfortable to handle manually, and requires no preparation for filling. It stacks very well when empty (50,000 cells per pallet) and washes easily in an automated system. Greenhouse space seems to us to be efficiently utilised.

The tray is injection molded with, in the case of the brand we use, a very high level of quality control. That is not to say that other brands are not adequate. It is just that we have not been given the opportunity to watch the manufacturing process with other brands. We have been told to expect 10 years of life from the trays. If we achieve only 8 years, then using the list price as an example, gives a cell cost of something like 1.4¢ per cell per year.

Of course there must be some down side. First and foremost, high initial capital cost. This is off-set by the very high manufacturing specifications and the long life of the tray. Availability can be a problem. One supplier, I believe, maintains molds in New Zealand so that availability is apparently no problem. However, the alternative supplier manufactures in New Zealand only when significant orders justify freighting the mould out here. Otherwise the delay time of sea freight applies, although this is improving.

Edge effect (where the outside cells dry more rapidly than the rest) is a drawback that growers need to overcome in some way, but is helped to some degree by a handling system which minimises the number of exposed outside cells.

Some species, depending upon the vigour of the root system and the efficiency of air pruning allowed by the handling system, will root between cells making extraction difficult or well nigh impossible without the added process of cutting. One supplier has designed his trays with off-set slits thus minimising the bridging effect.

In our experience of growing in these trays for 2 years now, these deficiencies are relatively minor when considering the undoubted advantages.

To sum up, we are convinced, converted, and enthusiastic at the potential the side-slit tray presents. It will not suit all growers and one aspect we are very aware of is that we are locked into a particular system on a large scale. We needed to be confident. We are.

Rooting in Transgenic Peas

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INTRODUCTION

Grain legumes have generally been difficult to regenerate and transform. Of the major grain legume crops—soybean, chickpeas, peas, cowpea, peanut, common bean, faba bean, and lentils—confirmed transgenic plants have been produced in all except faba bean, lentil, and cowpea (for a review see Christou, 1994). In soybean, chickpeas, and peas, plants have been produced using A*grobacterium*-mediated transformation. For soybeans the method was unrepeatable, and for chickpeas inheritance of the transgenes was not demonstrated. For peas, there are four published reports of *Agrobacterium*-mediated transformation (Puonti-Kaerlas et al., 1990; Schroeder et al.,1993; Davies et al., 1993; Grant et al., 1995). The Puonti-Kaerlas method takes 15 months to recover transgenic plants, all confirmed as tetraploid. While the method of Schroeder is successful in their hands, others have been unable to repeat it (A. de Kathen, University of Hanover and C.M. Stiff, University of Washington, pers. comm.). Davies developed an injection method that is not reproducible even in their own laboratory (D.R. Davies. John Innes Centre, Norwich, England pers. comm.).

At Lincoln we have developed a reliable method to produce transformed plants in a wide range of arable and processing pea cultivars. The explants used are immature cotyledons from "eating" stage peas from either field-grown or glasshouse-grown plants. The peas are at the stage of maximum size and before bleaching of the chlorophyll and drying of the seed. They are dissected, and the proximal half of the cotyledon and the embryo are discarded. The remaining half of the cotyledon is immersed for 1 h in an overnight culture of *Agrobacterium tumefaciens*. After co-cultivation the explants are grown on a medium containing a selection agent.

Callus forms on the cotyledon attachment scar and from this callus, transformed shoots are regenerated. The first transformed shoots are recovered after approximately 4 months and keep producing new transformed shoots for another 5 months. The first shoots root easily using 2 mg litre^{-1} IBA (indole-3-butyric acid)as described by Grant et al. (1995), however, after about 6 months in culture the rooting efficiency decreases. As we wish to maintain shoot cultures of transformed lines for micropropagation and as backup cultures, successful rooting of older material is important. Micropropagation of the transformed shoots and their subsequent growth in the glasshouse allows us to collect a larger number of seeds from the primary transformant, than would otherwise be available, to form the next generation for testing. In this paper we describe experiments carried out in an attempt to improve the rooting of transgenic pea shoots that have been in tissue culture for extended periods.

MATERIALS AND METHODS

Transgenic pea shoots, from eight cultivars and breeding lines of arable and process peas that had been co-cultivated with a range of vectors, were used for the two rooting experiments. For each treatment the shoots were visually graded for size so that similar shoots could be randomly placed into each treatment. In the first experiment 77 to 79 shoots per treatment were used, and in the second experiment there were 41 to 43 shoots per treatment.

For the treatments with the auxin in agar, the basic medium was Gamborg's B5 (1986) containing 30 g litre^{-1} sucrose, 8 g litre^{-1} agar (Difco), 150 mg litre^{-1} timentin (Beecham Research Laboratories), pH 5.8, to which was added one of the following: 2 mg ml^{-1} IBA, 5 mg ml^{-1} IBA, or 2 mg ml^{-1} NAA (α-naphthaleneacetic acid). Explants were cultured in these media for 6 days and then transferred to the basic medium without growth regulators.

For treatments with the auxin used as a dip, the auxin was made up in 50% ethanol and filter sterilized. The treatments were 2 mg ml^{-1} NAA, 5 mg ml^{-1} NAA, 2 mg ml^{-1} IBA, 5 mg ml^{-1} IBA, 1 mg ml^{-1} IBA + 1 mg ml^{-1} NAA, and 2.5 mg ml^{-1} IBA + 2.5 mg ml^{-1} NAA. The plantlets were given a quick dip in an auxin solution and then placed on the basic medium without growth regulators, as described above.

Plantlets were scored for rooting after a total of 4 weeks in culture. A subset of 20 shoots per treatment were transferred to the glasshouse into flats containing pure perlite, and regularly liquid-fertilised using modified Hoaglund's solution (Noggle and Fritz, 1976). The shoots were covered to maintain high humidity for 1 to 2 weeks and survival was assessed after 4 weeks.

Table 1. Rooting of transgenic pea shoots after 28 days.

Hormone treatment	Experiment 1		Experiment 2	
	Shoots rooted per treatment	Percentage rooting	Shoots rooted per treatment	Percentage rooting
2 IBA agar[1]	28/79	35%	17/43	40%
5 IBA agar[1]	43/79	54%	19/42	45%
2 NAA agar[1]	30/78	38%	15/42	36%
2 NAA dip[2]	32/78	41%	nt	nt
5 NAA dip[2]	nt	nt	22/41	54%
2 IBA dip[2]	24/77	31%	nt	nt
5 IBA dip[2]	nt	nt	18/41	44%
1 IBA/1 NAA dip[2]	33/78	42%	nt	nt
2.5 IBA/2.5 NAA dip[2]	nt	nt	18/42	43%

nt = not tested; [1] = no. mg l^{-1} in solidified media; [2]= no. mg ml^{-1} in 50% ethanol, liquid dip.

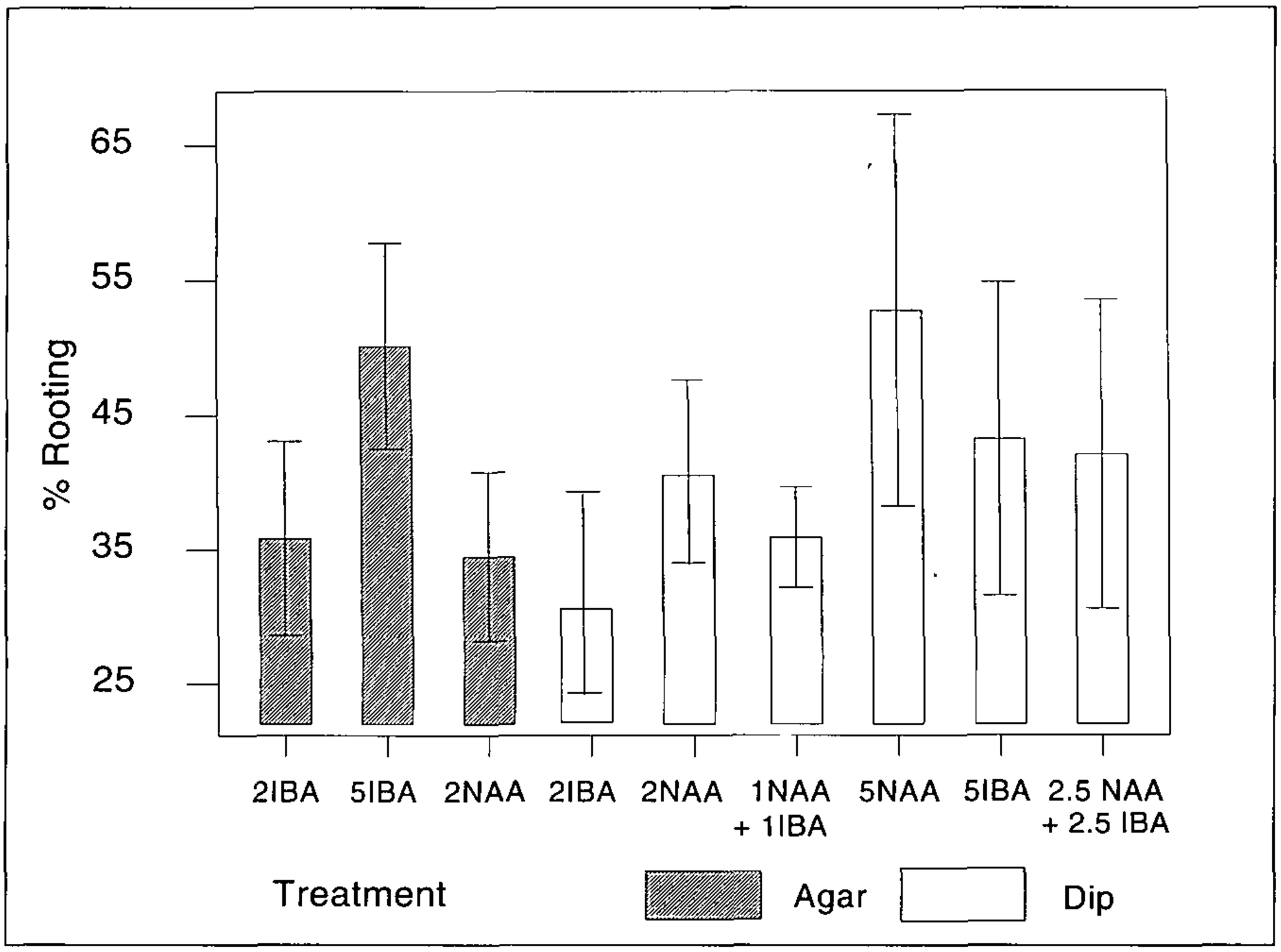

Figure 1. Rooting of transgenic pea shoots after 28 days.

RESULTS AND DISCUSSION

The results of the experiments are shown in Table 1 and Fig. 1. In Figure 1 the results of the agar treatments were pooled across the two experiments. The error bars represent one standard deviation in each direction. From Table 1 it appears that there is a small improvement in the rooting for treatments with increased auxin—5 mg ml^{-1} IBA in agar, 5 mg ml^{-1} NAA, and 5 mg ml^{-1} IBA liquid dips. The results of an analysis of variance showed no significant difference between the treatments. The variation in the results was due to the differences between each container rather than as a result of the rooting treatment. Owing to a shortage of material, some containers had shoots that were the same cultivar and others had shoots from up to three different cultivars. Pea genotypes exhibit a good deal of difference in seedling vigour in the field and this has been attributed, at least in part, to the ability to root well. Some late maturing process pea genotypes are also noted for their ability to root well and withstand "non ideal" environmental conditions better than other genotypes (D.R. Goulden. Crop and Food Research, Christchurch, N.Z., pers. comm.). Our experiments confirm such observations. Using the above treatments, there was no significant improvement in the rooting of our transgenic pea shoots overall. However, comparing the containers with high numbers of shoots that rooted, i.e. the better rooting genotypes, the treatments with higher auxin were consistently better. In the containers that had "poorer rooting" cultivars, the higher levels of auxin were always amongst the better treatments and were never the worst treatment. Further experiments using other auxins (e.g. indoleacetic acid) are underway.

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Advances In Micropropagation of *Nothofagus alessandrii* Espinoza, a Chilean Endangered Species

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Nothofagus alessandrii is one of the 11 endangered woody plant species in Chile. Its propagation is normally carried out sexually. The use of micropropagation systems might be a better way to increase the propagation rate. Initial studies comparing both bud- and embryo-culture methods show that it is feasible to achieve the production of plantlets by using either a woody plant medium or others, supplemented with 0.5 mg litre^{-1} BAP or less. The rooting process of the new developed shoots has to be induced by dipping the single shoots in IBA solutions in the last stage of in vitro propagation.

INTRODUCTION

Nothofagus alessandrii Espinoza is one of the 11 *Nothofagus* species growing in Chile (Rodríguez et al., 1983). Its natural distribution is discontinuous from latitude 35° 05'S to 35° 50'S in a very narrow area of the coastal cordillera, occurring at altitudes ranging from 160 to 440 m. The species covers a total area of 825 to 845 ha. (Landaeta, 1981; Villa,1986) within the forest type known as "Bosque maulino".

According to Donoso and Landaeta (1983)*N. alessandrii*, known in Chile as "Ruíl", is seriously threatened by both ecological and anthropogenic factors.

Since the Spanish settlement in the late 16th century, Ruil forests were intensively exploited to be used for firewood and charcoal production. Of all *Nothofagus* species it is considered the most primitive because of its floral structure. Owing to the apparent inability of the species to increase its range naturally and to its endemism in a very restricted area, the survival of Ruil is critical. Therefore, it was declared by CONAF, the National Forest Corporation, as one of the 11 endangered woody plant species of Chile (Benoit, 1989). At present it is the most important species within the National Forest Reserve "Los Ruiles" in the VII Region of Chile (Villa, 1986). It is being propagated by seeds in several official and private nurseries.

Nevertheless, little work has been done with vegetative propagation systems. Rooting of cuttings achieved by Mebus (1993) was very low (25%). For that reason, and in order to increase the regeneration potential of the species, tissue culture propagation was started in our laboratory, as it was done before with other Fagaceae like *Castanea* (Vieitez and Vieitez, 1980; Rodríguez, 1982), *Quercus* sp. (Vieitez et al, 1985; San José, 1986; Bennett and Davies, 1986; Johnson and Walker, 1990), and *Fagus* (Ahuja, 1984).

MATERIAL AND METHODS

Plant Material. Experiments were started using both dormant buds from mature trees and embryos from freshly harvested seeds. Initial sterilization of the explants was done by a four-step procedure consisting of:

a) Washing in distilled water with a few drops of Tween 20.
b) Shaking in a Captan 80 solution (1.5 g litre^{-1}) for 30 min.
c) Dipping in 70% ethanol (5 sec).
d) Sterilizing in NaOCl, 10% commercial bleach, for 10 min.

After that, buds were peeled and placed onto the culture medium. Mature embryos were extracted from the seed and sown individually.

Culture Media and Treatments.

Bud-Culture Experiments. Initially bud explants were cultivated on four different basal media: Murashige and Skoog Medium (MS), Woody Plant Medium (WPM), Aspen Culture Medium (ACM), and Sommer Culture Medium (SCM) (George and Sherrington, 1984). All the media were supplemented with 0.5 mg litre^{-1} BAP, 20 mg litre^{-1} adenine sulphate, 0.1 mg litre^{-1} thiamine, 0.5 mg litre^{-1} nicotinic acid, 0.5 mg litre^{-1} pyridoxine, 100 mg litre^{-1} myo-inositol and 20 g litre^{-1} sucrose. In all cases Difco-Bacto agar was used (8 g litre^{-1}) and pH was adjusted to 5.6 prior to autoclaving for 20 min at 121C. Culture tubes containing 10 ml of medium were used. Incubation was done under dark conditions and a temperature of 20±2C during the first month, changing to a 16-h photoperiod and 3500 lux during the following 30 days.

Afterwards, surviving shoots were randomly transferred to an ACM supplemented with the following hormonal combinations: 0.5 mg litre^{-1} BAP, 0.5 mg litre^{-1} 2iP, 0.5 mg litre^{-1} BAP + 0.1 mg litre^{-1} NAA, or 0.5 mg litre^{-1} 2iP + 0.1 mg litre^{-1} NAA, keeping all the other components constant. Incubation was done under light conditions.

Embryo-Culture Experiments. The following experiments were carried out.

- ACM and WPM supplemented with 0.5 mg litre^{-1} BAP or without BAP. All other components were kept constant as for bud-culture experiments.
- Same media (ACM and WPM) were supplemented with either 0.1 mg litre^{-1} GA_3 or 0.1 mg litre^{-1} GA_3 + 0.5 mg litre^{-1} BAP.
- Finally, the cytokinin source was compared in the following treatment: control (no cytokinin), 0.1 or 0.2 mg litre^{-1} either BAP or kinetin.

All the experiments were incubated under light conditions. Evaluation was performed after 35 days in culture. Where possible, data were submitted to ANOVA and means contrasted by Tukey's Honestly Significant Difference (HSD) with a 5% significance level.

RESULTS AND DISCUSSION

Bud-Culture Experiments. Initial establishment of sterile cultures was very difficult due to high levels of contamination ranging from 65% to 80% of the cultures. Nevertheless, on all media a few surviving explants were achieved. As Table 1 shows, survival rates ranged from 5% to 20% after a 60-day culture period, shoot development on all media was poor (0 to 2 shoots per explant) and reached up to 5 mm in length. Only WPM medium showed some callus formation.

The remaining plantlets, randomly transferred onto ACM with different hormone combinations, survived up to 83%, showing better responses in the presence of NAA in combination with cytokinin (Table 2). Auxin also improves shoot development. No root formation could be achieved during the incubation period. Further experiments

(not shown here) resulted in more and longer shoots, although rooting has to be induced separately by dipping single shoots in auxin solution as indicated by Vieitez et al. (1985) and Bennett (1987) with *Quercus robur* and *Q. shumardii*, respectively.

Table 1. Effect of culture medium on growth response of *Nothofagus alessandrii* dormant buds after 60 days.

Medium	Survival (%)	Shoot number	Shoot length (mm)	Callus formation (%)
MS	20	0	0	0
WPM	15	1	3	5
ACM	5	1	3	0
SCM	5	2	5	0

Table 2. Organogenic response of *Nothofagus alessandrii* as affected by hormonal treatment.

Treatment	Survival (%)	Shoot Number	Shoot Length (mm)	Callus formation (%)	Root number
BAP*	64	1.1	5.5	55	0
2iP*	64	0.7	7.0	64	0
BAP+NAA**	83	1.7	9.2	39	0.1
2iP+NAA	75	1.3	8.8	56	0

* 0.5 litre^{-1} ; ** 0.1 litre^{-1}.

Embryo-Culture Experiments. The use of mature embryos proved to be by far a better culture system to micropropagate *Nothofagus alessandrii*, achieving up to 95% sterile explants which could be grown into plants or even induced to multiple shoot formation. The use of ACM, differing from WPM only in some micronutrients, does not seem to lead to different results, as may be seen in Table 3. Nevertheless, the addition of BAP to the culture medium clearly increases the callus formation and the number of shoots, although the shoot length is not affected significantly by the addition of BAP. In contrast, as could be expected, the root development (number and length of roots) is affected by the addition of BAP to the culture medium.

A further experiment using the same basal media (ACM and WPM) supplemented with gibberellic acid (GA_3) alone or combined with BAP, showed differences in both callus and shoot development when seedlings were cultured on WPM (Table 4).

Root development is the same on both media. The addition of BAP combined with GA_3 increases the callus formation and the shoot number, but does not improve shoot growth within the incubation period. As expected, root development is

Table 3. Morphogenic response of *Nothofagus alessandrii* embryos to culture medium.

Treatment	Callus formation score**	Shoot number	Shoot length (mm)	Roots number	Root length (mm)
ACM-BAP	1.2 c	1.4 c	18.0 a	3.5 b	13.0 ab
ACM+BAP*	2.9 a	3.6 b	18.5 a	0.5 a	2.6 a
WPM-BAP	1.0 c	1.2 c	20.0 a	4.9 b	16.0 b
WPM+BAP	2.4 b	7.2 a	20.9 a	0.0 a	0.0 a
H.S.D. 5% (Tukey)	0.3	1.4	4.6	1.2	4.0

* 0.5 mg litre^{-1}; ** 1=min., 4=max. callusing.

Table 4. Effect of culture medium and hormones on morphogenesis of *Nothofagus alessandrii* seedlings after 35 days.

Source of variation	Callus score*	Shoot length (mm)	Shoot number	Root length (cm)	Root number
Medium					
ACM	2.0 a **	12.1 a	2.1 a	0.6 a	0.1 a
WPM	1.9 b	10.8 b	1.8 b	0.8 a	0.1 a
Hormones					
0.1 GA_3	1.3 b	11.8 a	1.3 b	1.1 a	0.2 a
0.1 GA_3+0.5 BAP	2.7 a	11.2 a	2.6 a	0.2 b	0.1 a

* 1=min., 4=max. callusing.

** Treatment means for medium and hormones followed by same letter do not differ significantly within the columns (P=5%, Tukey).

affected by the combination of GA_3 + BAP although the root number does not differ significantly.

Lowering the concentration and source of cytokinin (Table 5) as compared to previous experiments, does not bring additional advantages. In most of the parameters measured, the control (no cytokinin) was better than any other treatment. The use of Kinetin instead of BAP does not significantly affect the shoot development. The same occurs with the root number and root length. This would indicate, that after the initial growth phase of the explanted embryos, the addition of exogenous cytokinins to the culture medium would inhibit the further development of the seedling, but if cytokinins are used, BAP should be preferred.

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Table 5. Cytokinin effects on in vitro growth of *Nothofagus alessandrii* seedlings.

Treatment	Shoot formation (%)	Shoot number	Shoot length (mm)	Root number	Root length (mm)
Control	100	0.9 a *	16.6 a	2.5 a	59.9 a
0.1 BAP	53	0.6 ab	8.3 ab	0.7 a	23.2 b
0.2 BAP	67	0.6 ab	10.7 ab	0.7 a	23.5 b
0.1 KIN	40	0.3 b	3.7 b	0.9 a	13.0 b
0.2 KIN	38	0.3 b	3.6 b	1.1 a	5.6 b
H.S.D. 5% (Tukey)	-	0.4	6.5	n.s.	21.1

* Treatment means for medium and hormones followed by same letter do not differ significantly within the columns (P=5%, Tukey).

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Propagation of *Eucalyptus grandis* In Vitro

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Nodular tissue formed on cotyledonary explants derived from *Eucalyptus grandis* seedlings developed on NZFRI *Eucalyptus* Initiation Medium. If transferred frequently (7 days or less) on NZFRI *Eucalyptus* Proliferation Medium, somatic embryos formed on the nodular tissue. Infrequent transfer of tissue on the same medium tended to give rise to adventitious shoots. Variations of a somatic embryo germination protocol (Watt et al., 1991) gave rise to plants capable of transfer to the field.

INTRODUCTION

Eucalyptus species are amongst the most productive and fastest growing hardwood plantation species. In South Africa, *E. grandis* is the most important and commonly grown species, comprising 80% of the total planted area of *Eucalyptus* (Malan et al., 1995). *Eucalyptus* species are grown mainly for pulp for high quality paper and other forest products. Increasing demand worldwide for these products has created a demand for new methods for increasing the productivity of *Eucalyptus* species and for increasing the plantation area of eucalypts. *Eucalyptus* plantations are established by seedlings, cuttings, or coppice. There has been a trend towards clonal forestry using cuttings because of the potential gains in productivity and in selection for desirable wood properties (Campinhos, 1980; Chaperon et al., 1978; Easley, 1989; Lambeth, 1988). However, not all genotypes are amenable to propagation by cuttings (Davidson, 1978) and multiplication rates may also be limiting. Micropropagation techniques offer the potential for higher multiplication rates of some genotypes. Micropropagation systems will also be necessary if genetic transformation of genotypes is desired.

Somatic embryogenesis has the potential to provide high multiplication rates of uniform genotypes. Plants of *E. citriodora* (Muralidharan et al., 1989) and *E. grandis* (Watt et al., 1991) have been successfully regenerated via somatic embryogenesis. The New Zealand Forest Research Institute (FRI) has developed successful somatic embryogenesis protocols for pines, and a pilot project was initiated to develop similar techniques for *Eucalyptus* species. *Eucalyptus grandis* was chosen as a model system to establish somatic embryogenesis techniques, as the species is easily propagated by cuttings and also by tissue culture.

The aim of this study was to evaluate and develop techniques for production of somatic embryos from hypocotyl and cotyledon explants in *E. grandis*. Experiments were initiated to produce embryogenic tissue, to see if nodular tissue would produce somatic embryos, and to determine conditions required for the growth, development, and germination of somatic embryos.

MATERIALS AND METHODS

Seed Germination. *Eucalyptus grandis* seeds (Tanzania batch P8/0/77/17, Proseed, Rotorua) were sterilised for 5 min in 50 ml of mercuric chloride (270 mg litre^{-1}) with three drops of Silwet L77 added as a wetting agent. Seeds were then washed twice in sterile distilled water. Ten seeds per dish were placed on 1/2-strength MS germination medium (Murashige and Skoog, 1962) in sterile petri dishes (90 mm × 12 mm). Seeds were incubated under 16-h photoperiod (5 μEm^{-2}sec^{-1}) at a temperature of 21C day/17C night. After 5 days on germination medium, seedcoats were removed using sterile forceps and scalpel blades. With this procedure, seeds germinated in approximately 15 days and 90% to 100% germination was achieved.

Callus Initiation. The cotyledons and hypocotyls (2 to 10 mm in length) of germinated seedlings were cut into pieces 1 mm long. The cotyledon and hypocotyl pieces were placed on NZFRI *Eucalyptus* Initiation Medium (EIM) (Smith and Cranshaw, unpublished) in a line so that the origin of each explant could be easily identified. The explants were incubated under 16-h photoperiod, at a light intensity less than 5 μEm^{-2} sec^{-1} at a temperature of 21C day/17C night.

The cotyledon and hypocotyl explants were transferred after 2 weeks from initiation medium onto NZFRI *Eucalyptus* Proliferation Medium (EPM) (Smith and Cranshaw, unpublished). Explants were transferred to a fresh spot on this medium at 14 days, and placed on fresh medium every 28 days. Explants were incubated under 16-h photoperiod, at a light intensity less than 5 μEm^{-2} sec^{-1} at a temperature of 21C day/17C night.

Table 1. Response (percentage) of explants on *Eucalyptus* proliferation medium after 3 months.

Explant	Mucilaginous tissue	Nodular tissue	Nodular tissue with roots	No response
Cotyledon	0	50	15	35
Hypocotyl	15	15	10	70

In one experiment, after 10 weeks on EPM, nine clones which formed nodular tissue (Fig.1) (originating from both cotyledons and hypocotyls) were transferred to regeneration medium (Table 1) to see if nodular tissue would produce somatic embryos. The nodular tissue from either cotyledon or hypocotyl explants was placed onto separate dishes so that each explant could be traced back to its origin. Tissue was moved to a fresh spot on the medium at 14 days, and transferred onto fresh medium every 28 days. Tissue was maintained under 16-h photoperiod (light intensity less than 5 μEm^{-2} sec^{-1}) at a temperature of 21Cday/17C night for approximately 16 weeks. Somatic embryos formed on the nodules if subculture was frequent (7 days), and adventitious shoots formed with less frequent subculture (14 days or more).

The nodular tissue was split into 3- to 5-mm-diameter pieces and eight pieces per plate were placed onto 1/2 MS media containing different concentrations of growth

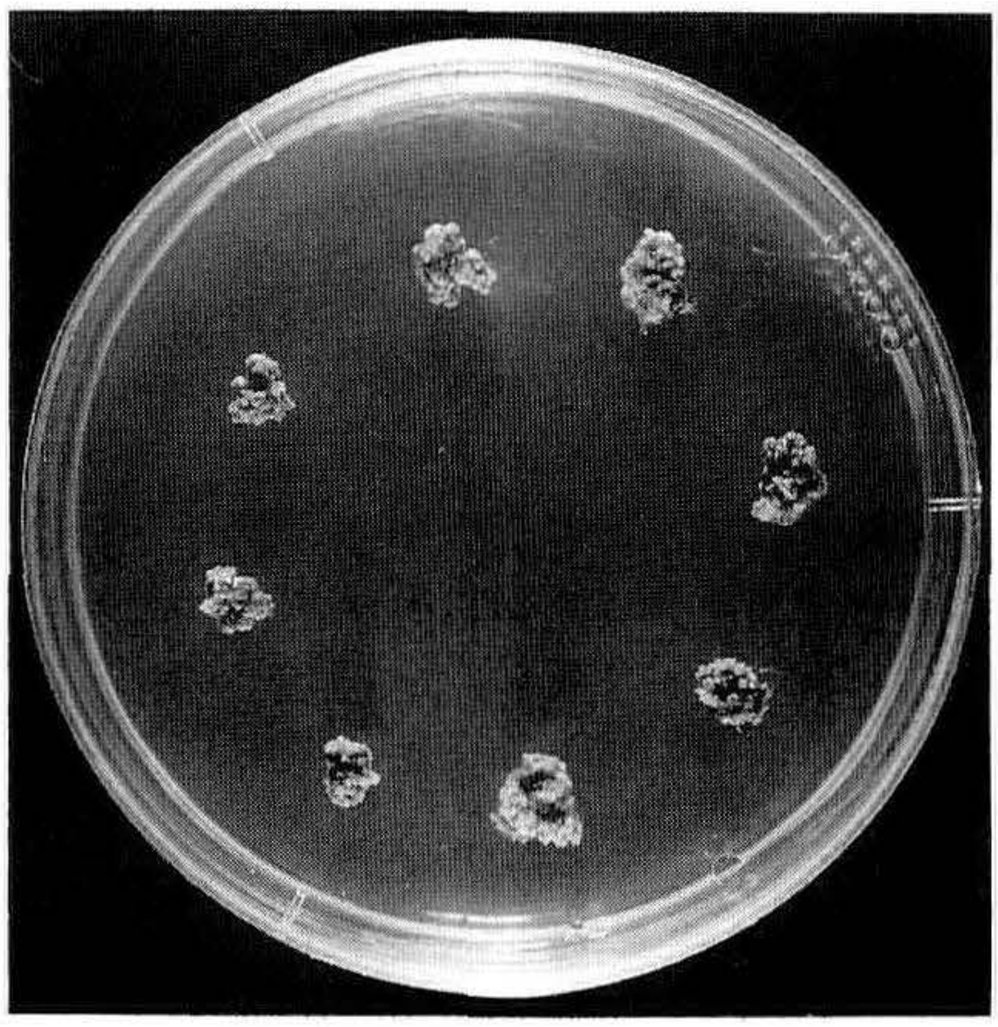

Figure 1. Nodular tissue of *Eucalyptus grandis* on regeneration medium.

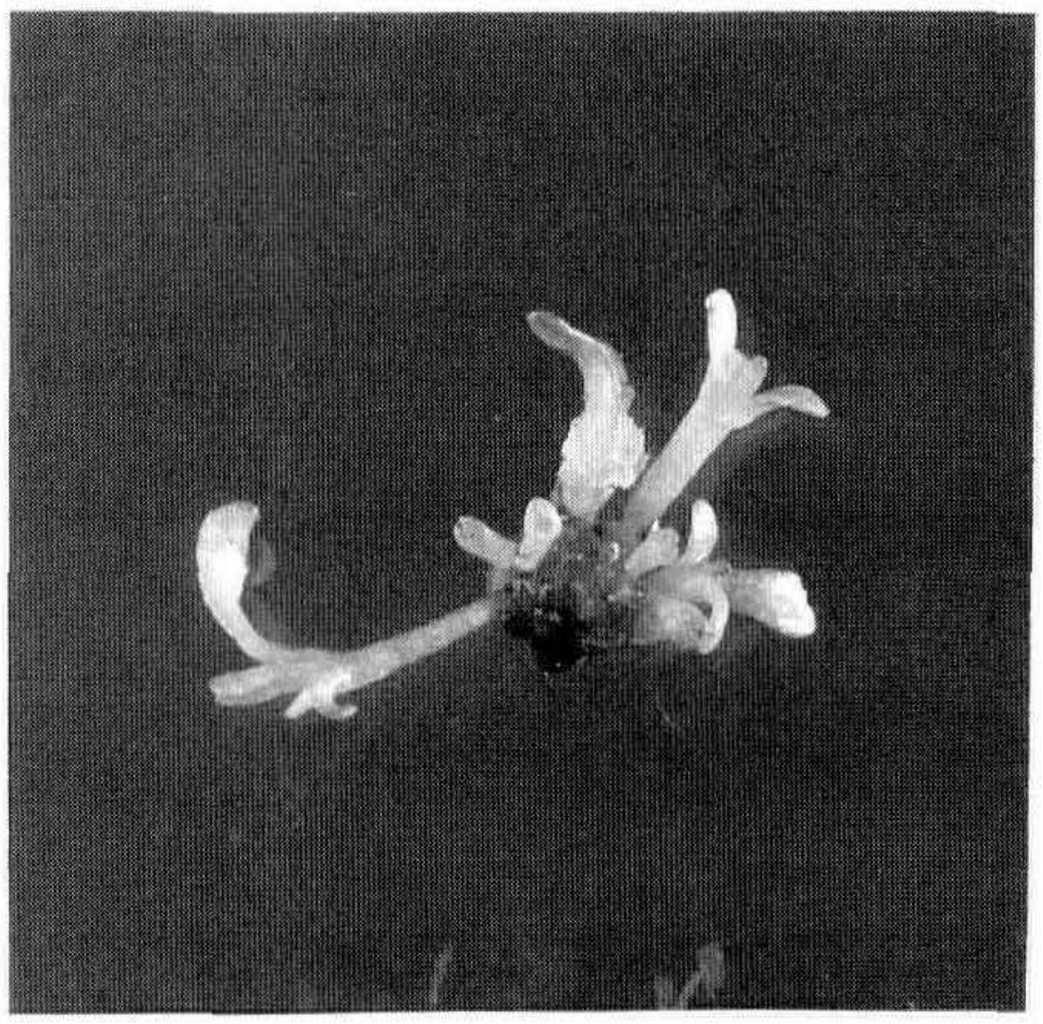

Figure 2. Nodular tissue of *Eucalyptus grandis* simultaneously forming somatic embryos and adventitious shoots. SE, somatic embryos; AS, adventitious shoots.

regulators as described by Watt et al., (1991). The medium was gelled with Gelrite at various concentrations (Table 2). The plates were kept in the dark (covered with black cloth) at 24C for 9 weeks.

Somatic embryos and adventitious shoots (Fig. 2) produced from the nodular tissue were counted under sterile conditions using a dissecting microscope. All somatic embryos were separated from the callus tissue and maintained on R9 medium (Watt et al.,1991) to enable elongation of the hypocotyl and cotyledons. Embryos were moved to a fresh spot on the medium at 14 days, and transferred onto fresh medium every 28 days. The somatic embryos were maintained under 16-h photoperiod, with low light intensity (5 μEm^{-2} sec^{-1}) at a temperature of 21C day/17C night. After 8 weeks on R9 medium, embryos were transferred to 1/2 MS medium with 4 g $litre^{-1}$

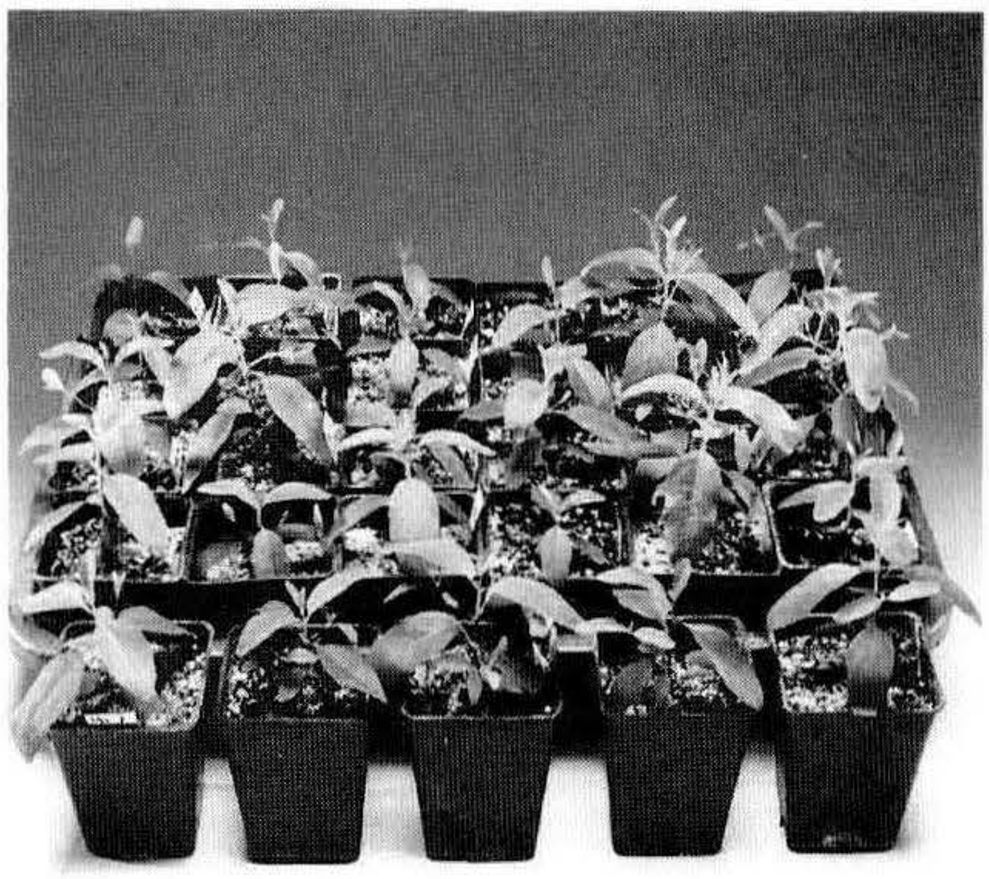

Figure 3. *Eucalyptus grandis* plants regenerated from somatic embryos, after 8 weeks in potting medium.

Figure 4. *Eucalyptus grandis* somatic seedlings in a "starved" state ready for field planting.

charcoal and were maintained under the same lighting conditions for a further 2 days. This procedure was to remove any phenolic substances which were exuded by the germinating somatic embryos.

Somatic embryos were then planted in a mix of perlite and commercial potting mix (1 : 2, v/v) in plastic propagation trays (29 cm × 36 cm) with transparent plastic lids. The propagation trays were placed in a greenhouse and watered every day. After 8 weeks, the plantlets (Fig. 3) which had germinated were transplanted into potting mix in (5 cm × 9 cm) plastic pots. Plantlets were retained in plastic pots for 3 months in a "starved" state as recommended by Faulds and van Dorsser (1987). The leaves turned red, increased in thickness and stems became woody (Fig. 4). This starvation regime is preferred because seedlings become hardier and more drought resistant and, therefore, are more suitable for planting on drier sites or during the drier parts of the growing season. Somatic seedlings of *E. grandis* were planted in the field near Whangarei in late August 1994.

RESULTS

The explants were monitored and scored for tissue development after 3 months (Table 1). A much larger percentage (65%) of cotyledon explants responded on EPM than did hypocotyl explants (30%). The predominant type of tissue produced by both types of explant was a green nodular tissue (Fig.1), a small percentage of which also produced roots (10% to 15%). The hypocotyl explants which did not respond either died or became translucent.

Somatic embryos were produced on all media tested (Table 2). The largest numbers of somatic embryos were produced on the media with higher levels of growth regulators (media 4, 5, and 6). The concentration of Gelrite in the medium influenced the number of somatic embryos produced, with higher concentrations of gelrite increasing the number of somatic embryos produced regardless of the concentration of growth regulators.

Table 2. Effect of 1/2 MS-based media on somatic embryo production and subsequent conversion.

Media	NAA (mg l^{-1})	BAP (mg l^{-1})	GA_3 (mg l^{-1})	Gelrite (g l^{-1})	No. of somatic embryos produced	No. of somatic established transferred to soil	No. of plants
1	0.01	0.1	0.1	2.0	87	10	1
2	"	"	"	3.0	138	27	7
3	"	"	"	4.0	148	15	4
4	0.04	0.4	0.4	2.0	154	35	11
5	"	"	"	3.0	213	18	5
6	"	"	"	4.0	334	13	2

However, the quality of the somatic embryos was adversely affected by high Gelrite concentration in combination with high growth regulator concentration. Although the greatest number of somatic embryos were produced on medium 6, less than 4% of these survived to be transferred to potting mix. The best quality somatic embryos were produced on medium 4, for over 22% of these embryos were transferred to potting mix and 31% of these grew (which equals 6.8% of initial embryos) and were established in the field. These plants are now 1 year old, over 1 m in height, and phenotypically normal.

DISCUSSION AND CONCLUSION

Cotyledon explants of *E. grandis* were the best tissue for regenerating nodular organogenic and embryogenic tissue. Although medium 6 produced the highest number of somatic embryos, medium 4 was the preferred medium, as better quality embryos were produced and subsequently these converted to plants more successfully.

Somatic embryos were successfully produced from cotyledon explants of*E. grandis* and somatic seedlings have been planted in the field. With the present protocol, both the yield of somatic embryos and the number that successfully converted to plants was relatively low. Further studies are needed to improve the methods so that larger numbers of high quality embryos can be produced and converted to plants.

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Horticultural Use of the Genetic Variation of New Zealand and Australian Teatrees

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HISTORY

The name teatree comes from the use of these plants for making a herbal tea by Captain Cook in his voyages to New Zealand beginning in 1769. This use was part of Cook's strategy to overcome scurvy, one of the curses of long distance sea travel in those days. The botanist on Cook's first voyage, Daniel Solander, identified two species of teatree which he ascribed to the genus *Philadelphus*. Seeds of these were taken back to England and by 1778 four kinds of New Zealand *Philadelphus* were being offered for sale by an English nurseryman (Brooker et al., 1988). These plants fetched a price of 7s 6d (75¢) each, which, on the basis of the inflation that has occurred since that time, must have been an astronomical price! One of these was named *P. aromaticus*, and the essential oils that give this aromatic character have been recently developed as new products in New Zealand and are reputed to have significant pharmacological properties.

On Cook's next voyage in 1773, the accompanying botanists, father and son—John Rheinhold and George Forster, recognised that the New Zealand teatrees were something quite different from the mockorange genus*Philadelphus* and established the genus *Leptospermum*. *Leptospermum* means narrow seeded, and the Forsters named the first species of the genus *scoparium*, meaning "broom like". This is the plant that is commonly known today as manuka. It was not until 1832 that a second species that had been recognised by Solander was described as*L. ericoides*, *ericoides* meaning "heath-like", by the French taxonomist A. Richard. This was from a specimen collected during the voyages of exploration by Duperrey and D'Urville in either 1824 or 1827. This is the plant that is commonly known today as kanuka. People continue to have difficulty separating manuka and kanuka but the differences between them are quite obvious once they are pointed out.

A third species of *Leptospermum* indigenous to New Zealand was described in 1899 by Thomas Kirk, one of New Zealand's most notable resident botanists of last century. This species, named *Leptospermum sinclairii*, is endemic to an area around Mt. Hobson on Great Barrier Island. Volume I of the Flora of New Zealand (Allan, 1961) recognised these three species of New Zealand teatrees. This reference also recognised the variety *incanum* of*L. scoparium* based on pink-flowered plants from northern North Auckland, and also the varieties *lineare* and *microflorum* of *L. ericoides*.

VARIATION AND ORNAMENTAL CULTIVARS

New Zealand botanists soon realised that both manuka and kanuka were very variable species. Leonard Cockayne (1919) remarked that manuka presented a diversity of forms that were seemingly impossible to classify. Even though our knowledge of manuka has advanced considerably since Cockayne's time, what he said about the difficulty of their classification remains largely true. New Zealand

nurserymen and gardeners soon came to regard this variability as an asset to be exploited. However, whereas English horticulturists were enthused by the novelty and simple beauty of the white, single-flowered forms brought back from Cook's voyages, these soon became commonplace to those who settled in New Zealand.

Instead, rare variants discovered amongst the widespread wild stands of manuka were brought into cultivation and provided the parents of most of the 100 or more named cultivars of *L. scoparium* that have been released since the beginning of this century (Harris, 1993a, 1994). Amongst the most notable of the manuka cultivars directly derived from wild plants were *L.* 'Nichollsii' from a crimson-flowered plant discovered near Kaiapoi in 1898, *L.* 'Leonard Wilson' a white double-flowered plant described by Cockayne (1918) from a plant collected at Port Levy, and *L.* 'Keatleyi', a plant with large pink flowers discovered near Parengarenga Harbour in the far north in 1917 (Stevens, 1944).

The next major step forward in the use of manuka as an ornamental plant began in 1939 in a crossing and selection programme by W.E. Lammerts (1945) in California. Lammerts produced a series of cultivars from the F2 progeny of the cross between *L.* 'Nichollsii' and a double-flowered cultivar *L.* 'Rose Double' of uncertain origin. Since Lammerts time other important series of selections have come from the E.F. Jenkin & Sons Nursery near Melbourne Australia, the "Nanum" series named after New Zealand birds released by Duncan and Davies, New Plymouth, New Zealand, in the 1950s, and the recent "Wiri" selections made by Jack Hobbs, Curator of the Auckland Regional Botanic Gardens.

THE AUSTRALIAN CONNECTION

Allan's (1961) opinion was that the three *Leptospermum* species indigenous in New Zealand were also endemic. He considered that in total there were about 35 species of *Leptospermum* and most of these were Australian. This view of *Leptospermum* was radically changed in the early 1980s when Joy Thompson, working on a revision of the genus, placed kanuka in the genus *Kunzea* as *K. ericoides* and included *K. sinclairii* with this species. She also stated that both *L. scoparium* and *K. ericoides* occurred naturally in both Australia and New Zealand (Thompson, 1983). In her published revision of *Leptospermum* (Thompson, 1989) she describes 79 species, and several of these were recently discovered plants. Amongst these was *L. spectabile*, a species with a very local distribution along the Colo River close to Sydney. We introduced and evaluated this plant at Lincoln and made a selection named *L. spectabile* 'Christmas Star' (Harris and Percy, 1988). Although in many respects it is a more spectacular plant than the manuka cultivars it has not become widely grown because it is difficult to propagate, has low frost resistance, and has a habit not convenient for container growing. However, I have a specimen at home that looks and grows well on the sheltered northern side of the house.

By the time Joy Thompson's findings became known I had assembled and raised 50 populations of manuka and 20 of kanuka from seed collected from sites throughout New Zealand. By bringing these populations to the one site and growing them in a common environment, genetic differences between these populations were revealed. Amongst the observations made on these plants were height and width growth, leaf and flower characters, flowering, disease and pest resistance, and frost tolerance. Very significant genetically based differences between these populations were revealed in this way, and within populations some very distinctive

plants of horticultural interest were found. As an example, variation of shrub form of both manuka and kanuka between and within populations is illustrated in Fig. 1. From this variation the distinctive compact dwarf *Kunzea ericoides* 'Karo Greenfingers' has been described and selected (Harris, 1994). 'Karo' is being included in the names of all the ornamental cultivars selected by Landcare Research. It is an acronym of "known and recorded origin" and highlights the importance of accurate recording of the origin and characteristics of cultivars before they are commercially propagated.

Joy Thompson's findings encouraged me to introduce seed of populations of both *L.* scoparium and *K. ericoides* from Australia. Also, several of the Australian species she described were introduced. As well as *L. spectabile* 'Christmas Star', a cultivar *L. variabile* 'Karo Crimson Pearl' has been developed (Harris, 1993a) and selections of several other Australian species are being tested by New Zealand plant propagators. While many cultivars of *L. scoparium* had been selected, relatively few cultivars of Australian *Leptospermum* species have been described. Australian's neglect of their *Leptospermum* species can be explained by the wealth of spectacular and colourful plants in their flora. Without the rare occurrence of red pigments and double-flowered characters in manuka it would not have attracted the use as an ornamental it has received. It was quickly observed that the Australian species had characters that would enhance the features of the ornamental *L. scoparium* if crosses could be made, but little information was available to indicate whether hybridisation was possible.

CHANCE AND DELIBERATE HYBRIDS

Two hybrids came into the research programme by chance, both spectacular in different ways and by different routes. Twenty-four plants were grown for each of the 70 populations of New Zealand manuka and kanuka so that the differences between plants within the populations could be studied as well as the differences between populations. Amongst the *K. sinclairii* population from Mt. Hobson, Great Barrier Island was one plant that stood out as being quite different from the rest. Consequently this plant received careful study and this showed it to be an intergeneric hybrid between *L. scoparium* and *K. sinclairii* (Harris et al., 1992).

This plant is a sterile F1 hybrid and the probability is that had the seed it grew from fallen on the ground in the wild it would not have grown into a plant. Following correct plant nomenclatural procedures this plant has been named ×*Kunzspermum hirakimata* the specific name being the Maori name for Mt. Hobson. Being a unique plant, and combining several of the good features of the parent species, this plant also deserved description as a cultivar—hence ×*Kunzspermum hirakimata* 'Karo Hobson Choice' (Harris, 1993b). Since the discovery of the intergeneric hybrid, several deliberate crosses between *L. scoparium* ornamental cultivars and *K. ericoides* and *K. sinclairii* have been tried with the aim of introducing red pigmentation into the flowers of kanuka. These have not been successful.

When the *L. spectabile* plants raised from seed obtained from Australia flowered and set seed, seed from a selection of these plants which showed strong red flower coloration was in turn sown. Amongst the seedlings from this sowing was one with leaves distinctive from those of *L. spectabile* and this was marked for closer attention. When this plant first flowered in 1991 it had large and distinctively coloured flowers, markedly different from the variation of flowers amongst the

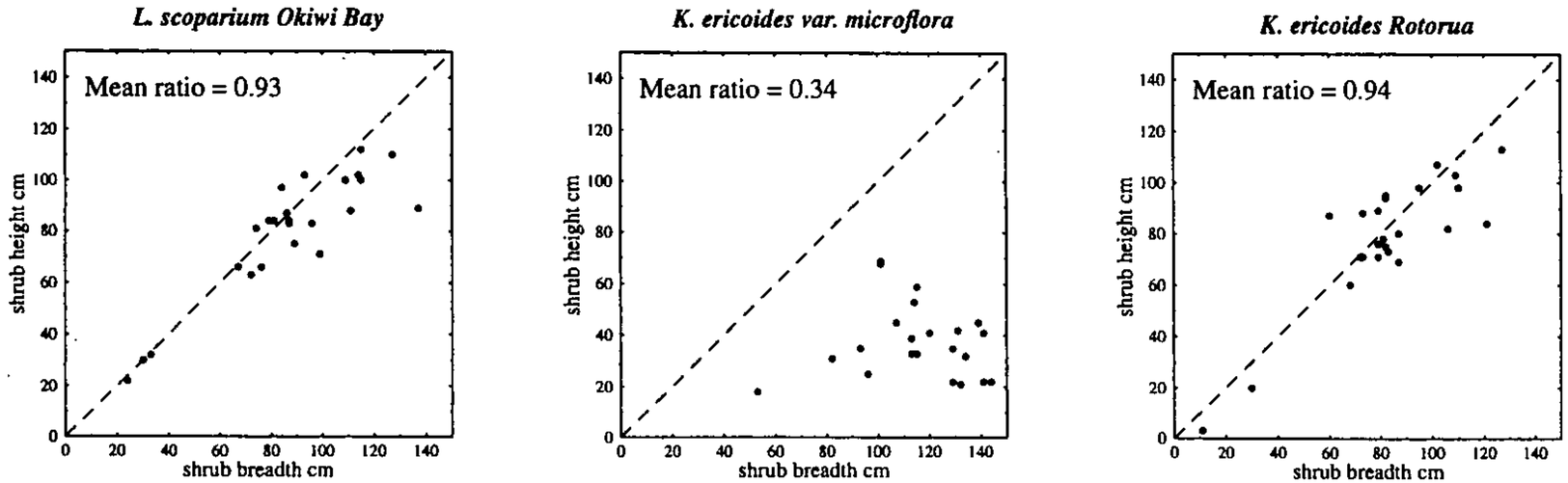

Figure 1. Variation between and within teatree populations of shrub dimensions. Means of the shrub height-to-breadth ratio are shown for each population. Prostrate shrubs are below the diagonal line and erect shrubs above the line (From Harris, 1994).

parent *L. spectabile*. Returning to the specific *L. spectabile* plant from which the seed had been collected, it was found that it was adjacent to a block of *Leptospermum* cultivars, mostly manuka cultivars but also a plant of *L. rotundifolium* 'Jervis Bay'.

The natural distribution of *L. rotundifolium* is in an area south of Sydney on the tableland escarpment of central eastern New South Wales to the coast near Jervis Bay. It has large flowers that vary in colour from white and cream to a purple that is not found in any other *Leptospermum* species. This plant, a spontaneous hybrid between the *Leptospermum* species with the most spectacular flowers, has been described and named as *Leptospermum* ×*violipurpureum* 'Karo Spectrobay'.

Although this hybrid has large and distinctly beautiful flowers, it has inherited the difficulties of propagation that characterise the parents. Similar to the specimen of *L. spectabile* 'Christmas Star', a specimen of *L.* 'Karo Spectrobay' looks and is growing well on the sunny side of a trellis in my home garden.

While these spontaneous hybrids were being discovered at Lincoln, research at Levin to improve the floricultural characteristics of *Leptospermum* had generated hybrids of *L. scoparium* with *L. rotundifolium* and *L. macrocarpum*. Also, my colleague Murray Dawson who made the very interesting discovery of tetraploidy and triploidy amongst *L. scoparium* cultivars (Dawson, 1990), obtained a successful cross between *L. scoparium* 'Pink Lady' and *L. spectabile* 'Christmas Star' in the late 1980s and has selected progeny from this cross for use as ornamental cultivars.

Since 1990 I have attempted crosses between a selection of *L. scoparium* cultivars and most of the Australian species grown in the collection at Lincoln and several other interspecific crosses. For the purpose of gaining fundamental knowledge about *Leptospermum* this has been done to define the reproductive barriers between the species of the genus. To do the possible 6162 interspecific crosses between the 79 species defined by Thompson (1989) is an impossible task even if all of the species could be grown at Lincoln. Using red-flowered cultivars of manuka is useful, as presence of red coloration in a hybrid usually indicates a successful cross, as all but a few species of *Leptospermum* have white flowers. These hybrids also have possibilities as ornamentals because of the combination of flower colour with the superior foliage characteristics, shrub conformation, and disease and pest resistance that several species have compared to *L. scoparium*. Amongst the more interesting hybrids are *L. variabile* × *L. spectabile*, *L. scoparium* × *L. rupestre* and *L. scoparium* × *L. polygalifolium*.

A SMELL OF SUCCESS

A scented flower is often an attribute of a successful ornamental plant. Aromatic leaves also add interest to a plant, and it would seem that this was one of the features of the teatrees that attracted horticulturists when they were first introduced to England as *Philadelphus aromaticus*. It is not certain whether this name was applied to manuka or kanuka as the crushed leaves of both species are very and distinctly aromatic. Aroma can be used to distinguish the species as kanuka has a harsher eucalyptus-like aroma whereas manuka leaves have a more pleasant, some say a more juniper-like aroma. More detailed sniffing of plants within the species also shows aroma differences between populations and between plants within populations. Recent research by the Crop & Food Institute has shown that there are a complex array of essential oils that contribute to the distinctive aromas of the teatrees (Douglas et al.,1994).

One of the successful developments of my research on the teatrees in the last two years has been the opportunity to work with the Plant Extracts Research Unit of the Crop & Food Institute. The Unit has used the provenance and species collection to prospect for different essential oil components in New Zealand teatrees and closely related Australian species. An example of the variation of a component, α-pinene, in New Zealand*L. scoparium* and provenances from New South Wales, Victoria, and Tasmania, shows that this is higher in all the Australian provenances compared to the New Zealand provenances (Fig. 2). The two New Zealand populations (1, 4) with high α-pinene both come from the North Auckland Peninsula. Populations 2, 3, and 5 from similar latitude, but from sites in Great Barrier Island and the Coromandel Peninsula have similar levels of α-pinene as the other New Zealand populations. This is very useful information for understanding the relationships between *L. scoparium* in New Zealand and related taxa in Australia. The variation may relate to the ecological situations of the taxa, one suggestion being that content of α-pinene may relate to fire-ecology.

TEATREES TO EUROPE

Although the novelty that greeted teatrees when they were first introduced to Europe soon faded, they still hold their attraction in a market for ornamental plants that is vast compared to that of Australia and New Zealand. The colder climate of Great Britain and Ireland severely limits the use of New Zealand plants, and for all

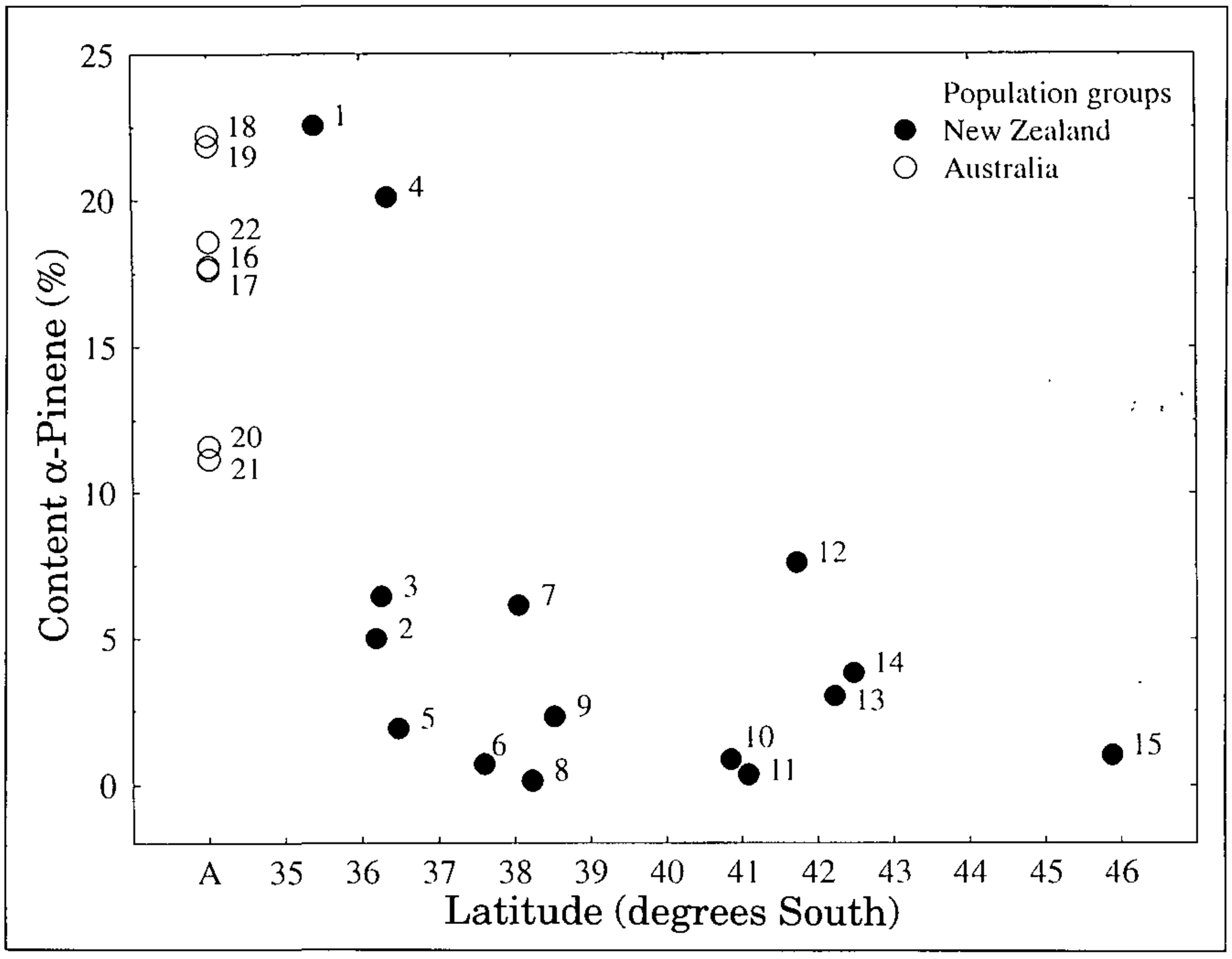

Figure 2. Variation in the percent content of α-pinene in 22 provenances of New Zealand *Leptospermum* and closely related Australian (A) taxa. The New Zealand provenances are plotted against their latitude of origin.

but a few species, their growth outdoors is limited to the southern and western regions of those islands. Even there occasional episodes of very cold air from continental Europe can cause severe damage. Cabbage trees (*Cordyline australis*), named the Torquay palm in S.W. England, and often shown on postcards to give a false impression of warm and palmy holiday getaways in Cornwall and Devon, have in very cold winters been killed to ground level.

In looking to Europe as a destination for New Zealand plants it is important to recognise that the southern most part of England is 3° of latitude closer to the polar regions than Stewart Island. The first introductions of New Zealand plants to Europe were more frequently from coastal and northern regions of New Zealand. This may have given New Zealand plants a poorer reputation for cold hardiness than if the plants introduced had come from southern and inland highland regions of the country. The main route of introduction from New Zealand to Europe via the United Kingdom, most likely filtered out many species and provenances that would be climatically suited to the Mediterranean latitudes that are the antipodes of New Zealand.

It was with these possibilities in mind that Luc Decourtye, international leader in the selection of fruit trees and ornamental shrubs from INRA France, came to New Zealand in 1986. His aim was to collect New Zealand tree and shrub species from higher altitude regions of the South Island, to prospect for more cold-hardy provenances better able to survive and show attractive ornamental growth in

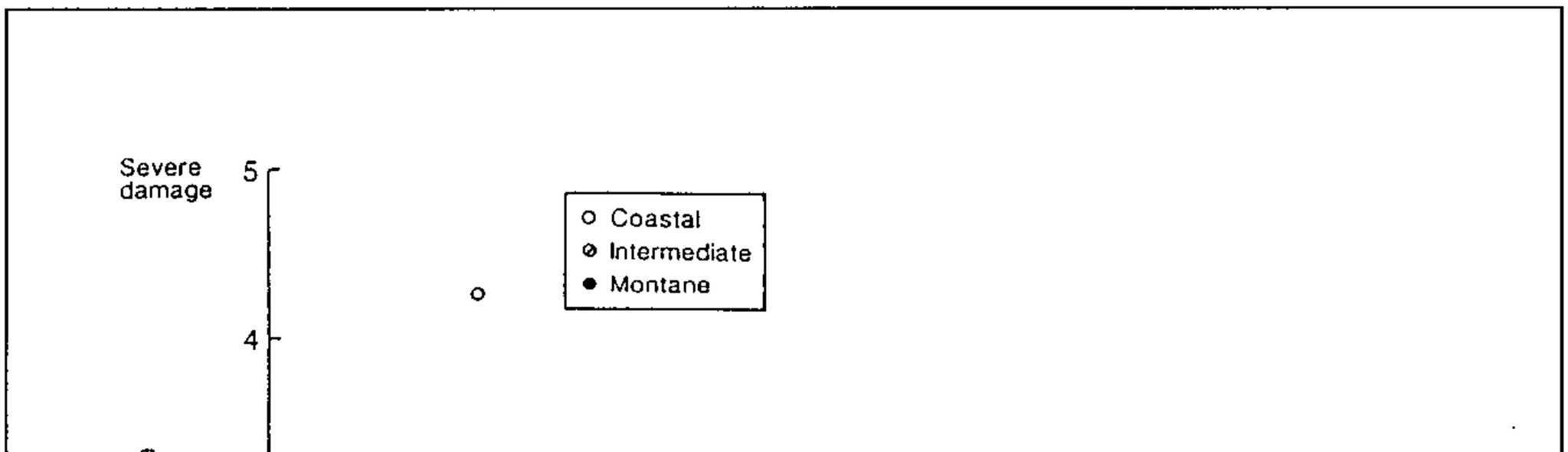

Figure 3. Relationship between cold damage score and latitude of origin of New Zealand populations of *Leptospermum scoparium* after the 1988-89 winter at Angers, France (from Harris and Decourtye, 1991).

France (Decourtye et al., 1991). It was through this contact that several of the provenances of teatree that I had gathered at Lincoln were also tested at Angers in the Loire Valley, Landerneau near the Brittany Coast and Fréjus on the Mediterranean coast of France. We found that the extent of cold damage to *L. scoparium* provenances during an average Angers' winter in 1988-89 was related to their latitude and altitude of origin in New Zealand (Fig. 3, Harris and Decourtye, 1991). The cold tolerance of the provenances was even more markedly defined after the severe 1990-91 winter when grass minimum temperatures fell to -12.5C (Decourtye and Harris, 1992). We also observed the cold tolerance of 75 other New Zealand plant species, and for some their provenances and cultivars, over 4 years at Angers (Harris & Decourtye, 1995).

This assessment of the variability of cold tolerance provides information that will give more confidence about the prediction of suitable areas of cultivation of New Zealand plants in the southern and south western regions of Europe. The opportunity is available for selection to improve the cold hardiness of New Zealand ornamentals. A difficult issue to resolve is that of controlling and gaining a return from the investment in such selection if it were to succeed in expanding the market opportunities for New Zealand plants in Europe.

CONCLUSION

My experience with teatrees has emphasised that natural genetic variation of plants provides a rich resource for the development of new plant materials for plant propagators. In recent times plant science has become bedazzled with the possibilities of applications of DNA-related technologies. It is important DNA applications do not blind us to the opportunities of revealing, classifying, conserving, and molding natural plant genetic variation to our needs.

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Blue Mountain Azaleas

Denis Hughes
Blue Mountain Nurseries, 99 Bushy Hill St., Tapanui, West Otago

Blue Mountain Nurseries was established by my father Stanley Hughes in 1932. His interests were strongly associated with the growing of plants beginning with quick crops, such as vegetables and bedding plants. With his primary interests being ornamental plants, it was not long before perennials, bulbs, cut flowers, and floristry became an appreciable part of his business. The war years saw vegetables returning to the forefront of his endeavours and elite plants were always kept to produce seeds for the following crops or for dividing and naming.

Examples of these were:

- Winter and spring harvesting cauliflowers.
- *Psylliostachys suworowii*—red form. This form does not seem to be available now.
- *Helichrysum bracteatum*—pastel pink forms. This has become common in seed lists.
- *Polyanthus* "Pacific Strain"—a selected seed strain with a wide mixed colour blend.

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- English iris in an assortment of colours.
- Narcissus.
- *Scabiosa caucasia* 'Blue Mountain' and 'Mount Cook'.
- *Gaillardia* 'Hughes Yellow', 'Hughes Red', and 'Judy Hughes'.
- *Pyrethrum* 'Otago' and 'Southland'.
- *Chamaecyparis lawsoniana* 'Hughes'.

It is from this background that I went into horticulture and studied at Lincoln College. As a student, on Saturdays I helped in the Molly Coker garden at Ilam in Christchurch, and it was here that I was introduced to the breeding and selection of Ilam azaleas. Through my father I was also aware of the work of Dr. Yates both with azaleas and lilies.

After leaving Lincoln I sourced my first azaleas from the Coker garden and later imported azaleas from England. It was while acclimatizing imported azaleas from England that a lucky break took place. As often happens with a plant under stress, a usually double-flowered form produced single blooms. My first thoughts were that I had received an incorrect cultivar, but pollinated the flowers with an Ilam azalea anyway. Three pods of seed ensued producing just over 300 seedlings. When these flowered over half were double, most in various shades of pink. While growing these seedlings for many years and observing their growth characteristics, much of what is good and bad in deciduous azaleas has been polarized. This has enabled me to form a list of desirable attributes for evaluating deciduous azaleas. These attributes are:

1) The dainty double flowers are appreciated by the public. Unfortunately the ones the public admired most generally did not have other important desirable traits.
2) Compact bushy plants. The larger flowers are produced on the taller plants. (Large flowers on compact bushy plants seem to be diametrically opposed.)
3) No seed. This is great for gardeners as deadheading in not required. But from a breeders point of view the best plants are the end of the line.
4) High health. Resistant to mildew and leaf spotting. This is a new addition to the selection process as these diseases are relatively new in New Zealand.
5) Clear popular colours. This would appear to be quite a fashion-driven selection criteria and hard to follow with a long-term crop like azaleas.
6) Ease of propagation. There is no use having the best plant in the world if it cannot be propagated.
7) Extended flowering season, October to December.
8) Large ball-shaped trusses. Short pedicels prevent the rain and wind from causing the flowers to be broken off.
9) Large wide funnel flowers.
10) Flowers of good substance. These will last well and be fine for floral art.
11) Flowers that are colour-fast or fade beautifully.
12) Bright autumn foliage.

In the first generation there were three plants of particular note. One, a double white (No 44) which has most of the attributes required, we have named 'Pavlova'

and now have PVR rights for. It is healthy, free flowering, and responds well to tissue culture. Hence we had this one on the market well ahead of other selections. It is becoming known, and is very popular with those gardeners who grow it.

This year we are releasing double apricot no. 12, a nice compact low-growing double apricot, reasonably early flowering (end of October in New Zealand) considering its siblings. We have named this one 'Sunray' and it has been propagated up to commercial numbers by conventional cutting methods.

Another important F1 is nicknamed 'Ballet Girl'. Nice as this one is, in its own right, we do not intend to propagate or sell this clone, but it is very important to us as it produces seed readily. We crossed it in 1989 with all the very best of the Ilam strain available and from the 10,000 seedlings produced we have been selecting, using the above criteria, and test propagating.

At the moment we have reduced these 10,000 to between 200 and 300 seedlings which are very promising in a wide range of colours. We have some at Exbury Garden in England being trialed with their Exbury selections. All the F2 generation, Blue Mountain azaleas as we call them, have large double flowers and are resistant to black spot and mildew. They are also vigorous and easy to grow, propagating readily from cuttings and have a good full flower truss.

It is interesting to note that in the first generation all flowers were pastel coloured but in the second generation with such a wide range of pollen parents they gave their progeny a wide range of colours.

Flower form is also extremely varied. In the double Blue Mountain azaleas the stamens are absent and five petals are present instead (hose-in-hose flowers).

Also, these petals tend to be pointed and this is certainly the dominant flower form, but rounded or frilled petals are also present. The frilled flowers tend to look like carnations. The doubling may be in multiples of 5 as you would expect, e.g., 5 single, 10 hose-in-hose, 15, and 20. However, a few plants have multiples of 6 and I suspect these may be tetraploid plants, e.g., 6 single, 12 hose-in-hose, 18, and one plant has 24-petalled flowers.

If flower form or colour were the only selection criteria it would be very easy to make decisions of which to name. But with all the other criteria evaluated at other times of the year it has made selection difficult. To aid in selection we have designed a labelling system. I usually do much of my evaluations when showing others through the seedlings. With this in mind green labels mean healthy foliage in the autumn, and orange labels mean double flowers. If after 5 years they still look great, a tall bamboo pole is placed beside the plant so that it can be readily found for test propagation. The numbers allotted to the selected plants are for example: 84-90-21

- The first two the year of hybridizing.
- The second two the year of selection.
- The last two the number selected that year.

The selected plants are then test propagated and the resultant strike rate is determined. These propagules are then trialed under our azalea production methods and the resultant plants are evaluated once again.

As an example we had a very good pastel double pink built up to 100 plants. These performed admirably in all respects so 5000 cuttings were struck and in due course planted out in beds. Unfortunately for us, this coincided with the introduction of azalea mildew into New Zealand and this selection was particularly susceptible. It is a very painful experience, both financially and psychologically to cultivate in 4500

saleable azaleas.

The next release will be called 'Softlights', a fully-double, large, soft peachy-cream-flowered form. This azalea is very healthy in growth and foliage producing copious flowers. Our staff and ourselves are very confident of this selection (no mildew).

If all goes well it takes 5 years to evaluate seedlings, a further 5 years of trials, and 5 years to build up a commercial number of plants for sale, a total of 15 years. It probably takes a further 10 years for the gardening public to become aware of a new introduction. However, with tissue culture, 1 year is adequate to build up commercial numbers and with a good advertising budget 1 year to promote a new cultivar to the public. With this in mind, initial evaluations of plants have become of paramount importance.

Now that we have almost completed the selection and evaluation work from the 1984 hybridizing, parents are now being selected for further breeding. Reds, in particular, are being targeted, even though this colour is not fashionable at present. What of the future? We would like to some day find a frilled red, carnation-like azalea flower with the substance to last a full month. The foliage would be a healthy lush green with bright autumn colours late in the season.

Learning To Identify Plants

Bronwyn Nichols
Kuriheka, R.D.10, Oamaru

I am currently teaching a group of students to identify plants. I begin by teaching the "easy" plants, then move on to plant genera that have less obvious features. The first signs of confusion come when they are shown the two species of native *Fuchsia*. How can *F. excorticata*, a small tree with pale stringy bark be related in any way to the small-leaved ground creeper *F. procumbens*? It is not until these plants flower that the students can see why.

One group of plants that is of particular interest to learn to identify is deciduous trees. When in a deciduous state, one tree looks much the same as another, but even when in this state each genus has very distinctive characteristics. These include differences in bud size and shape, stem colour, branch patterns, leaf arrangement, and bark colour and texture. For example, *Fagus* spp. have long slender pointed buds, *Aesculus* spp. have large sticky buds, the bark of *Platanus* spp. comes off in big flakes, the buds of *Acer* spp. are always in opposite pairs and the buds of *Alnus* spp. sit up on short stalks. To be able to recognise trees in a deciduous state is particularly useful to persons working on an open-ground nursery as winter is the time these trees are being handled the most.

Another group of plants of particular interest is the conifers. Most conifers that are commonly grown fall into one of several main families, within which the genera have common identifying features. For example, all members of the family Pinaceae have needle leaves, but take this one step further and look at the distinctive differences between the genera *Pinus* and *Picea*. *Pinus* species all have their needles arranged in small groups which are joined at the base, and large characteristic cones. *Picea*

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species have their needles arranged singly up the stem, a small peg remains on the stem when the needles fall off, and the long slender cones always hang downwards.

Learning to remember botanical names is a difficult task, but when working with plants every day, reading books and catalogues, and visiting nurseries, garden centres, and botanic gardens, it does not take long for these names to become familiar. Also, you soon begin to gain an understanding of the meanings or translations of these names, which makes it easier to relate to them. Most species names are a description of the plant, for example *Magnolia grandiflora*—the *Magnolia* with large flowers or *Pseudopanax ferox*—the fierce *Pseudopanax*. The same species names also begin to appear frequently. Several New Zealand native genera alone have species names, such as *crassifolium*, *arborea*, and *australis*. It seems the more plant names known, the easier it becomes to learn and remember new names. Another way of making the identification of plants easier is to familiarise yourself with botanically descriptive words. These include types of inflorescence, types of fruit, leaf types, leaf shapes, leaf margins, leaf arrangements, etc. Also, is the plant you are looking at a tree, a shrub, a climber, an annual, an herbaceous perennial, or a grass? Knowing these terms allows for keys and references to be followed and easily understood.

Being able to readily identify plants has many advantages:

1) It makes working within a nursery easier by being able to quickly access plants by sight rather the having to be constantly looking at labels or asking others for help.
2) It makes you more interested, aware, and appreciative of the plants that are around you everyday—in gardens, streets, parks, and native bush areas.
3) If you wish to propagate or learn about a plant, knowing what it is allows for fast and easy reference.
4) When reading books and catalogues, the plants can be easily visualised.
5) When propagating plants commercially, it is essential to have plants correctly identified and named.
6) Labelling of plants within a nursery can be significantly reduced if everyone knows the plants they are dealing with.

Since entering the field of horticulture I have particularly enjoyed the challenge of learning new plants and plant names and am constantly searching for unusual or new plants with which I have not yet become familiar. I also find that teaching the subject is very rewarding and I encourage anyone who knows the subject well to teach their employees or fellow workers to learn to identify plants and use botanical names everyday.

Sphagnum Moss Production: Experience from Environmental Room Trials to Compare Growth of Two Species of Sphagnum Moss

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INTRODUCTION

Sphagnum moss is one of the world's most common plants with an almost universal distribution in lands where water is abundant. It grows under conditions of extremely low nutrition and has been used in the monitoring of both atmospheric and water pollution (Clymo, 1987; Wegener et al., 1992).

In the recent past its major use has been in the nursery industry for orchid production, fine-seed germination, and the transport of bare-root seedlings (Blain et al., 1987). This utilises the moss's ability to hold approximately 20 times its dry weight in water.

More recent uses include surgical dressings, sanitary pads, disposable napkins, bedding and stable litter, and as a packaging material. Each of these utilise this unique water-holding capacity.

The current New Zealand export value is approximately $18 million mainly to Japan, Taiwan, and Korea for use in their orchid industries.

Although a number of species grow and flourish in New Zealand, the market utilises mainly *Sphagnum cristatum* though this is frequently intermixed with and often indistinguishable in the dried form from *S. australe*.

Among the major reasons for New Zealand research is the collection of data to determine the sustainability of harvesting and frequency of harvest, as well as, to investigate the potential for protected-environment culture.

Overseas it has been reported from natural environments, that 15-cm growth has been achieved in periods varying from 1 to 30 years (Moore, 1989). Many factors appear to influence growth under New Zealand conditions but research to quantify these is relatively recent (Buxton et al, 1990, 1991a, b, 1992). Current New Zealand research by HortResearch, Landcare, and Waikato University, into the individual and combined effects of light, water, and temperature will enable a better understanding of the regenerative ability and overall suitability of *Sphagnum* harvesting practices.

Crop & Food Research are investigating conditions for culturing moss in artificial environments, to achieve quality *Sphagnum* particularly suitable for pharmaceutical use, as well as looking to reducing the overall costs associated with harvesting,

sorting, and grading. Results to date indicate cultured moss dries very white and if experimental growth rates can be maintained then acceptable yields may be attainable. Commercial cultivation of *Sphagnum* in protected environments does not appear to have been attempted elsewhere in the world, although literature indicates laboratory experiments have successfully grown *Sphagnum* for experimental use (Baker and Boatman, 1985).

MATERIALS AND METHODS

Experimental Design. A 3 × 3 × 2 × 2 factorial split plot design with two complete replicates was used for the results reported. Treatments were:

Light levels. Full (no shadecloth), 50%, 35%. Shade levels imposed using neutral density shadecloth over the trolleys.

Propagule Types.

- Capitulum only—the tufted capitula removed from stems just behind the growing point.
- Capitulum + stem—as above with stem left attached so that the total length was 25 mm.
- Stem only—stem pieces taken from immediately behind the capitulum but not extending further than the first 100 mm of stem.

Species. *Sphagnum cristatum* and S. *australe.*

Moss Source. Burnbrae, Pell Stream.

Moss was harvested from both sites and transported back to Riwaka Research Centre where 80 propagules were used for each treatment and propagule type described above. Propagules were laid in plix trays and moistened with water collected from the Burnbrae site and transported to the HortResearch environment rooms at Palmerston North. Here they were placed on trolleys in rooms for 14 weeks from October 1994 until January 1995.

Temperature, relative humidity, and light for each treatment remained constant throughout the period. Daylength was constant at 12 h and carbon dioxide levels were unregulated. After an initial 3-week period of hand misting with water from two swamp sites, a misting system using bore water was set up. Water analyses were made regularly.

Moss extension growth was measured by placing a perspex lid onto the growing tray at measuring time and using a graduated pin pushed through three random holes in the perspex. This allowed growth to be measure at exactly the same point each time. Final measurements were made after transporting the trays back to Riwaka.

When moss began growing, it always grew vertically from the propagule allowing easy measurement of growth during the experiment. At the end of the experiment all new growth was separated and placed end to end to get the total growth made per treatment.

RESULTS

Total Extension Growth at Harvest. Total extension growth from capitula + stem collected from Burnbrae site was far superior to Pell Stream and to other propagule types.

	Burnbrae	Pell Stream
Capitula only	2340	1280
Capitula + stems	6810	2730
Stems only	2150	1370
sed	494	

Branching. The proportion of the original propagules which formed branches was highest where only the stems were used, and lowest where only the capitula were used.

Capitula only	10.4%
Capitula + stems	31.8%
Stems only	62.5%
sed	5.99%

Moss from Burnbrae showed a greater tendency to branch than that from Pell Stream. There was little evidence that either species impacted upon the proportion of the propagules that developed branches. A similar picture emerged when the actual number of branches was examined rather than the proportion of the original propagules to branch.

Dry Matter Accumulation. Dry matter accumulation was not affected by light level. However, Burnbrae moss accumulated more biomass than that of Pell Stream; *S. australe* accumulated more than *S. cristatum*; and the combined capitula + stems propagule type produced more than capitula alone which, in turn, produced more than stems alone.

The relative performance of the species did not differ between the two sites. However, although *S. australe* yielded higher than *S. cristatum* for all propagule types, it was when capitula + stems were used that it really excelled:

	Sphagnum australe	*Sphagnum cristatum*
Capitula only	1.55	1.32
Capitula + stems	3.79	2.70
Stems only	0.89	0.61
sed	0.197	

Similarly, it was when capitula + stems were used as initial propagules that moss from the Burnbrae site was clearly superior to that from Pell Stream:

	Burnbrae	Pell Stream
Capitula only	1.40	1.47
Capitula + stems	3.75	2.74
Stems only	0.81	0.69
sed	0.197	

DISCUSSION

The marked difference in performance of moss from the two sites has many implications. It suggests that there is potential for increasing growth by selecting the initial source of moss appropriately. Given the relative isolation of the two source swamps, it seems reasonable to speculate that the differences were at least partially of genetic origin. It is interesting that *S. australe* generally outperformed *S. cristatum* in terms of yield.

Although low light levels increased extension growth, the actual dry matter accumulation was not affected. It would appear that the low light effect was one of

etiolation rather than optimising conditions. There is a market demand for long moss. However, long etiolated moss would probably be unacceptable. For good growth over a period of a few months, it would appear that capitula need to be included in the original propagule. Branching, however, appeared better when a reasonable portion of stem was present. If it is desirable to have the capitula in the marketed product, then it may be necessary to consider some preconditioning for stem segments to initiate these prior to their use in further growth studies.

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Threatened Species and Their Recovery: The Challenges or the Art of Intelligent Tinkering

David R. Given
David Given & Associates, Christchurch and Department of Plant Science, Lincoln University, Canterbury

Perhaps I can best start by telling three stories of rare and endangered plants — three stories which embody parabolic truth.

The first concerns the most fascinating plant which I have ever had the privilege of studying. The Royal Horticultural Society bestows its merit awards on those plants which are outstanding species for garden culture. If ever the Society awards a wooden spoon I have the ideal candidate—*Helichrysum dimorphum*.

Discovered by Leonard Cockayne in the early part of this century, with further discovery of populations by Arnold Wall, *H. dimorphum* has only ever been found in the middle part of the Waimakariri Basin where it occurs in the rainshadow region between the alps and the front ranges. Even here it grows in only a few sites. By the 1970s only two reasonable-sized populations remained.

This *Helichrysum* is our only lianoid or scrambling member of the genus. Its grey colour and thin wiry stems make it difficult to see. It makes use of matagouri as a scaffold and scrambles up into the light as an interlacing mass of branchlets. Its unusual and perhaps unique feature in the flowering plant kingdom is that it produces two quite different kinds of leaves. One is a flat, wrinkled leaf 6 to 12 mm long and about 2 to 3 mm broad which is more or less at right angles to the stem. The other is a small scale leaf closely appressed to the stem. These are produced on the same stem at various times during the growing season so that a live stem of this plant has a succession of different leaf types.

In 1991, Bruce Pavlik, of the San Francisco Bay area and a leading rare plant physiologist, decided to do his sabbatical in New Zealand. We chose this plant and soon found that we were embarked on a very exciting piece of research into its drought tolerance and adaptability. The techniques themselves were unusual enough. We used a Schollander bomb.

This requires gathering plant material in the early hours of the morning—have you ever tried to crawl through matagouri scrub in the dark!—then inserting stem tips into a chamber which is then slowly filled with nitrogen gas up to a pressure which may reach several hundred pounds per square inch. Meanwhile your face is jammed up against the top of the chamber waiting to see the first drops of sap to exude from the end of the stem tip. It is at times like this that you wonder about your insurance and whether the maker of the instrument lavished the care on its manufacture that you assume.

What we found was quite strange. *Helichrysum dimorphum* grows in a region and a vegetation type which is prone to drought. But having evolved in this habitat and region it seems that it does everything wrong. Its associate, matagouri, flowers and fruits early and then settles down to enjoy the rest of the summer. In contrast, *Helichrysum* flowers late summer when conditions are hardest. Moreover, it appears to have no compensatory internal structure to counteract drought stress. Its stomata are "sloppy"—so much so that it may actually absorb water direct through

the leaves when it rains. It seems that the only mechanism left to combat drought is to alter leaf size and shape.

Here is a fascinating species—a species which may be a unique plant in its behaviour—yet a species which has minimal protection in the wild and for which the odds grow longer year by year. Its habitat has been fragmented beyond belief. Reproduction seems at a very low level. It has a defense system against drought which must be of only limited utility.

One of the two largest populations is under covenant, the other is unprotected. Plants are in cultivation and perhaps the best long-term chance of recovery for this species will be its preservation, at least in the short term in recreated shrublands. It can be readily propagated from cuttings which root well; propagation from seed seems somewhat more uncertain.

But its survival in recreated shrublands demands a horticultural input and up to the present the record of horticulture as a conservation tool in this part of the world has been somewhat spasmodic and irregular. I believe that we have enough knowledge to manage this plant both in the wild and in cultivation. What we may lack is the commitment to use the tools available.

My second example concerns a plant which is rather more widespread, and which is perhaps better known in cultivation. This is *Muehlenbeckia astonii*. It is only in recent years that this shrub appeared on threatened plant lists and like a Beatle's hit it rapidly climbed the charts to make it into the top listing as endangered. Surprisingly, it grows all the way from Kaitorete Spit near Christchurch to the coast of Wellington. However, within this range over 90% of known plants are in a small part of Kaitorete Spit. There are a scattering of plants in the North Island, and perhaps 25 or so plants each in North Canterbury and Marlborough, mostly as isolated individuals. At only one site that I know of is it possibly growing in intact vegetation.

Almost no young plants are known and what we have is a species made up of aging geriatrics—a situation colloquially known as "the living dead". That is not the end of the story, because the situation is repeated with a number of other dryland shrubs. A notable example is *Sophora prostrata* which is still common from Blenheim to its southerly limits in the inland Rangitata Valley and the MacKenzie country. Prostrate kowhai produces good seed but reproduction under natural conditions is very limited and for the most, populations are geriatric—another "living dead" example.

It is the unfortunate lot of both these plants along with others to occur in a much maligned and unrecognised habitat called "scrub". Rather than recognising it for what it is—a habitat rich in biodiversity—even conservationists sometimes want to convert it to forests or wetland. But within our remnants of scrub there is not only high species variation but probably also surprising genetic variation. The high level of variation in *Leptospermum* has been noted already at this conference by Warwick Harris. Preliminary work on other scrub species suggests similar untapped variation which we stand to lose unless we act quickly to protect, evaluate and grow our scrub species.

I suspect that the reason why we have relatively few extinct species in the New Zealand flora may well be because of the woody, long-lived nature of many of our plants. If so, we may be facing a extinction time bomb unless we start to pay attention to, and nurture the unique assemblage of biological diversity for which we exercise

stewardship. When these and other shrubs start to die off in large numbers it will be too late to act!

My third example is one which, in contrast, speaks of hope and opportunity, and perhaps indicates the sort of scenario which I believe will become more common in the future. This time we go to the Chatham Islands and the story is about a species which was scientifically described and named only a few years ago. This is *Cortaderia turbaria*, the Chatham Islands toetoe. It is found only on the Chatham Islands where it is a "soggy gum-boot" plant of gullies, lake margins, and wetlands. Surveys show that although once widespread on the Chathams it had retreated into a small number of sites.

I was asked several years ago to prepare a draft management plan for this species. This set out a number of steps by which the 140 or so remaining plants spread through about 12 sites, could be the subject of a recovery plan to save the species. In the absence of immediate moves to action the plan, funding was obtained from Lotteries Science funding through the Royal Forest and Bird Protection Society to undertake a rescue and recovery operation. Last year, with Simon Heppelthwaite, I visited the Chatham Islands and seed lots were obtained from several key populations.

The seed lots were divided up between a number of nurseries and botanic gardens: two at universities, two private, one zoo, one with Department of Conservation, and three botanic gardens. Arrangements were made to replant the species on two and possibly three private land sites on the Chatham Islands.

The day before presentation of this paper it was my privilege to check over 150 healthy young plants as a first step to the recovery of this special plant of the Chatham Islands. We are hopeful that many of these, augmented by plants being grown on elsewhere, can be taken to the Chatham Islands in a few months for planting out. As well, a national collection is being established at the Issac Conservation Trust property, Peacock Springs, on the outskirts of Christchurch. This will provide material for research, genetic analysis, future propagating stock, and a backup for unforeseen events in the wild.

What we are attempting to do is something rather unusual for New Zealand. I believe that we are taking the skills of enthusiastic individuals, applying their expertise, empowering them as part of a cooperative recovery programme, and making them each an integral part of the project. I do not believe that species are effectively recovered simply by government mandate, by committees, or by conservation strategies. These each have their uses, and have each played a vital role in conservation of New Zealand biodiversity, but globally conservation works best when dedicated individuals also give themselves and their time, and their dedication and enthusiasm to a project.

I have given the story of just three plants. There are a lot more out there. About 12% of the native flora of New Zealand is under threat. Important focal points in the South Island include inland Marlborough and Canterbury, central Otago, and the coastal littoral zone. Immediate habitat loss is a primary problem, but underlying this is a general deterioration in many ecosystems, and especially changes in dynamic processes at the landscape level. Very little is known of genetic variation in rare species or of processes at the genetic level. Information on ecological preferences is incomplete for some species.

A Review of Factors Affecting the Establishment of Magnolias in New Zealand

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INTRODUCTION

It was noticed that several grafted plants within the Lincoln University magnolia collection had performed poorly or died. It was decided to examine the possible reasons for this and to evaluate other plantings with the objective of explaining why these problems of establishment have occurred, so that recommendations can be made to help improve the success in establishing magnolias in the future.

PROPAGATION METHODS

A wide range of magnolias are commonly grafted (mostly by chip budding) onto rootstocks in New Zealand. Hooper (1990) discussed the grafting of magnolias and reported on the growth of several understock/scion combinations at one nursery. Up to the early 1950s most deciduous magnolias were grown from layering (Hillier, 1950) but Johnstone (1955) records how grafting was also becoming an important method of propagation. One experienced nurseryperson commented that the "early" layered magnolias, like *Magnolia campbellii*, had established really well; however later grafted plants of this species, have suffered several losses during establishment (Hughes, pers. comm.). Clones of *M. grandiflora, M. sieboldii, M.* ×*soulangiana,* and *M. stellata* (syn. *M. kobus* var. *stellata*), as well as Gresham hybrids, are now commonly grown from cuttings. Callaway (1994) states "today propagation by cuttings is the most common form of vegetative propagation, though some *Magnolia* species and cultivars, such as, *M. denudata* still remain difficult to root by this means." Early methods of commercial production by grafting, which began about 40 years ago, were approach and veneer grafting (Hillier, 1950). Chip budding has now become a very popular and successful means of propagation for the grafted species (Callaway, 1994; Itaya, 1981; Knuckey, 1969; Lane, 1993; Tubesing, 1987).

SURVEY RESULTS

A survey was carried out whereby a range of magnolia growers were asked for their observations on problems in establishing these plants. In addition the Lincoln University and Trott's Nursery plantings were visited and plants measured and evaluated (only conclusions from this are included generally within this article). Legend: C indicates species or hybrids of *M. campbellii.*

- Auckland Botanic Gardens, Auckland.
  Generally good establishment of *M. campbellii* hybrids particularly if open-ground stock planted in good soils with shelter (Hobbs, pers. comm.).
- Blue Mountain Nurseries, Otago. Magnolias that have died:

M. campbellii ssp. *mollicomata*	C
M. campbellii ssp. *mollicomata* 'Strybing White'	C
M. 'Mark Jury'	C

All these plants appeared to establish but then experienced scion death after 2 years with the rootstock remaining alive.

- Dunedin Botanical Gardens, Otago. Magnolias (examples only) that have died:

M. 'Athene'	C		
M. campbellii ssp. *mollicomata* 'Lanarth'	C	*	
M. 'Serene'	C		

* This cultivar has failed three times, with the fourth plant currently growing well (Matchett, pers. comm.).

- Elliott's Nursery, Canterbury. Magnolias (examples only) that have died:

M. ×*brooklynensis* 'Woodsman'
M. 'Susan'

Both plants were planted on a moist bank (Elliott, pers. comm.).

- Lincoln University, Canterbury. This collection consists of 80 plants which were mostly planted between 1990 and 1992. Magnolias that have died:

M. acuminata 'Golden Glow'		**	#
M. 'Atlas'	C		
M. 'Caerhays Belle'			
M. campbellii ssp. *mollicomata*	C		
M. campbellii ssp. *mollicomata* 'Lanarth'	C		#
M. campbellii ssp. *mollicomata* 'Strybing White'	C		#
M. 'Lotus'	C		
M. 'Mark Jury'	C		#
M. 'Milky Way'	C		
M. 'Spectrum'			
M. sprengeri 'Diva'			
M. ×*suishoren*			

** This plant flowered in its 2nd and 3rd years but the scion (only) died the following winter with the scion height at 2.06 m.

These plants later sent up suckers indicating scion death only. Most graft unions were measured and assessed for growth characteristics. Unions were generally smooth and in most cases the diameter of the stock was greater than that of the scion. One exception to this was the marked overgrowth of 'Mark Jury' compared to the stock.

- Tikitere Gardens, Rotorua. Magnolias (example only) that have died:

M. 'Vulcan' C

There had been several failures with container-grown stock, especially plants with *M. campbellii* "blood", particularly *M.* 'Vulcan'. Open-ground plants were found to establish more successfully (Robinson, pers. comm.).

- Trotts Nursery, Canterbury. Magnolias that have died:

M. acuminata

Mostly container-grown stock which have all established well, including *M. campbellii* hybrids (Trott, pers. comm.). About 30 plants were measured to compare the diameter of stocks and scions close to the graft union. Matching was generally excellent with little overgrowth and smooth unions.

REASONS FOR FAILURES

Species and Cultivars. There was a very high proportion of magnolia losses that were *M. campbellii* or cultivars directly related to this species, as indicated in the survey list. *Magnolia campbellii* ssp. *mollicomata* 'Lanarth' is an example of a cultivar that has proved particularly difficult to establish. At the Dunedin Botanic Gardens they are currently attempting to grow their fourth plant of this cultivar having failed with the previous three (Matchett, pers. comm.). It was also noted, in the survey, that *M.* 'Vulcan' had given repeated failures and this hybrid has 'Lanarth' as one of its parents. *Magnolia campbellii* ssp. *mollicomata* 'Strybing White' is another cultivar that has been noted to often give problems in establishment (Rumbal, pers. comm.). Further comment on individual species can be found under subsequent sections.

Soil and Climate Effects. Several plants that died were grafted ones where the scion died but the rootstock remained alive. Frost killing the top of the plant is a possibility. Harrison (1967) comments that there are several forms of *M. campbellii* grown in New Zealand and that the one most propagated in nurseries is the more tender Yunnan form. He states that the previous season's young growths can be badly damaged by frost. Hillier's Manual of Trees and Shrubs (Anon, 1977) also states that there is a considerable variation in the degree of hardiness. However, Fleming (1989) pointed out the value of grafted plants compared to cutting-grown plants of identical clone and grown in the same area were observed to be much less hardy than those that had been grafted. One would expect that planted magnolias would establish more readily in the warmer and more favourable climates of the North Island of New Zealand than in the South Island, although the climate in the latter is still a good deal more favourable than situations in the British Isles where so many species have been successfully established. The dry summer conditions in Canterbury are also a big contrast to the natural habitats of species like *M. campbellii* which comes from conifer-clad mountain slopes of southern China to a height of 3000 m or more (Treseder, 1978) but this should not result in death. There are very suitable conditions in autumn in Canterbury for the ripening of wood, a factor which has proved important for plants to avoid frost injury in England (Millais, 1927).

In the magnolia collection (over 100 plants) at the Auckland Botanic Gardens it has been noted that soil type and shelter are major factors in the establishment and successful growth of plants (Hobbs, pers. comm.). Plants grown in deep open soils tend to do well while those plants in sheltered areas have a much greater chance of success. It had been noted that magnolias on good soils, but exposed to the wind, would usually sulk and often die. This clearly concurs with Millais's (1927) statement that the rate of growth of magnolias depends entirely on their cultivation, situation, and climate.

Graft Incompatibility. The recorded evidence in the literature concerning incompatibility problems in magnolias does not appear to be strong or widespread. However, Humphrey (1966) reported that Hillier's nursery in England needed to grow five different stocks of magnolia in order to avoid incompatibility. Also Nelson's (1968) summary of incompatibility in grafted horticultural plants does record several instances. This review specifically states that *M. acuminata* and *M. campbellii* have been recorded as showing incompatibility with *M.* ×*soulangiana*

stocks. In contrast, and only a year later, there was a report on the ease of budding magnolias in which there was no mention of incompatibility even between evergreen and deciduous species, citing the example of *M. grandiflora* budded onto the deciduous stock, *M. kobus* (Knuckey, 1969). More recently Tubesing (1987) stated that he knew of no cases of intraspecific graft incompatibility in the genus *Magnolia*, such as occurs in *Acer rubrum*. Unsightly unions formed when *M. campbellii, M. sprengeri*, etc, were grafted onto *M. kobus* or *M.* ×*soulangiana*, but were not seen as a sign of incompatibility. In a recent report on chip budding of magnolias, Lane (1993) commented on the desirability of having stocks and scions of close genetical affinity, but again there was no information on actual problems. This was also the case for a New Zealand study recording the use of different magnolia clonal rootstocks (Hooper, 1990).

It appears that there is general acceptance of the fact that graft incompatibility in magnolias is seldom a problem and the genus has high affinity even between widely differing species. *Magnolia campbellii* is readily grafted onto *M.* ×*soulangiana* as reported by Hooper (1990) and there are also many other successful combinations, even between deciduous and evergreen species. Treseder (1978) also states that even though some people surmise that there are problems, "there is no evidence of graft incompatibility". Callaway (1994) in her recent book on magnolias summaries this situation by stating that some graft incompatibilities do arise where there are differences in growth between stock and scion which may result in a weak union. Also, the comment was made that graft incompatibilities are not as common with magnolias as with other genera, such as maples, so grafted magnolias are usually successful if the process is carried out correctly. It is noteworthy that of the many recent articles on magnolia grafting there is little or no emphasis on the danger or risk of graft incompatibility in magnolias.

However, there are some losses that are hard to explain other than incompatibility since only the scions died up to 3 years after planting, while often extensive suckering occurred from the rootstock. For example, *M. acuminata* 'Golden Glow' was planted at Lincoln University in 1990 (Edwards, 1994) and recorded as having flowered in 1991 and 1992. The scion died in 1993 when at a height of 2 m while the regrowth of the rootstock is now almost 2 m high and growing strongly. The cultivars 'Lanarth' and 'Strybing White', which are both selections of *M. campbellii* ssp. *mollicomata*, also showed scion death at Lincoln University and have since produced basal shoots from the stock. The latter cultivar had flowered in its second growing season but failed to grow after that. Sectioning of graft unions of some plants indicated that in the case of 'Lanarth' and 'Golden Glow' there is a strong indication of graft incompatibility due to the distinct dark colouring in the tissues shown in Fig. 1. This darkened area appears to indicate graft incompatibility and was completely absent in the section taken from M. 'Caerhays Belle'. There is, therefore, some evidence that graft incompatibility is a factor in the early death of some plants, particularly 'Lanarth' and 'Golden Glow'. Callaway (1994) has also stated that delayed incompatibility does occur and that cutting propagation, where possible, has the advantage of avoiding this problem.

Disease Losses. Magnolias are subject to a range of diseases, many of which are leaf spots and die-back disorders (Callaway, 1994; Pirone, 1978). Severe losses occurred with a planting of *M. grandiflora* in recent years in Canterbury (Morgan, pers. comm.). This was identified in the laboratory as *Verticillium* wilt, a disease that

has been noted on magnolias overseas (Pirone, 1978). However, no wilt symptoms were noted as occurring on any of the deciduous plants included in the survey, also there were no*M. grandiflora* losses. Some plants at Lincoln University have shown scion death followed by regrowth of the rootstock and as stated above there is some evidence to link this with graft incompatibility. Other possibilities are that disease could have entered the top part of the plant resulting in scion death but not root death.*Magnolia campbellii* (and others) may have greater susceptibility to this type of disease attack. Several plants at Lincoln University show tip die-back which results in dead wood for 10 to 15 cm from the ends of shoots. Growers (Blumhardt, pers. comm.; Hooper, pers. comm.) have noted major die-back on well-grown species of *M. campbellii* which was thought to be *Verticillium* wilt. Blast (bacterial wilt, *Pseudomonas syringae*) has been identified and recorded as a pathogen on magnolias in New Zealand and is a possible reason for scion death, however, Callaway (1994) only records this as causing leaf spots. A further consideration may be that systemic diseases like *Verticillium* wilt could readily be transmitted on budwood.

Transplanting Loss. Millais (1927) begins this topic in his book by saying: "Practically the only difficulty with magnolias is to get them established after planting." The roots are thick, fibrous, and fleshy, and it is important to avoid damaging the soft and fragile roots of young seedlings when potting (Bean, 1973; Treseder, 1978). Damage could be done by rough handling or excessive firming. It is most important to avoid planting too deeply and to plant sensitive species preferably in late winter to early spring (Huxley et al., 1992; Millais, 1927; Treseder, 1978). Several authors also recommended deep cultivation in the planting hole, incorporation of organic matter, and the value of mulching. The Royal Horticultural Society Dictionary of Gardening (Huxley et al., 1992) states that planting too deep is one of the most common causes of poor growth or even subsequent death in newly

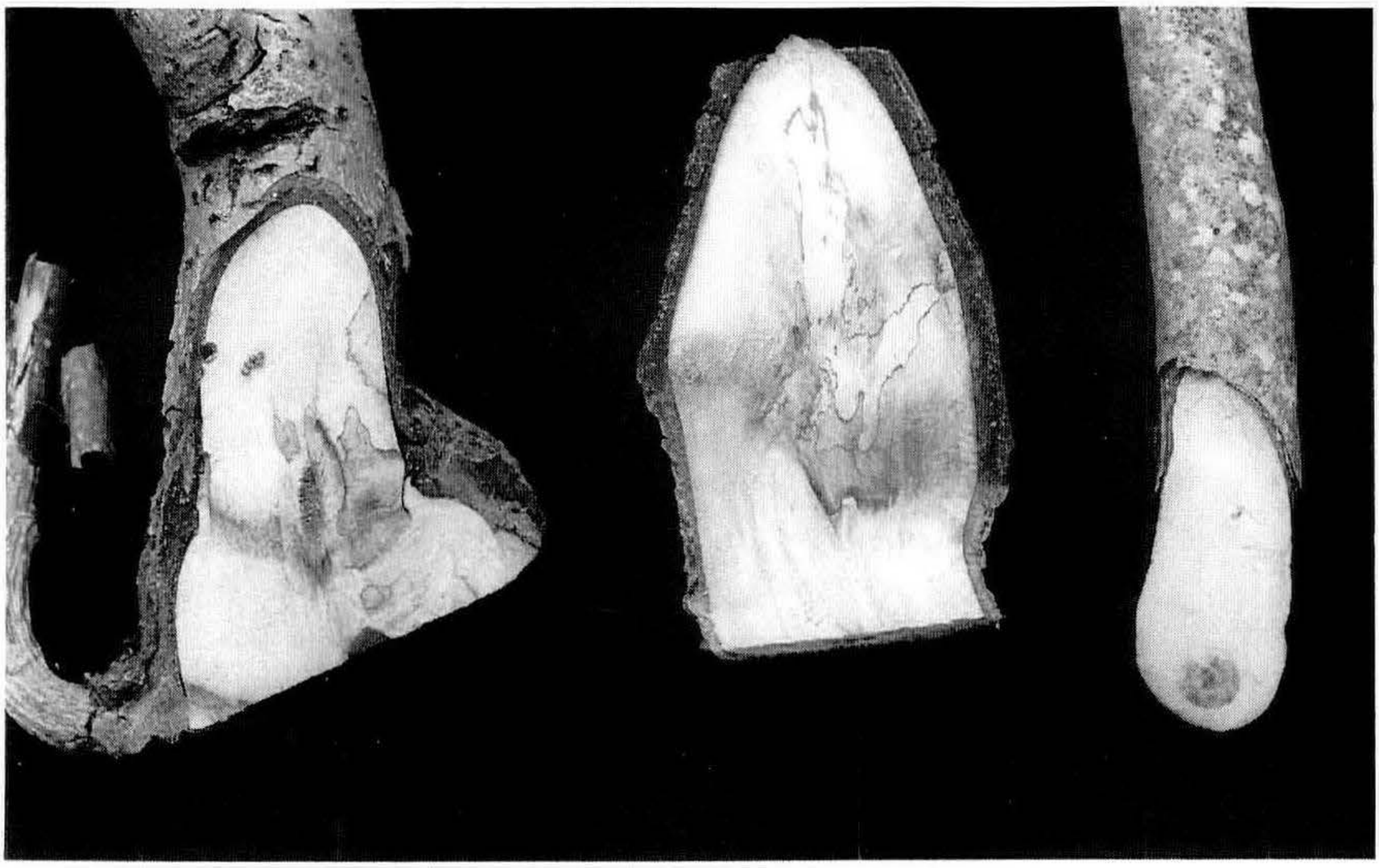

Figure 1. Cross sections of the graft unions of three cultivars of magnolias. Left to right: 'Lanarth', 'Strybing White', 'Caerhays Belle'.

planted magnolias. Young plants are probably more prone to loss than large plants since there are accounts of moving large specimens, for example a 10-metre-high specimen of *M. campbellii* was successfully moved from England to Ireland on a truck (Treseder, 1978).

Harrison's (1967) comments on transplanting and establishment of magnolias are worthy of special attention as they link several factors together. He states that these plants are quite easy to grow in any good free-draining soil but in districts with very cold and wet winters, losses often occur during transplanting. This is due to the fact that the fleshy roots, damaged by lifting and handling, die back from the cut and bruised portions, and under such conditions spring planting is best. Huxley et al. (1992) suggest that to leave the planting until the sap begins to rise, as is sometimes advocated, is doubtful advice. Harrison (1967) also states that *M. campbellii* and the *M. stellata* forms are particularly subject to root collapse under such conditions.

CONCLUSIONS AND RECOMMENDATIONS

The difficulty of assessing the cause of losses is compounded by the fact that certain species are sensitive to transplanting shock, so that although genotype is probably the key factor in incompatibility problems, the genetic constitution is also very significant in being the cause behind many failures to establish magnolias. Based on this review it was noted that a large proportion of the losses involved species and hybrids of *M. campbellii* and clearly the "blood" of this species does confer a weakness in the establishment phase.

It is probable that graft incompatibility was the cause of the death of the scions in those cases where the rootstock remained alive and sent up suckers. In the majority of cases, where the whole plant died, causes other than graft incompatibility are likely. Disease infection of the scions is considered another possibility (disease attacking the scion of a grafted plant is not strictly graft incompatibility unless the graft union is affected). It is suggested that this again indicates the sensitivity of *M. campbellii* and that in this case it is disease susceptibility. Graft incompatibility and disease susceptibility would appear to warrant further study to establish their relative significance.

It is recommended that nurseries take special care with the production of magnolias, and especially grafted *M. campbellii*, so that they are produced with healthy compatible root systems and not allowed to become pot bound or lacking in vigour in the nursery. Growing advice needs to be passed on to customers to help minimise losses, especially on *M. campbellii* plant labels, etc. Such aspects as site selection, shelter, soil preparation, and planting depth, need to be publicised through educational pamphlets and labels.

Finally, the authors acknowledge that some conclusions and evaluations of factors causing losses have been rather speculative given the lack of conclusive evidence. Clearly more research is needed. We **would greatly appreciate receiving comments** and observations from magnolia growers around the world so that we can continue to "seek and share" and fulfill this noble aspiration of our society, for the establishing of magnolias is clearly one of the most dominant problems which stand in the way of more widespread use of these magnificent plants.

Epilogue: A valuable comment was made after the conference paper by Phil Carson. He pointed out that he had looked on *M. campbellii* as a plant with a root system that never seemed to really go dormant. This means that the fleshy roots are

very subject to damage when transplanting is carried out, since the roots always have some degree of activity.

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Alternative Pest Management At The Christchurch Botanic Gardens

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INTRODUCTION

In 1993 the Christchurch Botanic Gardens nursery and conservatory staff recognised a need to change from their traditional chemical "cocktail" approach of pest and disease prevention to an alternative system.

This change was brought about through concerns for staff and public safety, increasing environmental concerns related to using synthetic chemicals, restrictive health regulations, escalating chemical costs, increasing pest resistance, and the better availability of "how to" information for using alternative systems.

IDENTIFICATION OF PESTS

One of our initial tasks was to identify the pests involved. In the past our knowledge of entomology vaguely covered the main groups of pests. In each case we could distinguish an aphid but not go so far as whether it was a peach aphid or melon aphid, etc. By being species specific it meant we could have a better understanding of its life cycle and in turn the best way to deal with it. This sort of knowledge is not a necessity to using our system but because we are involved in staff training and providing information for the public, we deemed it an important focus in what we are doing.

Our staff also now view the nursery and conservatories as a complex ecosystem and that pest populations are part of this system. A shift in perspective is necessary when dealing with a complex biological community.

INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) is the use of a pest's natural-found enemy to control it in conjunction with a suitable spraying programme that does not harm the predator. This means IPM can be used in conjunction with some synthetic chemicals, with the results being reduction of chemical use but not necessarily their elimination. We have taken the system one step further and developed the use of plant-derivative sprays (PDS) in conjunction with IPM. We believe this addresses our environmental concerns, reduces the chances of health hazards to our staff, and the general public and a recent study has shown it to be cost effective.

PLANT-DERIVATIVE SPRAYS

PDS are simply sprays that have been derived from plants. This includes old favourites like Derris Dust, a stomach poison derived from several tropical plants.

Pyrethrum, a toxic spray derived from the flower of a species of *Chrysanthemum*, through to more refined products like Safers, a spray made from the fatty acids of coconut oil.

We also use a range of anti-feedant sprays. These are simply sprayed onto the foliage of plants and taste terrible to a pest, causing it to move on. This includes garlic

concentrate, seaweed, compost tea, and the magic Indian neem tree long revered by Indians for its pest preventative properties. This list is being added to continuously as more plants and their products are found to be effective in management of pest prevention. We also use other products that seem more at home in the kitchen than the garden. As a good control for mildew, baking soda (sodium bicarbonate) has proved effective. This causes the leaf surface to become alkaline and unsuitable for this fungus.

Vegetable oil (which has been modified) is an integral product used as a sticker. It also holds the spray in suspension in water and once sprayed, gives lethal doses to the pests resulting in a much greater knockdown.

ENVIRONMENTAL CONSIDERATIONS

The microclimate in which the beneficial insects will live, may need to be monitored and adjusted to provide a favourable environment for the particular introduced insects. This can include increasing or reducing heat, humidity, and cultural treatment of plants in cultivation. Another consideration is to provide effective mulches for pupating insects in order to help their establishment. In Cunningham House this is a natural mulch as the central bed is a reflection of a rainforest and provides its own mulch. In order to help establish a complete ecosystem it is necessary to grow plants with shallow nectaries for feeding beneficial insects, such as, hoverflies. This may not be completely possible inside the conservatory or glasshouse because of the particular plants being grown. However, if consideration is given to the landscaping around the conservatory/nursery, you can integrate plants that provide shallow nectaries across the seasons. This can effectively provide a more complete ecosystem with the beneficial insects flying in and out of the glasshouse ventilation system.

CONCLUSION

Introducing new systems of pest and disease management to an established nursery where conventional treatments have been the mainstream does have its own set of problems. The layout of the nursery may not be ideal for planting nectar-feeding areas, therefore some adaptations may be needed. The saying "you can't teach an old dog new tricks" is often prevalent in a work place, especially if the old dog is comfortable and reliant on the old tricks. Sometimes the old dogs need a bit more encouragement and help to learn the new methods.

The management of pests and diseases in the Christchurch Botanic Gardens conservatories and nursery has evolved to suit our requirements. It may work differently in other areas. There is, however, a need for a continuing commitment to the least toxic solution, with both beginners and the already converted. New Zealand has a clean green image and the potential to capitalise on this in the future. We need to act now to protect ourselves from the mistakes made in the past by other countries. It is everyone's responsibility to protect our environment now and for the future from chemical and biological mistakes and to support those who are leading the way.

We need to preserve tomorrow's future, today.

Direct Cover, Economical Control

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Direct cover is economical because cost efficiency is all important and it is control because that is what we seek to do with water to keep unrooted cuttings turgid. Direct cover brings these two aspects together successfully for many greenhouse crops. A typical propagation unit is to a nursery, what the kitchen is to a home, full of expensive equipment but vital to the well being of its operators. To contain costs the unit often proves to be a bit small at peak production times. Direct cover enables us to spread the borders of propagation.

SO WHAT IS DIRECT COVER?

Simply laying some form of light-weight material, directly on top of the stuck cuttings, will maintain their current moisture level until they become complete functioning plants. Basically, we are aiming to control light, temperature, and moisture during the propagation cycle.

In a heated greenhouse we have the ability to control temperature and light. Direct cover efficiently adds moisture or water control. Because facilities are much cheaper, more space can be used, so cuttings are generally set directly into a pot in which they can be later sold. This helps immensely with labour savings. Faster growth is generally achieved by not disturbing young roots. This method also allows the cuttings to root straight into full-nutrient-supplied growing medium. Many species root faster under cover than under mist. I believe this is due to less humidity fluctuation and also basically warmer temperature as the cuttings are saved from having frequent cold showers.

The only added cost is the cover material which is usually cheap and reusable many times. We use: perforated clear cellophane, 50-micron clear polythene, 125-micron white polythene, and frost cloth.

The savings are obvious:

- No expensive misting or fogging equipment.
- Savings of water.
- There can often be a saving in nursery transportation and also specialized propagation trays.
- Once the system is up and running you do not have to keep checking on it and worrying about equipment failure.
- A small specialized propagation unit does not need to limit production.

Heating, lighting, or shading requirements are no different from general greenhouse growing, provided a minimum of 16C can be achieved. Starting with the right moisture level is important for success and trials in your own environment will be needed. A normal hygiene regime is required. An advantage is that fungicides applied last longer.

This technique can be used on a range of crops but is not perfect for all. Over the years I have used this method for propagating the following: *Acalypha* spp., *Aloe vera*, *Aphelandra* spp., *Begonia* ×*hiemalis* (syn. *B. elatior*), *Cissus rhombifolia*

'Ellen Danica', *Codiaeum variegatum* var. *pictum* 'Norma', *Columnea* spp., *Dieffenbachia* spp.,*Ficus*spp.,*Hebe*spp.,*Hedera*spp.,*Hoya*spp.,*Nematanthus*spp. (syn. *Hypocyrta*), *Impatiens* New Guinea Hybrids, *Kalanchoe blossfeldiana*, *Rosa* spp., *Schlumbergera* (syn. *Zygocactus*), and many herbaceous perennials. Two plants which have proved difficult are *Euphorbia pulcherrima* and *Hibiscus rosa-sinensis*.

A perforated or porous cover can also be used in conjunction with mist. This can help support a particular species on the bench or maybe for the first few days off, to prevent flagging during the hardening-off process.

So tuck your crops under a blanket and leave them to nature. Go have a holiday. When you return they will have rooted without you pulling one out every day for inspection.

The Propagation of *Hydrangea paniculata* with the Use of a Misting System

Rachel Vogan
Bayliss Nurseries, Belfast, Christchurch

INTRODUCTION

Bayliss Nurseries was established in 1899. I started working there as an apprentice in September 1987 and I was the first female apprentice that the nursery had seen for some time. One of my first success stories was with the propagation of*Hydrangea paniculata* 'Grandiflora'. The species is a bushy shrub that originates from Japan and China. It is one of the most spectacular plants I know. It produces lovely, long, deep-red stems and large panicles of white flowers in the spring continuing on into the summer. As the flowers age they get gently frosted with pink icing.

PROPAGATION

I was told to take cuttings of 'Grandiflora' in winter when I did all the hortensia types. Not one cutting rooted. I took mostly stem cuttings with a few tips and the odd heel cutting.

So the following season I decided to try these in the summer as I had heard that a lot of deciduous plants strike quite well in the summer months. At this time in the late 1980s there were no good regular supplies of*H. paniculata* as growing on lines and the demand from the garden centres was growing. I took my first batch in the middle of December. The growth was soft and the stock plant had only just started flowering. I used stem cuttings and a few tips and decided not to wound the cutting as the wood was so soft. The hormone was Seradix 2 mixed with a portion of Captan and water. I put the cuttings into our humidity tent and crossed my fingers. The results were not good. Everything in the tent collapsed after about 3 weeks. I decided the material must have been too soft.

Late in January I made a great discovery in a friend's garden, a large flowering*H. paniculata*. I managed to get about 50 cuttings from this plant and made the same type of cuttings as before but this time the wood was a lot harder than the previous batch.

'Ellen Danica', *Codiaeum variegatum* var. *pictum* 'Norma', *Columnea* spp., *Dieffenbachia* spp.,*Ficus*spp.,*Hebe*spp.,*Hedera*spp.,*Hoya*spp.,*Nematanthus*spp. (syn. *Hypocyrta*), *Impatiens* New Guinea Hybrids, *Kalanchoe blossfeldiana*, *Rosa* spp., *Schlumbergera* (syn. *Zygocactus*), and many herbaceous perennials. Two plants which have proved difficult are *Euphorbia pulcherrima* and *Hibiscus rosa-sinensis*.

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Late in January I made a great discovery in a friend's garden, a large flowering*H. paniculata*. I managed to get about 50 cuttings from this plant and made the same type of cuttings as before but this time the wood was a lot harder than the previous batch.

Half of the cuttings were dipped in Liba 10,000—mixed with water (1 : 2, v/v)—for a few seconds. The other half of the cuttings I did in Seradix 2 mixed with Captan and water. I left the leaves intact on all the cuttings. The cuttings were put under mist with bottom heat set at 21C. In late March the *H. paniculata* cuttings were ready to tube. They all looked quite healthy but as the weather was cooling down the leaves had started to change colour. There was no obvious difference in the trays in regard to the hormones used.

We obtained 45 well-rooted cuttings out of 50 cuttings. The tubes were all overwintered in a coldhouse and potted up the following spring ready for sale in the autumn.

Next spring I kept a close eye on our stock plants to see how hard the growth was. When the material was at the right stage, I took cuttings. It was mid summer and the plant still had quite a bit of flower. Half the cuttings were treated with Liba 10,000, mixed diluted as above. The other half of the cuttings were dipped in Seradix 2 as a dry powder. The cutting was wet so the dry powder stuck.

The leaves on cuttings in one of the trays were cut, just to see what the results would be. The cuttings were all placed under mist with the bottom heat again set at 21C. As the summer progressed into autumn the leaves started to change colour. The cuttings with reduced leaves lost their leaves first. Tubing this year was done quite a bit later and all the leaves were off the cuttings.

The success rate of well-rooted cuttings was 85% and the strike was very even over all the trays. There was no difference between plants with reduced leaves and those with entire leaves. I concluded that if room was a factor, trimming of the leaves would be an advantage as more cuttings would fit in a tray. I feel that constant moisture in the air and on the plant was a major factor in the success of this propagation.

Perilla: Production in Japan and Potential for New Zealand

J.M. Follett
Crop & Food Research, Ruakura Agricultural Research, Hamilton

INTRODUCTION

Perilla (*Perilla frutescens*), a member of the family Labiatae, is an annual herbaceous plant native to Asia. It is used extensively in Japanese cuisine and has a wide variety of uses. There are two main types, red perilla and green-leaf perilla or "oba". Both types are commonly called "shiso". Red perilla is used as a dye for pickling fruits and vegetables, as a dried powder to be used as a side dish with rice, as an ingredient in cake mixes, and as a flavouring in beverages. It is generally harvested and sold as a bulk commodity directly to the processing industry. Red perilla flower heads are also used as a condiment with "sushimi", and 3- to 6-week-old seedlings or sprouts are used as a garnish. Green-leaf perilla, the product most commonly seen in the Japanese markets, is used as a vegetable. Its leaves are used as a wrapping for rice cake, in salads, and tempura. Perilla is also grown for its seed which can be used for oil production or for flavouring foods especially pickles.

CLIMATE AND SOIL

Perilla requires an equitable climate to grow well as it is damaged by frost. Consequently, it is unsuitable for areas that experience out of season frosts. Warm temperatures, long day length and adequate moisture are required for good vegetative growth with short days required for flower production.

Most soils considered suitable for horticulture will grow perilla. Sandy soils rich in organic matter are considered optimum. Fertility levels and pH are often modified using dolomite, compost, and N : P : K fertiliser mixes. A typical fertiliser programme for producing red perilla in Japan, for example, would include a basal application of 12 t ha^{-1} of compost, 1.5 t ha^{-1} chicken manure, 1.0 t ha^{-1} oil seed hulls, 0.6 t ha^{-1} superphosphate, 1.5 t ha^{-1} dolomite lime, and 0.8 t ha^{-1} 8N : 8P : 8K. This would be followed by two side dressings of N : P : K at 0.4 t ha^{-1}.

PROPAGATION

Perilla is an annual and propagated by seed. Plants flower and seed in late summer-autumn and require a winter stratification before germinating. The seed germinates readily in spring with an optimum germination temperature of 20 to 22C. Cool temperatures or dry conditions during germination are likely to have a detrimental effect on germination and seedling emergence. Seed can be successfully stored for up to 2 years at a temperature of 0 to 3C and relative humidity of 50% to 60%. Seeding rates and spacing depend on the production system used.

PRODUCTION METHODS

There are four production methods depending on the product required. These products are as follows:

Perilla Sprouts. Perilla sprouts are used as a garnish by restaurants and hotels. In order to supply these markets all year round, sprouts are produced in the open

during summer and under cover in heated beds in winter. Prior to sowing, base fertiliser is applied and worked into the soil. The ground is then worked into raised beds and the surface raked to produce a fine tilth. The seeds are then broadcast sown. Soil or sand is sieved over the seeds until they are just covered. The beds are next watered and covered with straw mats. After the shoots have started to appear the mats are removed. Once the seedling leaves have fully opened and the first true leaves have started to form the seedlings are cut with scissors, washed, and packaged into small wooden boxes ready for market.

Perilla Flower Heads. Perilla flower heads are used as a condiment and are required by the Japanese restaurant and hotel industry all year-round. This demand is satisfied by using a range of cultivars and growing under cover during winter. Seedlings are raised in a nursery and when they have developed 5 to 6 true leaves they are transplanted into beds. Seedlings are planted in rows 90 to 120 cm apart. Within row spacing depends on the time of the year. Early cultivars flower quicker and, therefore, require less space. If produced during the off season, the crop is covered by a plastic tunnel to maintain the temperature at 15C. Liquid fertiliser is sometimes applied depending on the rate of growth. For market the flower stalks are cut 15 cm from the tip when 5 to 6 of the flowers have opened. During grading the stalks are cut to a length of 8 to 10 cm before packaging ready for market.

Red Perilla. Red perilla, which is not usually produced out of season, is grown as a bulk commodity and used in Japan mainly by the processing industry. It is sown, in spring, directly into raised beds that have first been fertilised and cultivated. Five to six seeds are sown per station in 80-cm-wide raised beds. Seedlings are not thinned, with four plants per station at harvest considered optimum. Seeds are sown every 12 cm in rows 40 cm apart. A black plastic mulch is often used to keep the crop weed free. As perilla seeds require light to germinate, a thin plastic film is sometimes used to help keep the surface-sown seeds moist. In early summer, when the plants are about 40 cm high, the top 10 cm are machine harvested. This harvesting procedure is repeated as often as required until autumn when the crop starts to flower. Growers usually harvest their own seed.

Green-Leaf Perilla or "Oba". From a New Zealand perspective green-leaf perilla or oba is probably the most important form of perilla because of the high price it commands in the Japanese markets.

The most common production method in Japan is under cover in glass or plastic houses. The main period of leaf production is during long days with oba quickly running to seed with the onset of short day lengths. With artificial heating, lighting, irrigation, and successive planting, it is possible to produce oba continuously throughout the year. The high prices achieved for production in the off season make up for the high costs associated with production under cover.

A less expensive production method is semi-protected planting. Seedlings are grown in heated beds in a plastic house in late winter for subsequent transplanting followed by harvesting during the summer months. With this method, plants can remain covered when growing conditions are marginal, giving protection from wind and rain. However, without artificial lighting, the plants quickly bolt in autumn.

The least expensive production method involves seedling production in unheated beds in early spring followed by transplanting in late spring. Harvesting is carried out over the summer months. Once the plants are 30 cm high, leaves that are 10 cm

long (excluding the petiole) are plucked from the stem. Bundles of 10 leaves are tied with a rubber band and packaged ready for market. Harvesting, which is labour intensive and a major cost to the grower, should be carried out at least once every 2 days and more often if the plants are growing rapidly.

CULTIVARS

A wide range of perilla cultivars are grown, the choice of cultivar depending on the intended use of the product. The main cultivars for oba production are 'Ao-oba' (green large-leaf), 'Ao-jiso' (green), and 'Ao-chiri-men-jiso' (green cotton-crepe) but in reality most growers develop their own lines by continually selecting seed from their best plants. When selecting plants for oba production the following are considered desirable characteristics:

1) Bright-green, broad, oval-shaped leaves
2) Leaves with deep serrated edges
3) A strong aroma
4) Creped leaf surfaces
5) Vigorous growth
6) Tendency to produce many side shoots
7) Reluctance to bolt in autumn

PESTS AND DISEASES

Cutworm, mites, aphids, and leaf-eating caterpillars are all problems in perilla production. A range of chemicals can be used to control these pests but withholding periods after chemical application must be strictly enforced. There are also reports from Japan that fungi including damping off, downy mildew, and rust may be a problem in growing perilla. In New Zealand, browsing caterpillars have been the main problem.

PROSPECTS FOR NEW ZEALAND

Trials in the Waikato, Hawkes Bay, and South Auckland areas have demonstrated that perilla (red and green leaf cultivars) can grow well in New Zealand. This fact, coupled with the constant demand by Japanese restaurants and hotels for a year-round supply of high quality green-leaf perilla, could make this a profitable crop for New Zealand growers. In Japan, green-leaf perilla production is greatest during the summer months from May to September with production dropping in autumn as the plants start to run to seed. This reduction in supply is not necessarily associated with a price premium because the autumn supply is of poor quality.

New Zealand growers could easily produce green-leaf perilla during the Japanese off-season without the expensive heating and lighting systems required in Japan, and they would also benefit from the high prices paid at that time of the year. The main problem is likely to be the relatively short shelf-life of the harvested leaves and the high cost of labour required for picking and grading. However, these problems could be overcome by the use of appropriate storage, transport, and processing technologies. There may also be a small local market for perilla based on the growing number of ethnic Japanese restaurants in New Zealand.

The commercial production of red perilla in New Zealand for the Japanese market is unlikely because it is readily available in Japan and there is no local market. However red perilla may have potential as an ornamental herb for home gardens.

Perilla shoots and flower heads command small niche markets in Japan, however, an assessment of their potential for production in New Zealand is difficult without accurate market statistics. Other market opportunities include oil production from both foliage and seed or production for medicinal use (perilla has bactericidal properties).

Acknowledgements. I am indebted to AGMARDT for a grant to study *Perilla* production in Japan. I would also like to thank J.A. Douglas for his support of this project and Angela Templeton for her critical review of this paper.

Propagation of Chilean Native Plants with Ornamental Value

Peter Seemann
Facultad de Ciencias Agrarias, Universidad Austral de Chile, Casilla 567, Valdivia, Chile

Many Chilean native plants may be used as ornamentals. Nevertheless, little knowledge exists on their propagation and culture. Experiments into the cutting propagation of six species have been carried out in order to determine the effect of auxin (IBA) concentrations on rooting. Results show the following: *Crinodendron hookerianum* roots best with 2500 ppm IBA; both *Mitraria coccinea* and *Sarmienta repens* have excellent natural rooting abilities; *Desfontainia spinosa* does not have an increased rooting response within the range of 0 to 5000 ppm IBA; rooting of *Lomatia ferruginea* cuttings fluctuates between 42% and 72% but no clear effects are obtained by the use of IBA; *Embothrium coccineum* roots best with concentrations up to 500 ppm IBA.

INTRODUCTION

Chile has a rich vascular flora, reaching 6265 species (Marticorena, 1990), from which almost 85% are endemic and/or native plants. A great many of those species have a potential use as ornamentals. Nevertheless, only a few have been brought into culture. That is why the propagation systems of most of the native plants have not been properly studied in our country, although many of them are well known in other latitudes for their ornamental use.

A few years ago we started the first experiments into the vegetative propagation of a number of native plants growing in southern Chile, selecting some species for their most ornamental character: flowers or foliage. A great help in this project has been the work of Hoffmann (1982), providing rich information including descriptions, use and distribution of the species, with excellent drawings of their shape, flowers, and foliage.

This paper deals with six species growing in different areas of southern Chile, which might be introduced to horticulture as ornamental plants. All these species grow in "the Chilean lake district from the south of Temuco to the island of Chiloé, covering an area of about half the size of New Zealand's South Island, with which it has many botanical affinities" (Gardner, 1990).

The species are as follows:

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The species are as follows:

***Crinodendron hookerianum* Gay (Elaeocarpaceae)** is known in Chile by the vernacular names of "polizón" or "chaquihue". This plant grows along the coast between Valdivia and Chiloé by stream margins and in swampy forests and shady conditions (Donoso and Ramírez, 1994). It is a bush of up to 4 m in height. It has very showy, solitary, hanging flowers of a light-red colour. As a very decorative and ornamental bush, it should be more frequently cultivated in public and private gardens (Hoffmann, 1982).

***Sarmienta repens* R. et Pav. (Gesneriaceae)** known as "medallita", is one of the three native gesneriads. As an epiphytic creeper it has long, striated stems with pulpy, thick, light-green leaves. The flowers are bright red, almost tubular, with the corolla widened in the middle and narrowing towards the upper part (Martínez). Its distribution is from Maule to Chiloé growing at a certain height above the sea level in both Cordilleras, predominantly in humid places.

***Mitraria coccinea* Cav. (Gesneriaceae)** is known as "botellita" for its similarity to a little bottle. It is less a true climber forming often spherical entanglements perched high up in the canopy of the surrounding flora (Gardner, 1990). This species grows in humid and shady places from Maule to Magallanes in the Andean and Coastal Cordilleras. It is a climbing shrub or facultative perennial creeper. The flowers are tubular and isolated, light to dark red, 4 to 5 cm long with a pubescent corolla (Hoffmann, 1982).

***Desfontainia spinosa* R. et Pav. (Desfontainiaceae)** is known in Chile as "taique". It grows from Maule to Magallanes but it is more abundant near Valdivia. As a small bush which does not exceed 2 m in height, it thrives in humid areas on sodden soils. It has very showy, large, tubular flowers with an orange/red corolla and yellow margins. Leaves are perennial, thick, thorny and serrated (Donoso and Ramírez, 1994).

***Lomatia ferruginea* (Cav.) R. Br. (Proteaceae)** is known in Chile as "romerillo", "fuinque", or "palmilla". It grows from Talca up to Magallanes in humid forests. It is a small tree up to 8 m in height with large fern-like leaves. The flowers are greenish-yellow and red inside. It is a very beautiful species for southern region gardens (Donoso and Ramírez, 1994; Hoffmann, 1982).

***Embothrium coccineum* J.R. et G. Forster (Proteaceae)** is known in Chile as "notro" or "ciruelillo" and in the British Islands as Chilean fire tree or fire bush. It has simple and alternate leaves with a very variable shape and dark green colour. In October the trees are covered with beautiful red flowers, being one of the most spectacular plants in its distribution area (Gardner, 1990; Donoso, 1994). Yellow-, white-, and orange-flowering genotypes exist in nature but are very rare (Muñoz, 1980; Kramm, 1987). It grows from the Maule River up to Magallanes on the hills, but it is more abundant near Valdivia (Donoso, 1994).

MATERIAL AND METHODS

Plant Material. During the spring and summer months, cuttings were made differing in length according to the species. Most of them had at least four nodes. The species used for rooting experiments were: Chaquihue (*Crinodendron hookerianum*), Botellita (*Mitraria coccinea*), Medallita (*Sarmienta repens*), Taique (*Desfontainia spinosa*), Romerillo (*Lomatia ferruginea*), and Notro (*Embothrium coccineum*).

Auxin Treatments. After preparing uniform cuttings, they were dipped for 5 sec in 50% hydroalcoholic IBA solutions between 0 to 5000 ppm. One species (*C. hookerianum*) was also treated with NAA or IAA solutions, in the same range of concentrations.

Rooting Conditions. A peat : sand mixture (1 : 1, v/v) was used as a substrate in propagation beds in a glass-covered greenhouse. An air temperature of 22±2C and rooting zone temperature 20±2C were maintained. Humidity was provided by a misting system which was controlled by a self-made humidostat. Light conditions during the rooting period followed the natural photoperiod (13 to 15 h per day).

Experimental Design and Evaluation. For each particular species separate experiments were carried out using a completely random design where treatments were given by auxin type and concentration. Each treatment used 10 to 30 replicates, depending on the experiment.

Evaluation was done after rooting had been evident, 30 to 120 days after the beginning of the experiment. Rooting percentage as well as some rooting parameters (root number, length of the principal root, and rooting score on a 1-4 scale) were recorded. Data were submitted to ANOVA and means were contrasted by Tukey's H.S.D. procedure with a 5% significance level.

RESULTS AND DISCUSSION

Crinodendron hookerianum. Natural rooting capacity of this species seems to be very good (Table 1), reaching 84% rooting, without the use of exogenous auxins. Nevertheless rooting percentage was increased to 100% by 2500 ppm, but auxin source did not play an important role. Root number, length, and rooting score were significantly increased by the use of 2500 ppm IBA. Auxin type, specially IAA, only affected root length positively.

Table 1. Effect of concentration and auxin source on rooting of *Crinodendron hookerianum* cuttings.

Main effect	Rooting percentage	Roots		
		Number	Length (cm)	Score*
Concentration				
0	84.0	12.8 a	6.6 ab	2.3 a
2500	100.0	20.9 b	7.5 b	3.7 b
5000	100.0	17.3 ab	6.5 a	2.9 ab
H.S.D. 5% (Tukey)	--	5.4	0.9	0.0
Auxin source				
IAA	97.8	16.9 a	7.5 b	2.9 a
IBA	95.6	17.7 a	6.5 a	3.0 a
NAA	91.1	16.3 a	6.5 a	3.0 a
H.S.D. 5% (Tukey)	--	n.s.	0.9	n.s.

* min. = 1; max. = 4

Table 2. Rooting capacity of two Chilean gesneriads: *Mitraria coccinea* and *Sarmienta repens*.

IBA concentration (ppm)	Rooting percentage		Root number		Root length	
	M.C.[1]	S.R.	M.C.	S.R.	M.C.	S.R.
0	100	85	9.0 a	9.2 a	6.4 c	3.7 ab
250	100	100	14.6 c	20.8 b	6.5 c	4.0 b
500	100	95	22.0 d	31.0 c	6.5 c	5.1 c
1000	100	100	12.6 bc	18.2 b	5.3 b	3.7 ab
2500	100	80	11.2 ab	17.2 b	4.5 a	4.0 b
5000	100	80	11.4 ab	8.8 a	4.6 ab	3.1 a
H.S.D. 5% (Tukey)	--	--	3.0	5.8	0.8	0.6

[1]M.C. = *Mitraria coccinea*, S.R. = *Sarmienta repens*.

Table 3. Rizogenesis of *Desfontainia spinosa* cuttings as affected by IBA concentration.

IBA concentration (ppm)	Rooting		Root	
	Percentage	Score	Number	Length (cm)
0	75.0	2.5 a	14.4 a	13.3 a
250	77.7	2.4 a	11.9 a	13.0 a
500	68.8	2.4 a	16.4 a	13.2 a
1000	83.8	2.5 a	17.2 a	13.4 a
2500	77.7	2.5 a	18.3 a	13.6 a
5000	72.8	2.4 a	21.5 a	12.3 a
H.S.D. 5% (Tukey)	--	n.s.	n.s.	n.s.

Table 4. Rooting response of *Lomatia ferruginea* cuttings.

IBA concentration (ppm)	Rooting		Roots	
	Percentage	Score	Number	Length (cm)
0	71.6	2.5 a	7.0 b	10.0 a
250	50.9	2.2 a	4.7 c	5.8 a
500	64.2	2.4 a	9.4 ab	8.2 a
1000	54.2	2.2 a	6.8 b	6.5 a
2000	67.5	2.3 a	10.1 a	8.3 a
4000	42.0	2.0 a	4.9 c	4.6 a
H.S.D. 5% (Tukey)	--	n.s.	2.7	n.s.

Table 5. Effects of IBA concentration on rooting behavior of two *Embothrium coccineum* genotypes.

IBA concentration (ppm)	Rooting percentage		Rooting score*	
	Yellow	Orange	Yellow	Orange
0	18.8	11.1	1.5 b	1.2 a
250	44.4	55.6	2.1 c	2.0 c
500	50.0	50.0	2.0 c	1.9 c
1000	27.8	27.8	1.7 b	1.5 b
2500	5.6	5.6	1.1 a	1.1 a
5000	5.6	5.6	1.1 a	1.1 a
Mean	25.3	26.0	1.6	1.5

* 1 = min, 4 = max. rooting.

Table 6. Effects of IBA-concentration on root development of two *Embothrium coccineum* genotypes.

IBA concentration (ppm)	Root number		Root length (cm)	
	Yellow	Orange	Yellow	Orange
0	1.5 a	1.2 a	1.8 b	1.2 a
250	4.5 bc	3.2 b	2.5 c	2.3 d
500	4.8 c	3.1 b	2.3 c	1.9 c
1000	3.8 b	2.7 b	1.8 b	1.6 b
2500	1.3 a	1.3 a	1.1 a	1.1 a
5000	1.1 a	1.4 a	1.1 a	1.1 a
H.S.D. 5% (Tukey)	0.8	0.6	0.3	0.2

***Mitraria coccinea* and *Sarmienta repens*.** Both species have excellent inherent rooting abilities—*Mitraria* reaching 100% rooting in all treatments (Table 2) and *Sarmienta* at least 80% rooting. Nevertheless, root number and root length were significantly increased by the use of up to 500 ppm IBA. Higher concentrations led to decreased rooting in the two species.

Desfontainia spinosa. The use of synthetic auxins does not improve the good natural rooting ability of this species. As Table 3 shows, the rooting percentage ranges from 69 to almost 84%, obtaining a fairly good rooting score (2.5 on a 1 to 4 scale). Root number is slightly but not significantly increased by IBA concentrations higher than 1000 ppm, while the root length stays equal with all concentrations. Rooting of this species might be increased by better selection of the cutting source and by using a fog system.

Lomatia ferruginea. Natural rooting of this species using either 1 or 2 noded cuttings reached nearly 70%. No auxin treatment could increase the rooting response (Table 4). Only the root number was significantly higher by using 2000 ppm IBA. Nevertheless, no clear responses could be observed by increasing concentrations. This might be due to the use of cutting material not completely ripened—harvesting plant material later in summer might improve rooting results. On the other hand, the use of powder-based IBA concentrations might be better when using softwood cuttings of this species (Awad, 1993).

Embothrium coccineum. As Table 5 shows, both yellow- and orange-flowering genotypes have similar rooting responses. Rooting percentage is increased by low doses of IBA up to 500 ppm. Higher concentrations seem to be harmful, inhibiting the rooting responses. A similar tendency was observed in the rooting scores of both genotypes.

Values of root number and root length (Table 6) were highest with 250 to 500 ppm IBA, decreasing with higher concentrations. In spite of the low rooting responses of this species, the best responses are obtained in mid spring and early summer propagation, just before and after flowering flushes. Other seasons gave no rooting

results. Timpson (1986) reports rooting success of up to 85% using cuttings taken in early February (England).

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Soil Recycling, the Odering Way

Ray Lawson
Odering's Nurseries (CHCH) Ltd., P.O. Box 996, Christchurch

We grow two crops in soil based mix. The first, freesia, is grown for out-of-season cut flower production. A soil with a silty-loam texture and containing clay particles is best. At Odering's Nursery we feel that the best soil is taken from virgin, clover-grown fields.

In the beginning of November the soil to be used is rotary hoed, heaped up, and transported to our nursery site for processing. The amount of soil required is 150 m^3 and processing takes 3 days. Preparation of the soil for a *Freesia* crop involves the following steps. First the soil is steam sterilised at a temperature of 212F (100C). We use four bins, two at a time, with each holding two-thirds of a cubic meter. It takes 10 min for the steam to reach the top of a bin and then a further 10 min to complete sterilisation. Following sterilization, bins are transported to a concrete pad and emptied. Next, an equivalent volume of mix, consisting of sphagnum peat and sharp sand (3 : 1, v/v), is added to the sterilised virgin soil. To this mix is added: agricultural grade lime, 5.4 kg; lime, 3.0 kg; P.G. Mix, 5.0 kg (orange bag); sulphate of potash; 3.0 kg; and Terraclor 0.3 kg for fungus disease prevention.

This mix is put through a shredder by two people. They have 20 min to complete the task, before the next two bins arrive. The total process requires five people. One, on a motorbarrow, fills the bins and keeps time, and four are on mixing—these spread the peat, sand, and apply fertilisers. While two are doing the mixing, the other two weigh out the fertilisers and other ingredients.

At the end of November the *Freesia* bags are put down. We use cut down Pb 40's which are sterilised with formalin then filled in place. Rows of 100, four deep occupy a 30,000 ft^2 greenhouse. Ten freesia seedlings (which are sown from late October) are pricked out and planted per bag. The freesias begin production in April and continue until August, then the space is used for bedding plants.

Processing the soil for bedding plants begins by removing the freesia corms from the bags. The foliage is cut off and corms are stored. Soil from two bays, i.e. 16 rows of bags, are put into one bay (this works out to be 20 m^3 of soil). It is then covered with a polythene sheet, sealed with sand, and sterilised with methyl bromide at the rate of 500 g per 100 ft^2 of soil. The plastic cover is removed after 48 h, sand is incorporated, and the soil removed from the greenhouse and stored.

For bedding plants 4 m^3 of soil is processed at a time. The following are added to the soil: agricultural grade lime, P.G. Mix, Azulon, and Ridomil. The mix is then put through the shredder.

From September onwards the majority of bedding plants are transplanted into the reconstituted freesia mix, thus recycling the soil which is returned to the earth.

The Latest In Plant Variety Rights: Part I

Bill Whitmore
New Zealand Plant Variety Rights Office, P.O. Box 24, Lincoln

GROWTH IN PLANT VARIETY RIGHTS

Interest in obtaining plant variety rights (PVR) has grown rapidly in recent years. Back in mid-1990 there were 588 plant varieties protected under the Plant Variety Rights Act 1987. By the middle of 1995 the number of protected varieties had grown to 1035. With numbers of this order, those of you who are working in the horticultural industry are probably unavoidably involved with protected varieties. In saying this I am not trying to paint a picture of plant variety rights being an unavoidable evil. It is quite the contrary. I believe that the growing interest in plant variety rights is an indication that people in the industry see plant variety rights in a positive light, as a means of obtaining constructive investment in horticulture.

GROWTH IN THE INTERNATIONAL PLANT VARIETY RIGHTS ORGANISATION

UPOV, the InternationalUnion for the Protection of new Varieties of Plants, is also growing steadily. Six years ago there were 17 member States, now there are 27.

This growth is likely to continue for some time as a result of the finalisation of the Uruguay Round of the GATT Agreement in 1994. Most, if not all, countries in the world have signed the agreement and have become members of the World Trade Organisation. Countries that are members of the World Trade Organisation are required, if they have not already done so, to provide for a national system of plant variety protection. The logical thing for any such country is to introduce a system of plant variety protection following the UPOV model.

The more countries that belong to UPOV, the more opportunities there will be for New Zealand breeders to protect their varieties abroad.

A particular problem that has faced New Zealand breeders in the past is gradually lessening. While many countries such as those in Western Europe or Japan have had plant variety protection schemes for many years, they offered protection only for certain specified genera. They have not offered protection for the whole plant kingdom as New Zealand has done for the last 15 years. These countries are now moving to extend their schemes. Some, such as Germany and The Netherlands, have already opened up their schemes to the whole plant kingdom, while others are moving in this direction.

WHAT CHANGES CAN BE EXPECTED IN THE FUTURE?

The Plant Variety Rights Act 1987 is to be amended at some time in the future. We had hoped this would have occurred by now but for various reasons it has not.

New Zealand must amend the Act in order to bring it into conformity with the UPOV Convention as rewritten in 1991. There will be some significant changes made. Some of the more important are the following.

Terms of Grants Are to Be Extended. Presently a PVR grant can remain in force for 23 years for a woody plant and 20 years for a non-woody plant. In future the term will be 25 years for any kind of plant.

Breeders to Have More Comprehensive Rights. At present the holder of a PVR has the limited exclusive right to propagate the variety for sale and to sell reproductive material.

Under the amended Act a holder of a PVR will be able to prohibit others from the following acts: production and reproduction (multiplication), conditioning for the purpose of propagation, offering for sale, exporting, importing, stocking for any of the purposes above.

One interesting change concerns varieties propagated by a municipal authority, such as a parks and reserves department. At present such an authority can buy a few bushes of a protected rose variety and then in its own nursery is free to propagate, from those few bushes, new bushes in large numbers, perhaps in the thousands. These could then be planted out for public display in parks or traffic islands. Such large scale propagation could be done quite legally without getting the approval of the PVR holder, or without paying him or her any royalties.

At present a PVR gives the holder rights over the propagating material only. Under the amended Act, if the breeder is unable to exercise his right over the propagating material, he will be able to exercise his right over the material harvested from the propagating material. If, for example, a rose breeder is unable for some reason to exercise his right over the propagation of his/her protected rose variety, he/she will be able to exercise his/her right over the sale of cut flowers of the variety.

Essential Derivation. A significant change will be the introduction of the entirely new concept of "essential derivation". It is being introduced to meet a specific concern raised by certain breeders in the past. It can happen that a breeder follows a long and costly breeding programme which results in a superior variety with considerable commercial potential. He protects it by PVR and releases it onto the market. However, soon after its release a mutation appears in a grower's crop that differs from the original variety in some characteristic which, while it might be commercially unimportant, is sufficient to make the mutation a distinct variety for PVR purposes. Despite the fact that the grower has put in only a minimal breeding effort compared with that of the original breeder, he is able to obtain a PVR for the mutation and is free to sell the mutation in competition with the original variety. The original breeder's returns can be greatly reduced. Under the amended Act, such a mutation would be regarded as an essentially derived variety and its discoverer would be unable to sell material of it without the approval of the original breeder. When such a situation arises in the future under the new law, one would expect that it would be in the mutual interest of the two persons to get together and reach an agreement to sell the variety, perhaps under a royalty-sharing arrangement.

The Latest In Plant Variety Rights: Part II

Chris Barnaby
New Zealand Plant Variety Rights Office, P.O. Box 24, Lincoln

RECENT DEVELOPMENTS

This part of the presentation will cover some recent developments on the technical side of plant variety rights (PVR) and should assist existing or future applicants. I will conclude with some general comments on labelling protected varieties that will be of interest to all as protected varieties are becoming increasingly common.

The Requirement to Supply Photographs and the Technical Questionnaire at the Time of Application. It has been proposed to amend the Plant Variety Rights Act 1987 to make it compulsory for a photograph of the variety and the correct technical questionnaire for the species or genus to which the new variety belongs, to be supplied at the time of application. The Commissioner would then be unable to accept an application if photographs and the technical questionnaire are not supplied.

This change has arisen because the PVR Office has experienced difficulties in obtaining technical information from some applicants. This delays the testing of the variety and is unacceptable. The consequence of any delay in testing is the unnecessary prolonging of the period of provisional protection and it may unfairly disadvantage another applicant who has a close or similar variety. It is hoped that the Act will be amended soon.

What is the Real Purpose of the Technical Questionnaire? Many technical questionnaires for new varieties are completed inadequately. It is important that all questions are answered. Absent or vague information makes the technical examination more difficult. The major purpose of the technical questionnaire is to inform the PVR Office why the applicant considers that the new variety is different or distinctive from all others. The technical questionnaire is a preliminary technical *look at the variety. It is by no means a complete and detailed description of the* variety. I urge all applicants to fill out the technical questionnaire as fully as possible. We can never have too much technical information.

The Supply of Plant Material to the PVR Office and PVR Growing Trials. The PVR Office has a general policy of requiring plant material of a variety under test to be made available for PVR evaluation purposes within 12 months of the application date. This 12-month deadline has some limited flexibility depending on the type of plant and quarantine requirements for imported varieties. The period may be extended at the discretion of the Commissioner. This deadline is to ensure that no unnecessary delays occur in testing the new variety. The majority of ornamental varieties, other than roses, are tested on the applicant's property in a PVR growing trial. For this situation the PVR Office would reasonably expect the trial to be established within the 12-month deadline even if actual evaluation did not occur until later. I can supply more information to those who have particular questions about PVR growing trials.

The PVR Office normally requests plant material to be supplied for reference purposes in addition to plant material for a PVR growing trial. The plant material requirements for reference purposes should not be confused with those for growing trial purposes. In some cases, several of the plants supplied for evaluation purposes will be retained for reference purposes at the conclusion of the evaluation trial.

Labelling Protected Varieties. There has been, and continues to be, confusion over what is required under the Plant Variety Rights Act 1987.

With respect to labelling there are two specific offences under the Act.

1) To sell reproductive material, including whole plants, of a variety without using the approved variety name or denomination. All nursery owners and retailers must be clear about the difference between a protected variety name and a commercial or trade mark name. This requirement does not exclude the use of other names but the variety name must be present somewhere on the label.
2) To falsely claim when selling material of a variety, that the variety is protected by Plant Variety Rights or is the subject of an application. This may occur when using imported labels. A variety protected in Australia may or may not be protected in this country. A plant variety right only applies in the country in which it was issued.

In conclusion, the changes we have made should help applicants clarify why they consider a variety is distinct and reduce the time a variety is under test. With labelling, marketing practice may suggest otherwise, but use of the variety name is a legal requirement. Be cautious about the use of imported labels. Variety protection information on the label may be misleading or incorrect for this country.

TECHNICAL SESSIONS

FRIDAY MORNING, 3 NOVEMBER 1995

The Forty-fifth Meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:00 AM in the Sheraton Hartford Hotel, Hartford, Connecticut, with President David Beattie, Presiding.

President Beattie: Good morning. We have many interesting speakers at our meeting but before we start our presentations Deb Donahoe will begin our meeting with a welcome from the Connecticut Nurseryman's Association and then our awards presentations will begin with Mike Johnson and his tribute to Cecil and Jim Wells.

WELCOME TO CONNECTICUT FROM THE CONNECTICUT NURSERYMAN'S ASSOCIATION

DEB DONAHOE: It is an honor and privilege to be here this morning to welcome such a prestigious organization to our State of Connecticut.

The green industry in our state is the largest economic sector of agriculture. It generates more than $600 million on the wholesale level. More than 14,000 acres are in cultivation, more than 500 acres are under glass, and over 5000 workers are employed. We produce woody ornamentals, annuals, perennials, ornamental grasses, cut flowers, potted crops, Christmas trees, sod, and herbs.

We have many outstanding green industry professional organizations, such as the Connecticut Nurserymen's Association, Connecticut Florist's Association, Connecticut Christmas Tree Association, Connecticut Groundskeepers, and the Farm Bureau to name a few, in addition to famous horticulturalists including Drs. Sidney Waxman and Dick Jaynes.

On behalf of the Connecticut Nurserymen's Association I welcome you to Connecticut. I hope this will be a time of learning, sharing, and camaraderie and that you enjoy your stay in our state.

TRIBUTE TO CECIL AND JIM WELLS

MIKE JOHNSON: As all of you should know, this meeting has been dedicated to Cecil and Jim Wells. Those of us here in our declining years among us know the Wells' family quite well; however, as I look about I see many young faces who may not know how important these people have been to the International Plant Propagators' Society.

Jim was one of the founding members of the Society and was its president the first 2 years of its existence. I think it is safe to say that without his perseverance, determination, and vision we might not be in this room today as there might not be an International Plant Propagators' Society.

When the time came for this Society to become international, Jim was very instrumental in helping the chapter in England and Ireland get started, as well as those in New Zealand and Australia. Cecil and Jim's vacation time from their nursery was taken with traveling to these far-off places to help the local nurserymen establish their chapters. The time and effort they gave to this Society is almost impossible for the rest of us to comprehend, and for this alone, they deserve our thanks.

However, it is not only this Society but the nursery industry in general that owes the Wells' a large amount of gratitude. For although Jim was an excellent nurseryman, I feel that it is through his research and educational abilities that he became the eminent plantsman that he is. I have never met another man in this industry so willing to share knowledge, and the fact that he did it in so many ways is unique.

He wrote a book on alpine plants many years ago and also a book on miniature daffodils quite recently. But it is his book, *Plant Propagation Practices,* first published in the 1950s and republished recently that is most notable. Every propagator should have a copy. It was my bible when I started in the business and is by far the most readable and practical book that I've come across.

In addition to the books, Jim has written countless articles on propagation and many other phases of the nursery industry. His nursery was a research center because he was never satisfied with what he accomplished. Some of the new methods he tried cost him dearly, but he never gave up the quest for 100% rooting and the perfect plant; and throughout it all, he was ready to share immediately everything he learned. Because of this, quite a few of us got to know Jim Wells.

However, those of us that were fortunate enough to know the Well's family realized that this was not a one-man show—Cecil has been with him all the way. During World War II when Jim was raising food crops in England, girls were conscripted to work on the farms since all the men were in the army or navy. It was Cecil who saw that these girls were taken care of, housed, and fed.

Later at Wells Nursery in New Jersey, she again became a surrogate mother. This time to the English horticulture students that came to work at the nursery—Jim being the educator here once again. Her vacation time was spent interviewing these students in England and seeing to it they were taken care of as with the girls in England during the war. As I mentioned before, she was with Jim when helping to get other chapters of this Society started.

Although we all can agree the life of a nursery wife is very often difficult, Cecil has met this challenge with grace and energy. I'm sure Jim will not mind my repeating what he said to me in a serious moment sometime ago, "without Cecil I never would have amounted to anything."

And so it is we honor two people today, two people who have meant so much to this Society, the nursery industry, and those of us who have known them throughout the years.

To commemorate this occasion, we have a plaque from the Plant Propagators' Society—Eastern Region for Jim and also another plaque which reads "A tribute to Cecil Wells—For her inspirational support in a very successful partnership, with grateful appreciation, from members of I.P.P.S. and other horticultural friends."

AWARDS PRESENTATIONS

PRESIDENT BEATTIE: It is my pleasure to make the next award. Will Darrel Apps come forward. I have know Darrel for a number of years and have enjoyed our friendship and enjoyed working with him. In fact I owe my job at Penn State to him. I enjoyed working with him when he was at Longwood Gardens and with the Perennial Plant Association. Darrel was the Secretary-Treasurer of the Eastern Region for 3 years. To show our appreciation as an organization, we have an original botanical print from about 1810 of a hand-colored daylily. I took a look at it earlier and it is amazing how vibrant the colors are after all these years.

FELLOW RECIPIENTS—EASTERN REGION

TIM BROTZMAN: This is the fifth year that Fellow recipients have been given. We have an outstanding group of individuals for you today. They are recognized for their contributions to the field of propagation, but also for their contribution to the Eastern Region at large. The recipients are the following:

- **Jack Alexander:** The first award goes to a person who has been a member for 18 years. Every year he moderates the New Plants presentation of our conference. He is a noted propagator and is always willing to share his knowledge if you call.
- **Darrel Apps:** You have heard earlier this morning about the contributions of our next recipient. He has been a solid supporter of I.P.P.S. and he is intent to flaunt his floral creations across the landscape of the U.S.
- **Dick Bir:** The next individual has only been a member for 10 years but has had a very productive time. He has participated every single year that I have been here. He could be a Southern Region member but because of the altitude that he lives probably feels more at home with us and makes the trip every year to our meeting.
- **Don Shadow:** Our next recipient can not be with us because he is preparing to speak at the Southern Region. He is a true southerner but feels a strong affinity for our region because of the plants he grows. He is also a past president of the Eastern Region and feels honored that we would give him an award. He sends his regrets that he could not be with us.
- **Robert Simpson:** Our last award goes to member who joined in 1952 which is 2 years after its founding. We know his name very well and also his plant contributions to the industry including hollies, crabapples, and hawthorns. He could not be with us today, however, his daughter Betsy has come to accept the award for him.

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AWARD OF MERIT

ALAN JONES: It is a great honor and privilege to present to you the recipient of the 1995 Eastern Region Award of Merit. This is the highest award the Eastern Region can bestow on a member. Recipients must have over 10 years of active membership, as well as providing outstanding contributions to plant propagation within the nursery industry.

This year's award winner has a lengthy and impressive background.

His academic life started with a bachelors in pomology from Penn State, then a masters in vegetable breeding from Ohio State, and if that was not enough he went on to get his Ph.D. in genetics from the University of Wisconsin.

With this background I suppose it was inevitable that he would end up in plant breeding.

In 1960 he took up the call and the challenge to become head of the holly breeding program at Rutgers University in New Jersey, but soon found that man cannot live by *Ilex* alone, so he added a *Pyracantha* breeding program.

In the 35 years he has been at Rutgers he has introduced 20 *Ilex* selections, two *Cornus florida* selections, four *Pyracantha* cultivars, and six cultivars of his famous *Cornus kousa* × *C. florida* crosses—known as the" Stellar Series". In his spare time, he teaches plant propagation at Rutgers University.

This gentlemen is probably best known for his breeding work with dogwoods, but one of his major contributions to plant propagation was the research, development, and introduction of a commercially acceptable method for rooting stem cuttings of *Acer rubrum* cultivars. This method has now totally replaced the need to bud red maples and, therefore, eliminates grafting incompatibility problems with this species.

Our recipient has given numerous papers to this organization as well as many other horticultural organizations in this country and is known as someone who should be given the amount of time specified to present his paper, as he has been known to become very irritable and impatient when the time allowed for presentation of his paper gets cut short. Despite this one very minor shortcoming, this gentlemen has provided the industry with a wonderful range of new and interesting plants for which we are all very grateful.

It is my pleasure to announce that the 1995 Award of Merit is presented to Dr. Elwin Orton of Rutgers University.

INTERNATIONAL AWARD OF HONOR FOR 1995

PETER ORUM: It is my pleasure as the director to the International Board from the Eastern Region to announce the recipient of the International Award of Honor for 1995 because our recipient is a member of the Eastern Region.

First let me give you a little background on the award. It was established by the International Board to recognize outstanding contributions at the international level in our Society. The Award recognizes exceptional and distinguished service to I.P.P.S. and outstanding accomplishments in the field of plant propagation.

Only a small number of individuals have received this award and include individuals, such as Bruce Briggs, and our own Jim Wells, Ralph Shugert, and Bill Snyder.

The International Board gathered in Harrogate, England this August and an-

AWARD OF MERIT

ALAN JONES: It is a great honor and privilege to present to you the recipient of the 1995 Eastern Region Award of Merit. This is the highest award the Eastern Region can bestow on a member. Recipients must have over 10 years of active membership, as well as providing outstanding contributions to plant propagation within the nursery industry.

This year's award winner has a lengthy and impressive background.

His academic life started with a bachelors in pomology from Penn State, then a masters in vegetable breeding from Ohio State, and if that was not enough he went on to get his Ph.D. in genetics from the University of Wisconsin.

With this background I suppose it was inevitable that he would end up in plant breeding.

In 1960 he took up the call and the challenge to become head of the holly breeding program at Rutgers University in New Jersey, but soon found that man cannot live by *Ilex* alone, so he added a *Pyracantha* breeding program.

In the 35 years he has been at Rutgers he has introduced 20 *Ilex* selections, two *Cornus florida* selections, four *Pyracantha* cultivars, and six cultivars of his famous *Cornus kousa* × *C. florida* crosses—known as the" Stellar Series". In his spare time, he teaches plant propagation at Rutgers University.

This gentlemen is probably best known for his breeding work with dogwoods, but one of his major contributions to plant propagation was the research, development, and introduction of a commercially acceptable method for rooting stem cuttings of *Acer rubrum* cultivars. This method has now totally replaced the need to bud red maples and, therefore, eliminates grafting incompatibility problems with this species.

Our recipient has given numerous papers to this organization as well as many other horticultural organizations in this country and is known as someone who should be given the amount of time specified to present his paper, as he has been known to become very irritable and impatient when the time allowed for presentation of his paper gets cut short. Despite this one very minor shortcoming, this gentlemen has provided the industry with a wonderful range of new and interesting plants for which we are all very grateful.

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nounced the recipient for 1995 at that meeting. Our honoree this year is well known to many of us in the Eastern Region. He has been a member for 36 years and we recognize him from his many contributions in the form of papers to our meetings. He is widely know for his research in the fields of micropropagation and juvenility. Although he has never served the Eastern Region as an officer, we can't thank him enough for he was the person who assembled our 30 year index for Volumes 1 to 30. Anyone who has ever tried to locate propagation information in our Proceedings is well aware of the benefits of the index.

It is my pleasure to announce the 1995 recipient of the International Award of Honor, Dr. Richard Zimmerman. As part of the award, Volume 45 of the I.P.P.S. Combined Proceedings will be dedicated to Dr. Zimmerman.

Thank you Dr. Zimmerman for all you have done.

Putting Roots on Shrub Roses

Mike Hoffman
Bailey Nursery, 6750 103rd St., Cottage Grove, Minnesota 55016

Bailey Nurseries propagation facility, (Nord Farm), has been in production for about 14 years. At present, we have 13 acres under plastic for the propagation of woody, perennial, and annual plants. Each house is filled and emptied at least two times per year.

Most propagation is carried out in ground-level sandbeds. The sand which is mined on the premises is 20 to 24 in. deep and drainage tile is used to enhance drainage. The sandbeds are leveled, watered, and treated with vapam before cutting propagation. Cuttings can be stuck about 2 weeks after the vapam treatment.

Rose cuttings are taken from our container production beds or flown in from Arizona where we field grow shrub roses on contract. From our container production, we try to get as long a cutting as possible, (usually about 5 in.), and trim off the flower heads and strip the bottom leaves. This yields a fairly skinny cutting about 4 in. long. We allow 3 to 4 weeks between cutting harvests from the containerized roses.

Prepared cuttings are placed in poly boxes, moistened, and stored in a 45F cooler with an air-over-water humidity system. We pre-dip the roses in 1000 ppm K salt of IBA—this is a 2-sec quickdip, and then they are put back into the cooler until planting. Cuttings are kept in the cooler a maximum of 6 days before sticking in the propagation house.

The cuttings from Arizona come from field-grown roses. In the Arizona environment the roses grow very rapidly and we are able to take a 7- to 8-in. cutting. After trimming off the top 3 in., we are left with a thicker-stemmed 4- to 5-in. cutting to root. Cuttings from the field-grown plants are cooled, wrapped in moist newspaper, placed in poly bags, boxed with dry newspaper surrounding the bag as insulation, and then flown out in the early morning, same-day air. When we receive these cuttings, we cool them down, pre-dip them in hormone, and then stick the cuttings in the greenhouse. These cuttings produce a stronger rooted liner and root at a little higher percent. The use of cuttings from Arizona allows us to grow our container plants larger since we are not cutting them back as often to obtain the cutting numbers we need.

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In the greenhouse, we use a dibbler to make holes and set the spacing. Spacing for roses is set at 2-5/8 in. × 2-5/8 in.—this allows for growth after the cuttings are rooted. Cuttings are watered in after sticking and misted with a traveling irrigator using 80-01 nozzles at 14-in. spacing which provides 1/10 gal per min. Plants are kept on the moist side during the first 3 days and a foliar fungicide is also applied during this time. After this, we get the foliage as dry as possible in the evening without causing any visible stress—this allows us to keep the cuttings dry all night. In the morning we keep the cuttings dry as long as possible before starting the mist cycle. We greatly reduce our fungal disease problems with this schedule. Low-volume fans are also used to keep the air moving around the cuttings.

For approximately the first 2 weeks in the propagation house, cuttings are given a heat treatment. We close the doors and vents around 5:00 PM on sunny days so the heat builds up in the sand. This procedure also allows us to turn the mist off earlier because the humidity builds up.

Most shrub rose cultivars root quickly and evenly with roots visible 7 to 10 days from sticking. Cuttings can be taken off mist anywhere from 20 to 30 days from sticking depending on cultivar and rooting conditions. As roots emerge mist is cut back gradually until it is turned off.

When cuttings begin rooting, they are fertilized 2 times per week with 200 ppm 20N-20P-20K fertilizer. Once cuttings are off mist they receive constant fertilization with 200 ppm nitrogen from a 20N-20P-20K fertilizer. When most cuttings have grown about 3 in., we cut them back with a mower which is mounted on a frame that can roll up and down the greenhouse. The first cut is about 1 in. above the original cutting, each cut after that is a little higher up.

Pest and disease control on shrub roses requires a weekly spray schedule. We spray for various foliar fungal diseases, mites, and aphids.

In early September, the rooted cuttings receive about 3 to 4 applications of 4N-25P-35K fertilizer and then all fertilizing is stopped for the rest of the season.

The plants are dug bare root in November and stored in pallets in a cooler kept at 34F with close to 100% humidity supplied by an air-over-water system. These plants are graded into large, small, and restick, and then roll-wrapped with sphagnum peat in bundles of 100. The bundles are stored in a freezer at 28F. On average, we end up with a success rate of 85% on shrub roses after the grading process is completed. Most of these rooted cuttings are planted in containers or lined out in the Arizona fields. We are also beginning to sell any surplus liners.

Shrub roses are easy to propagate and grow but, of coarse, there are a few cultivars—such as *Rosa* 'Agnes', *R.* ×*harisonii* 'Harrison Yellow', and *R. foetida* 'Persiana' (syn. 'Persian Yellow')—that are difficult to propagate from softwood cuttings. We are presently looking into propagating these by tissue culture.

Bailey's currently sells about 50 cultivars of shrub roses and plans to gradually expand this through our rose breeding program in Oregon as well as new introductions from other sources.

The Propagation of Hardy, Woody Plants from Root Cuttings: A Review

Peter Del Tredici
Arnold Arboretum of Harvard University, 125 Arborway, Jamaica Plain, Massachusetts 02230

INTRODUCTION

Many successful plant propagation techniques draw their original inspiration from observing the behavior of plants in nature. What plant propagator has not observed sprouts arising at some distance from the main stem of a tree or shrub and thought to themselves that this plant might be propagated from root cuttings. Such observations can be traced back at least to the propagation of hardy, woody plants from root cuttings in the days of John Evelyn, who, in 1706 (and perhaps as early as 1664) observed that species of *Ulmus, Prunus*, and *Populus* produced root sprouts that could be dug up and planted. Remarkably, Evelyn also gave detailed instructions for how to propagate trees from roots: "To produce suckers, lay the roots bare and slit some of them here and there discretely, and then cover them." The most famous case of plant propagation from root cuttings is, of course, that of the breadfruit, *Artocarpus altilis*. This was the plant that the notorious Captain Bligh of the *Bounty* was charged with of transporting from the South Pacific to the West Indies. It was during the breadfruit's 5-month propagation period, spent in Tahiti, that the crew developed the taste for freedom that ultimately led to their infamous mutiny in 1789.

Since the mid-1800s, an extensive literature on the propagation of plants from root cuttings has grown up. Interestingly, there are references to root cutting which seem to be more numerous in the older literature than in the modern. This is probably because advances in softwood stem cutting technology (rooting hormones and intermittent mist) have rendered the slower and more laborious process of root cutting propagation obsolete. Nevertheless, a number of difficult-to-root woody plants—primarily in the families Anacardiaceae, Leguminoseae, Myricaceae, and Rosaceae—are still most effectively propagated from root cuttings.

Unfortunately, much of the literature on root cutting propagation is difficult to interpret because of the imprecise use of terminology. In particular, many horticulturists consider any woody structure that occurs underground to be a root, regardless of its anatomical origin. This means that plants that produce shoots from underground stems—including rhizomes, stolons, or lignotubers—are often incorrectly classified as "root sprouters." Another problem is that many horticulturists have uncritically copied plant lists from earlier writers, without either evaluating the validity of the prior observation or citing a proper source (e.g., Donovan, 1976).

The primary purpose of this article is to cut through the confusion that has plagued the horticultural literature on root cuttings by identifying those species that have actually been reported to reproduce from root cutting by more than one author (Tables 1 and 2). I have made an exception to this requirement of independent confirmation if an author actually provides documentary evidence for a given species. Those genera that are not confirmed by a second author are listed at the end of this article as good candidates for future research (Table 3).

An especially interesting article is by Wobst (1868), a German author who provides an extensive list of species—including many not mentioned by other authors—that can be propagated from root cuttings. Other early articles on root cutting propagation are by an American (Saul, 1847), a German (Katzer, 1868), and an Englishman (Lindsay, 1877, 1882). A more modern reference that is extremely interesting, but has not been cited in the horticultural literature, is *Silvics of North America* (Burns and Honkala, 1990). This book, which covers the ecology of important timber species, has a special section for each entry on vegetative regeneration. In Table 4, I have included a list of those species that are reported in this book to reproduce from root sprouts following logging. Of the 108 nontropical, native angiosperms listed, 22 of them (21%) are reported as showing the ability to reproduce from root sprouts. Whether this figure is representative of the general proportion of root sprouting to non-root-sprouting species for a wider sample of trees remains to be determined.

It is worth noting that all of the species discussed in this article are angiosperms. The only two gymnosperms have ever been documented to produce root suckers in nature are tropical conifers, *Araucaria cunninghamii* (Burrows, 1990) and *Dacrydium xanthandrum* (Wong, 1994). Interestingly, *Araucaria cunninghamii* was also listed by Wobst (1868) as propagated from root cuttings. Despite reports that *Ginkgo biloba* and *Sequoia sempervirens* produce root sprouts (Donovan, 1976), recent research (Del Tredici, 1992) has shown that these gymnosperms produce shoots from underground stems (lignotubers) not from roots.

The anatomy and physiology of root sprouts is a very complex subject and outside the scope of this paper. For this information, one should consult the excellent review by Peterson (1975). For a detailed ecological study of root sprouting by a tree in its native habitat, one should consult the article by Kormanik and Brown (1967) on *Liquidambar styraciflua*.

What follows below is a summary of the general information on the techniques of propagation of hardy woody plants from root cuttings, as described in the English-language horticultural literature. To critically evaluate the extensive literature on tropical plants or herbaceous perennials propagated from root cuttings would be a massive task that is well beyond this authors' experience or expertise. Following the techniques section are the lists of species that have been successfully propagated from root cuttings.

TYPES OF ROOT CUTTINGS

When discussing the propagation of plants from root cuttings, precise terminology is essential to describe the so-called polarity of the root. Proximal describes the end of the root nearest to the stem from which the root grew, distal describes the end furthest from the parent stem. This is an important concept because when a root cutting develops a shoot bud, it typically forms at the proximal end. Following the classification system established by Hudson (1956), five distinct types of root propagation can be distinguished among woody plants, based on the relationship between parent plant and root sprouts, or suckers as they are also known:

- **Natural Suckering without Division.** This category includes species that produce root suckers naturally near the parent trunk, forming a densely packed cluster of stems.
- **Natural Suckering with Division**. This category includes plants—mainly shrubs—that sucker from uninjured roots at some

distance from the base of the parent plant. Under undisturbed conditions these plants form large, spreading colonies. The connecting roots have a tendency to wither away, thereby creating natural divisions of the parent.

- **Induced Suckering.** This category includes plants that form root suckers in response to superficial injury to the root, such as that caused by lawn mowers. Induced suckering can also be seen following traumatic injury to the trunk of a tree or shrub, provided its root system is left intact. Many of the tree species listed in *Silvics of North America* (Burns and Honkala, 1990), fall into this category, insofar as they only produce root sprouts following logging.
- **In Situ Whole Root Cuttings.** This category includes plants that form root suckers from a root that has been completely severed from the parent plant but left *in situ* until a sucker has grown from the proximal end. This phenomenon is often observed in nurseries after a tree or shrub has been dug, leaving the distal ends of severed roots behind. Provided the ground is not disturbed, these roots will eventually give rise to vegetative shoots.
- **Ex Situ Detached Root Cuttings.** This category includes plants that form root suckers from root cuttings that are dug up in the fall or winter, cut into short segments, and planted in the field or in containers. From the propagator's point of view, this is the most important category of root cutting propagation because it allows for rapid increase in the numbers of plants.

SOURCE OF ROOT CUTTINGS

When propagating plants from root cuttings, the source of the propagules is critical. The following generalizations apply:

- There is a distinction between roots spouting in nature and induced sprouting from root cuttings. Some species that do not normally sucker can be induced to produce sprouts from root cuttings under nursery conditions.
- Selections in which the desired mutation consists of a periclinal chimera, including many variegated plants, will not come true from root cuttings. This is because root buds typically arise endogenously from the interior of the root, while buds that are produced on shoots arise exogenously from more superficial tissue layers. This difference in the point of origin produces slightly different types of meristematic organization between root and shoot buds (Creech, 1954; Peterson, 1975).
- While it may seem obvious, it is important to remember that selections grafted onto seedling understock cannot be propagated from root cuttings.
- Younger plants reproduce more reliably from root cuttings than older plants.
- Thick pieces of the root proximal to the parent trunk seem to produce shoots more readily than thin root pieces distal to the parent trunk (Creech, 1954).

TIMING OF ROOT CUTTING COLLECTION

Most authors agree that late fall or early winter—from October through December—is the best time to collect root cuttings, when roots possess their maximum carbohydrate concentrations (Flemer, 1961; Browse, 1980b; Macdonald, 1987; Hartmann et al., 1990). In areas with cold climates, root cuttings are also collected in late winter to early spring (Saul, 1847; Flemer, 1961). Because root buds must develop *de novo* from the inner tissues of the root, they can often be quite slow to develop. In general, the later in the season the root cuttings are collected, the warmer the environment they require for successful propagation (Hudson, 1956; Browse, 1980b).

SIZE OF ROOT CUTTINGS

The optimal size of the cuttings is determined by the environment in which the cuttings will be placed. In general, cuttings stuck in a greenhouse can be 3 to 6 cm long, while those planted directly out-of-doors should be 10 to 15 cm long (Flemer, 1961; Dirr and Heuser, 1983). As Browse (1980b) points out, however, such generalizations can sometime oversimplify the situation: "Only experience can dictate the length of the root cutting of any particular plant and only then in relation to the environment to which it will be subjected—usually a prepared outdoor bed, a cold frame, or a glasshouse bench—the size of the cutting needed decreasing with the warmth of the environment. Size is, of course, a function of two parameters, length and thickness, and although it has been shown that thicker cuttings produce shoots more effectively, those produced from thinner roots establish better."

POLARITY OF ROOT CUTTINGS

All authors agree that the so-called polarity of the cuttings always be respected. Buds tend to form most readily at the proximal end of the cutting (that closest to the trunk). Most authors recommend that this end of the cutting be given a straight horizontal cut, while the distal end of the cuttings receives a sloping, diagonal cut (Flemer, 1961; Macdonald, 1987). This makes it easier to establish proper orientation when sticking the cuttings into the propagation bed. When the cuttings are being stuck, they can be either vertical or diagonal, with the proximal end of the cuttings just at or slightly above the soil surface. Cuttings can also be placed horizontally in flats and covered with a centimeter or two of soil (Creech, 1954; Macdonald, 1987).

TREATMENT OF ROOT CUTTINGS

Fungicide application greatly improves the success rates of root cuttings (Browse, 1980b; Macdonald, 1987). Once cuttings are prepared, they should be put in a plastic bag with a powdered fungicide or dipped briefly in a liquid formulation and shaken so that the entire root piece is covered. Treating root cuttings with superficially applied cytokinin does not appear to significantly enhance shoot production above that of the untreated controls (Brown and McAlpine, 1964; Macdonald, 1987).

WINTER STORAGE OF ROOT CUTTINGS

Root cuttings collected in the fall can be stored in boxes or flats, covered with a moist, well-aerated medium, and put in a frost-free storage structure until early spring. During this storage period, the cuttings will callus over and begin the bud formation

process. In late winter or early spring the cuttings can be planted out in the nursery or planted in containers in the greenhouse (Flemer, 1961; Browse, 1980b; Macdonald, 1987).

PROPAGATION ENVIRONMENT

Good discussions of the relationship between the propagation environment and root cutting performance, as well as lists of what plants are best propagated under what environmental conditions can be found in Browse (1980b) and Macdonald (1987).

Out of Doors. In areas with mild winters, root cuttings can be planted directly in the field in late fall or early winter. In areas with severe winters, root cuttings can be collected in the fall and put in cold storage until spring, when they can be planted directly in the nursery. Direct field planting works best with suckering shrubs that naturally form root buds (Flemer, 1961).

Cold Frames. These have been reported to be used successfully in areas with relatively mild winters, such as Great Britain or the Pacific Northwest. They afford more protection to the cuttings than does field planting and therefore offer a greater chance of success.

Cool Greenhouse. For propagation in a cool greenhouse, fall-collected root cuttings that have been kept in cold storage work very well when direct stuck in individual containers in late winter. Root cuttings can also be collected in late winter or early spring, in which case they should be immediately planted in a cool greenhouse with bottom heat (Dirr and Heuser, 1987).

PROPAGATION MEDIUM

The rooting medium should be very well drained to provide maximum aeration. Successful mixes consist of various percentages of peat, bark, sand, grit or perlite. The well-drained medium inhibits the growth of pathogenic fungi and enhances root development (Flemer, 1961; Browse, 1980b; Macdonald, 1987).

ROOT CUTTINGS AS A SOURCE OF STEM CUTTINGS

Interestingly, many root cuttings will produce shoots relatively quickly, but soon collapse after failing to generate new roots (Creech, 1954; Macdonald, 1987). Typically, new roots do not form on a cutting until after the shoot is formed, and often they develop adventitiously from the base of the new shoot rather than from the original root piece. Because of this phenominom, a modified technique has been developed that involves forcing shoots on root cuttings in the greenhouse, which are then removed and used as softwood cuttings. Because these shoots are physiologically juvenile they tend to root more readily than cuttings taken from other parts of the tree (Creech, 1954; Flemer, 1961; Fordham, 1969).

IN SITU ROOT CUTTING TECHNIQUES

It is important to keep in mind that there are many species that sucker naturally in nature (e.g. *Asimina triboba*), that have not been successully propagated from ex situ root cuttings. The species must be propagated using in situ techniques applied in the late fall. This method involves cutting around the stem(s) of a plant with a sharp spade, then moving out the 15 to 25 cm and cutting a second concentric circle around the first. All servered roots are left in the ground and shoot buds will form

at their distal ends come spring. Such "pre-cut" plants can easily be dug up and potted the following year.

Table 1. Hardy trees that have been successfully propagated from root cuttings, followed by their appropriate literature citations.

Ailanthus altissima: 2, 4, 6, 14, 17, 23, 26, 27
Albizia julibrissin: 1, 2, 4, 8, 10, 14, 15, 17, 23, 26
Amelanchier species: 4, 10, 14, 23, 27
Asimina triloba: 1, 2
Broussonetia papyrifera: 2, 10, 17, 23, 26
Carya species: 2
Catalpa species: 2, 4, 23, 26, 27
Toona sinensis (syn. *Cedrela sinensis*): 1, 2, 4, 23
Cladrastis species: 2, 4, 10, 23
Crataegus species: 1, 22, 27
Cydonia oblonga: 2, 12, 26, 27
Elliottia racemosa: 15
Euonymus species: 1, 12, 24
Tetradium (syn. *Euodia*) species: 2, 4
Ficus carica: 17, 27
Gleditsia triacanthos: 10, 24
Gymnocladus dioica: 4, 10, 22, 23, 26
Halesia species: 2, 26
Kalopanax septemlobus (syn. *K. pictus*): 10, 23
Koelreuteria paniculata: 1, 2, 4, 8, 10, 17, 23, 26
Laurus nobilis: 2, 12
Liquidambar styraciflua: 3
Maackia amurensis: 4, 8, 10
Maclura pomifera: 4, 5, 22, 26
Malus species: 4,10, 14, 17
Morus species: 2, 14, 27
Paulownia tomentosa: 6, 23, 26, 27
Phellodendron amurense: 2, 4, 10, 23
Picrasma quassioides: 1,4, 15, 23
Populus species: 1, 10, 14, 17, 23, 25, 26
Prunus species: 1, 2, 4, 8, 14, 17, 24, 27
Pterocarya species: 1, 10
Pyrus calleryana: 10, 17, 24
Robinia pseudoacacia: 2, 14, 17, 23, 25, 27
Sassafras albidum: 2, 4, 14, 17, 23, 26
Sophora japonica: 17, 27
Staphylea species: 2, 10, 27
Ulmus species: 10, 14, 17, 27
Xanthoceras sorbifolium: 1, 2, 4, 8, 10, 21, 23
Zizyphus jujuba: 2, 17, 27

Table 2. Hardy shrubs and vines that have been successfully propagated from root cuttings, followed by their appropriate literature citations.

Acanthopanax species: 2, 17
Actinidia deliciosa: 10, 17
Aesculus parviflora: 4, 10, 14, 17, 23
Amorpha species: 4, 27
Aralia species: 1, 2, 4, 10, 14, 17, 23, 27
Aristolochia species: 1, 22
Aronia species: 4, 24, 27
Berberis species: 12, 27
Bignonia capreolata: 4, 23, 26, 27
Camellia species: 8, 19
Campsis radicans: 4, 14, 17, 23
Caragana species: 2, 27
Celastrus species: 1, 2, 4, 14, 17, 27
Chaenomeles species: 2, 4, 8, 10, 14, 17, 23, 24, 26, 27
Clematis species: 21, 27
Clerodendrum species: 1, 4, 10, 14, 17, 23, 22
Clethra alnifolia: 1, 8, 10
Comptonia peregrina: 1, 4, 10, 14, 17, 23, 27
Corylus maxima: 12, 17
Cotinus species: 11, 24
Cyrilla racemiflora: 8, 10, 17
Daphne species: 4, 8, 10, 17, 23, 27
Decaisnea fargesii: 23
Elaeagnus species: 2, 26
Fatsia species: 2, 4
Forsythia species: 12, 17, 24, 27
Fothergilla species: 10, 27
Gardenia species: 19, 27
Hippophae rhamnoides: 2, 26, 27
Hydrangea quercifolia: 10, 14
Hypericum calycinum: 17, 12
Ilex species: 8, 24
Illicium floridanum: 10, 11
Indigofera species: 4, 10, 23
Lagerstroemia indica: 4, 8, 10, 23
Leitneria floridana: 1, 4
Lonicera species: 12, 27
Meliosma species: 4, 23
Myrica species:10, 14, 17
Nandina domestica: 26, 27
Orixa japonica: 4, 23
Paliurus species: 2, 26
Pyracantha coccinea: 10, 24
Rhododendron species (azaleas): 8, 16, 27
Rhodotypos scandens: 10, 24
Rhus species: 4, 10, 14, 17, 23, 26, 27
Ribes species: 10, 27
Robinia hispida: 4,10, 14, 17, 23
Rosa species: 2,10, 14, 17, 21, 23, 27
Rubus species: 1, 2, 4, 10, 14, 17, 18, 23, 27
Sambucus species: 2, 23
Sorbaria sorbifolia: 2, 10
Spiraea species: 11, 24
Symphoricapos species: 17, 24
Syringa vulgaris: 2, 8, 10, 14, 17, 23, 24, 27
Vaccinium species: 1, 2
Viburnum species: 24, 27
Wisteria species: 4, 8, 14, 27
Xanthorhiza simplicissima: 14, 27
Zanthoxylum species: 2, 4, 10, 23, 27

Table 3. Hardy, woody genera that are reported by only one authority to be propagated from root cuttings or to produce root suckers in nature. These *unconfirmed* genera are good candidates for future research.

Alnus: 27
Buckleya: 1
Buddleja: 11
Calycanthus: 27
Cercis: 27
Chimonanthus: 11
Coriaria: 11
Cornus: 12
Cotoneaster: 27
Cytisus: 11
Diervilla: 27
Diospyros: 11
Dirca: 27
Genista: 27
Hibiscus: 11
Jasminum: 11
Kerria: 27
Ligustrum: 27
Lindera: 26
Lycium: 11
Mahonia: 24
Menispermum: 27
Mespilus: 11
Neillia: 12
Parthenocissus: 11
Phoebe: 11
Photinia: 27
Potentilla: 11
Ptelea: 27
Punica: 11
Sapindus: 11
Sarcococca: 24
Sorbus: 27
Stephanandra: 11
Tamarix: 27
Trachelospermum: 11
Vitex: 11
Vitis: 11
Weigela: 27
Zelkova: 1

Table 4. Native North American timber trees listed in *Silvics of North America* (5) as reproducing from root sprouts following logging. Those genera marked with an * have not been reported in the horticultural literature as propagated from root cuttings.

*Acer negundo**
Carya cordiformis
C. ovata
Diospyros virginiana
*Fagus grandifolia**
Gleditsia triacanthos
Liquidambar styraciflua
Maclura pomifera
Morus rubra
*Nyssa sylvatica**
Populus balsamifera
P. deltoides
P. grandidentata
P. tremuloides
P. balsamifera ssp. trichocarpa
Prunus pensylvanica
*Quercus michauxii**
*Q. virginiana**
Robinia pseudoacacia
*Salix nigra**
Sassafras albidum
Ulmus thomasii

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Putting Roots on Plants Economically

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My talk today will describe how we looked back into the past and took those things which were applicable to our situation and formulated a method to put roots on plants as cheaply as possible.

The situation I referred to is that Four Season Nursery and Landscape is a first generation nursery. As with most young people, we were full of enthusiasm, lots of energy, and very little money. But where there is a will there is a way.

We started out strictly as a landscape company with a $10,000 loan, no equipment, and no land—a typical start for a nursery business. At that time, 1972 to be exact, there was a scarcity of good quality plant material for our landscape jobs. Well it didn't take us long to decide that maybe we should grow some of that material.

Not having any real propagating experience, I went seeking information. I first called a college roommate who was in the nursery business. He gave me a lot of ideas and encouragement. One of the things he said was keep the acronym "K.I.S.S." in mind. What in the world is K.I.S.S.? Well for those of you that were in the armed forces knows what that means—KEEP IT SIMPLE STUPID! I hope he wasn't referring to my intelligence, but keeping that acronym in mind has saved me a lot of aggravation and money.

The next thing I did was go to a library and scan all the proceedings of the International Plant Propagator meetings. This was an immense source of information.

To make a long story short, we leased some land until 1980, at which time we bought 20 acres. Having just bought the land, we again had very little money. Visions of a high-tech propagation house died very fast. I had to design a propagation system that would put roots on plants, but do it in an inexpensive manner. This lead me to doing strictly summer propagation in a home-built greenhouse.

First I will tell you about which plants propagate well in summer for us. Then I will get into the kind of structure we use.

We root all of our broadleaf evergreens in the summer. Rhododendrons are the first of the broadleaf to be stuck. Timing is very important. We don't want to stick them too early because of the possibility of rot and we don't want to wait too long because the ambient night temperature would not be high enough to maintain rooting. We take the cutting right after the first spring growth has hardened off. In our area, this is approximately the third week of June. We continue to take the cuttings until all taxa are completed. We may get into a situation where the second growth begins. If that occurs, we remove all of the second growth. All of the large-leaved broadleaf evergreens are stuck in a bench under mist set at 15 sec every 30 min but more if the temperature is extremely high and the sun bright.

Azaleas and other small-leaved broadleaf evergreens that root fast are stuck in flats and put outside under the shade of tall trees. We found that if we stuck them along with the slower-rooting large broadleaf cuttings, they became infected with a fungus and rotted.

About 5 years ago, we started doing softwood deciduous shrub cuttings. These cuttings are taken as soon as the new growth hardens off. This is generally in late

May or June. If the cuttings are taken at this time, rooting takes approximately 2 to 3 weeks. The cuttings are stuck in 3-1/2-in. pots, two to a pot, and placed under mist. We do them in these pots because we feel that disturbing the roots in the early stage of development in some of these species is detrimental. There is a large window of time in which you can take most deciduous shrubs. This year, we weren't able to take our deciduous cutting until the first week of September. Most species rooted quite well, although taking much longer to root than if taken in June.

A good reference for doing cuttings is a book by Dirr and Heuser entitled *The Reference Manual of Woody Plant Propagation: From Seed to Tissue Culture.*

We take the cuttings early in the morning to get a highly turgid cutting. All cuttings are dipped in a 5-min fungicide bath and then rinsed very thoroughly to remove any of the pesticide. The cuttings are then prepared for the bench or flat depending on the species.

We felt that it was important that the large broadleaf cuttings be rooted in a deep bench where drainage would be good and roots would have room to develop. It was also important that these plants not be allowed to freeze that first winter. As I mentioned before, cost was also a very important consideration.

Keeping all of these factors in mind, we designed a greenhouse with deep benches and a heating system that would keep the cuttings above freezing that first winter. It was far from perfect but it did the job then and it is still doing it today. We used raised benches so we could have a spot for our just-rooted flats of small-leaved broadleaf evergreens. In essence, we were getting twice the bang for the buck. This 14 ft × 96 ft house can root approximately 30,000 large-leaved broadleaf evergreens per year and overwinter another 30,000 to 40,000 cuttings in flats under the benches.

In the springtime the clear overwintering plastic is taken off the house and replaced with older plastic in which holes have been cut both in the sides and top to promote ventilation. A shade cloth is placed on top of the plastic to provide about 50% shading. After removal of the cuttings, any leftover rooting medium is removed and the house is disinfected with Clorox. A rooting medium of coarse perlite and peat (1 : 1, v/v) is used.

As I noted earlier, our small-leaved broadleaf evergreens are propagated in flats under trees. As a matter of fact, I got this idea from a man who worked for Jim Wells in New Jersey. I went to this gentleman's house looking for some plants and noticed all of these flats of azaleas under some rather large oak trees. I asked him what he was doing and he told me this was his azalea propagation facility. I asked him where his mist system was and he laughed at me and said I go out there 3 to 4 times a day and hit them with a hand held mister on the end of a hose. That was a cheap propagating facility so I tried it at my place with a few modifications and it worked splendidly. It just goes to show that we are still feeling Jim Wells' influence today in the nursery industry, directly and indirectly. Thank you Jim Wells for all you have done.

Just so you don't think we are still in the dark ages, in the last year we have put up two heated greenhouses with state-of-the-art heating and ventilating systems. With a biotherm heating system in the floor we can propagate just about any time of year. Right now we are using the houses to cut a year off the production time needed to produce a marketable azalea.

In September we take the rooted cutting from the flat and put it into a 4-in. pot and place it into a heated house. We try and develop a substantial root system by the end

of November. In December we lower the night time temperature to approximately 40F and let it go to 70F during the day. In the middle of March the nighttime temperature is raised to 55F and top growth starts. In May we will have a plant ready to go into a 3-gal container.

In conclusion, the point I wish to make today is that you don't have to have a high-tech facility to propagate successfully. A lot of money is not necessary to get started. All that is necessary to get started is spirit, determination, and the ability to observe what others have successfully done in the past.

Research Update on Tissue Proliferation

Brian K. Maynard
Department of Plant Sciences, University of Rhode Island, Kingston, Rhode Island 02881

INTRODUCTION

This paper is intended to update the I.P.P.S. membership on a condition, known as tissue proliferation (TP), which affects a number of rhododendron cultivars. It would be impossible to summarize all the information on TP in this brief forum. The reader is directed to have in hand any or all of the articles listed at the end of this paper, in particular that by Linderman (1993).

Tissue proliferation refers to a gall-like growth usually found at the base of the main stem on certain cultivars of*Rhododendron*, primarily, though not exclusively, when they are propagated from tissue culture. These galls range from 5 to 20 mm in diameter, usually are loosely attached, covered by a rough spongy rind, and may or may not produce small, spindly, short-lived shoots. TP typically shows up in the second or third growing season out of propagation (e.g., from a tissue culture microcutting) and galls may wither each winter only to regrow the following year. TP appears not to be contagious, and only rarely are all the plants in a block affected. Plants possessing TP may grow slower or be more disease-prone, but more often are healthy and vigorous.

Tissue proliferation was first observed in the 1980s, and attracted widespread attention in the early 1990s when growers started seeing large numbers of galled plants and some nurseries lost or destroyed a lot of plants. Adverse publicity brought the issue to the fore, and soon groups of scientists met in the northwest (1991), the northeast (1992), and Ohio (1993) to discuss TP.

CAUSES OF TISSUE PROLIFERATION

Is it a Disease? When first encountered, TP was thought to be crown gall, caused by *Agrobacterium tumefaciens*. Thankfully, early work detailed a number of differences between TP and crown gall, including shoot production on TP galls, the woody nature of the TP gall, and the inability to spread TP by co-cultivation, or inoculation of healthy plants with gall pieces or extracts. Numerous studies since have attempted to isolate pathogenic forms of*Agrobacterium* from TP tissues, to no avail. Indeed there is some doubt if rhododendrons ever get crown gall. Attempts to infect rhododendrons with pathogenic *Agrobacterium* from other plants has been unsuccessful, as have attempts to implicate other gall-forming diseases. As time

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passes it seems increasingly unlikely that a pathogenic cause of TP will be found.

Other Causes of Tissue Proliferation. The most common factor linking observed cases of TP is propagation from tissue culture. Though in isolated cases TP has been found on seedlings, cuttings, and even grafted rhododendrons, the majority of TP-affected rhododendrons have come from tissue culture. Unfortunately, TP appeared just as many growers were buying tissue cultured rhododendrons for the first time. Some growers were quick to implicate commercial labs in TP. Yet, this actually may be a blessing in disguise—an opportunity for the industry to focus on how young tissue cultured plants should be handled in the conventional nursery.

The attention TP focused on tissue cultured rhododendrons came at the same time that the issue of tissue culture variability was being addressed in a number of trade magazines and journals. These reports defined several forms of variability turning up in tissue cultured plants, including genetic variation, epigenetic variation, and habituation.

Genetic variation is a stable change in the plant's DNA that can affect the plant's appearance dramatically (e.g. doubling, dwarfing, and sports). Epigenetic variation is a change in the way the plant's DNA is expressed, though the DNA itself is not changed. This switching of genes "on" and "off" occurs naturally in all living things as they develop and mature (e.g. changes in leaf shape and size, flowering, and growth habit). When propagating plants asexually (by cuttage, graftage, or tissue culture), we strive to avoid epigenetic variation as we pursue uniform shapes and colors. Yet it is remarkably easy to alter plants epigenetically . For example, the rejuvenation of plant material, often resulting in increased rooting capacity, is well documented in stooling, cutting propagation, and particularly in tissue culture. It is not surprising that tissue culture promotes epigenetic variation—in tissue culture individual cells are bathed in chemicals, nutrients, and light at much higher levels than normal. Habituation is an odd sort of epigenetic variation in which tissue cultured cells gain the ability to grow without some plant growth regulator they previously required. This usually develops after exposure to the chemical for weeks or months. Habituation to auxin and cytokinin is common in tissue culture. Cytokinin habituation may be responsible for some of the juvenile characteristics of tissue-cultured plants, including greater vigor, more basal branching, and darker leaf color. The effects of habituation can be lost once the plant is taken out of culture—the plant eventually reverts to normal. Variation can occur in all forms of asexual propagation, yet appears to be more common in tissue culture. The habituation of rhododendron cultures to cytokinin was one of the earliest hypotheses proposed for TP, and remains a distinct possibility (see "The Tissue Culture Link" below).

Another early hypothesis for TP arose from the appearance of TP as a swelling at the base of the stem. Ecologists familiar with Mediterranean plants noted that TP resembled lignotubers, swollen areas of the stem with multiple shoot primordia buried in a rind, that occur naturally on certain plant genera including, in the Ericaceae, *Arctostaphylos, Kalmia*, and *Rhododendron*. As with crown gall, differences in the characteristics of lignotubers and TP led some to discount a link between the two. These differences included the relative permanence of lignotubers, which develop slowly and are not so easily removed as the typical TP gall. Furthermore TP galls develop rapidly over a growing season, and even regrow the following season if they slough off over winter. Finally, lignotubers appear to function as a survival structure that sprouts new shoots after the main stem is damaged. TP galls, on the

other hand, form only short-lived shoots that are poorly attached to the stem. Research conducted since 1993 has shown that some cultivars exhibiting TP won't even produce shoots when the main stem is cut back to the gall, i.e. TP galls cannot function as normal lignotubers. This doesn't mean there is no relation of lignotubers and TP. Even lignotubers sometimes fail to sprout after the main stem is damaged or removed—factors such as gall age, root development, and plant health surely play a role in the regenerative capacity of lignotubers, and perhaps TP galls. TP may be a type of highly modified, rapidly growing, dysfunctional lignotuber.

A compelling argument for TP being a form of lignotuber is the observation that particular rhododendron species form lignotubers (including *R. griersonianum, R. maximum, R. occidentale,* and *R. ponticum*), and that some of these are represented in the parentage of TP-prone rhododendron cultivars. Some of the new techniques in molecular taxonomy might be valuable in elucidating common lignotuber-forming parents among TP-affected cultivars.

On another front, researchers are working to characterize the developmental anatomy of TP galls. This daunting task may be critical in reinforcing or undermining the link between lignotubers and TP.

An interesting hypothesis is that TP represents a partial epigenetic switching "on" of a lignotuber gene or complex of genes. For this to happen, TP plants first would have to possess genes for lignotuber formation. Secondly, an epigenetic change would be required, such as rejuvenation through tissue culture. These changes would "predispose" the plant material to form galls in response to some sort of environmental trigger, such as rapid growth or stress. In a predisposed plant, "pushing" growth in the nursery with heavy fertilization and pruning, application of pesticides, or the use of growth retardants, is a likely trigger for TP. The role of stress in natural lignotuber formation has been documented in damaged *Kalmia* seedlings. The differences seen between cultivars might be explained by the degree to which their lignotuber genes are "switched on". Likewise, cultivars lacking the gene would never develop TP. The dramatic differences in the incidence of TP between nurseries, even when growing rhododendrons from the same source, might reflect the need for an environmental trigger to set off the TP phenotype.

The Tissue Culture Link. How tissue culture leads to TP needs to be studied carefully. Using *Rhododendron* 'Montego' as a model system, one researcher has shown that plants with TP go into culture faster, multiply faster, and become cytokinin-habituated earlier than plants without TP. TP-negative plants also can be converted to TP-positive plants by long term exposure to cytokinin, or by selecting for adventitious shoots. In one study a five-fold increase in cytokinin led to a five-fold increase in the incidence of TP. Using leaves as the explant source (i.e. all shoots of adventitious origin) led to a 15% incidence of TP. Several labs have begun the arduous task of determining cytokinin levels in TP-positive and TP-negative tissues. No results are available at this time.

It is interesting to note that the work with 'Montego' shows a range of TP-positive morphological changes in leaf shape and size, and degree of tumor formation. This observation supports the above hypothesis that a number of genes control TP. The use of 'Montego' as a model system has been questioned, in part because this cultivar alone forms galls during tissue culture. This extreme behavior could reflect a greater degree of habituation than is seen with other tissue cultured rhododendron cultivars. On the other hand, this trait makes 'Montego' a useful tool because the TP-

positive phenotype can be detected earlier. The cultivar 'Solidarity' has been suggested as another model system because it too forms galls predictably, though not while in culture. 'Montego' should be kept as a model system, if only because it has been studied so long, while parallel studies are conducted with 'Solidarity'. Similar results in the two systems would lead to even stronger conclusions.

Cultural Triggers. An aspect of TP that remains most troubling is that if identical material is sent to two nurseries one may see a high percentage of TP while the other sees none at all. This fact lends the strongest support to the idea of culture triggering TP in predisposed plants. Yet, numerous attempts to link herbicide, pesticide, or growth regulator use to TP have failed. A consensus among those growing rhododendrons is that TP is more severe on container-grown plants. Apparently it is not difficult to produce quality plants in the field from TP-positive liners. Several commercial firms have grown TP plants in the field for long term evaluation and report they are doing fine. Consider too that container-grown plants usually are grown in lightweight media and receive more fertilizer, water, pesticides, and herbicides than field-grown plants. Container-grown plants also grow faster and may require more frequent pruning or the application of growth inhibitors. Introduce to this production system a plant that is predisposed to TP and you may wind up with TP. TP galls also have been shown to grow larger on faster growing, more vigorous stock.

Conventional wisdom tells us that TP will be less common if growers use less fertilizer, plant growth regulators, and pesticides. Furthermore, container mixes should include more soil, and crops should be grown a little "leaner and meaner".

TISSUE PROLIFERATION VERSUS QUALITY

To those who have been following the TP debate, the most dramatic change since 1993 has been a perceived decline in concern about the quality of TP plants. Perhaps the early consensus that TP is not a disease cooled things down. Perhaps commercial tissue culture firms are rouging more suspect plants. Apparently, some firms have stopped marketing the more TP-prone cultivars. In addition, though many growers still buy tissue cultured plants, a few have returned to cutting-propagated liners, at least when buying rhododendrons. Certainly, at the onset of TP more growers were unwilling to accept galled plants, and some experienced more severe problems, including increased disease and mortality, and slower growth. Also, the way rhododendrons are tissue cultured or grown may be changing in ways that will reduce the incidence of TP. And last but not least, more people now believe that TP does not reduce plant vigor or survival—the problem is only cosmetic. TP-positive plants in the landscape often grow normally, or nearly so, and some even lose TP with age (is this epigenetic reversal?). One study lined out TP-positive and TP-negative plants and found no increase in *Phytophthora* or blackvine weevil. Another saw only a slight increase in mortality, and actually documented a decline from 100% to 45% of the plants affected with TP over a 3-year period. Lower soil fertility in the field and landscape might be reducing the incidence of TP. Certainly, these plants should be tracked. Do they survive? Do they grow well? Do they form lignotubers as they age and mature? If they come from a lignotuber-competent lineage we might expect that they would. It's interesting that syndromes similar to TP have been observed on *Kalmia, Pieris*, and *Vaccinium* for years without serious consequences.

By and large the excitement over TP seems to have waned. Tissue cultured rhododendrons are still in demand, even though some growers are staying away. Only the continued perseverance of a few researchers, propagators, and growers will solve this mystery and, if possible, eradicate tissue proliferation from the nursery.

REDUCING THE INCIDENCE OF TISSUE PROLIFERATION

Based on scientific reports, and a consensus among growers, there are a number of steps that can be followed to avoid TP in your nursery.

- Keep a lookout for TP. If you find it, don't throw the plants away. Notify your source of the problem and work with them and your Cooperative Extension Service to determine why it appeared in your nursery. Screen plants for pathogens, experiment with soil fertility and container mixes, and evaluate performance in the landscape.
- Be prepared to educate your plant inspector if your crop is tagged for crown gall. Keep copies of the articles listed at the end of this paper. Most of them detail the differences between TP and crown gall.
- Experiment with your cultural methods to see if you can grow an acceptable crop using heavier soil mixes, less fertilizer, and fewer chemicals. Avoid "pushing" tissue-cultured rhododendrons.
- Do not take cuttings off production blocks. TP-positive plants yield TP-positive cuttings. Stick to TP-negative stock blocks or buy liners from a commercial source.
- Commercial labs should continue to use as little cytokinin as possible, avoid subculturing from basal- or callus-derived shoots and small-leaved or otherwise aberrant growth. Initiate cultures from shoot tips or axillary buds only. Restart cultures periodically, and store maintenance cultures in the refrigerator to slow growth. Grow plants to as large a size as possible before selling them—eg. sell liners rather than microcuttings—and rouge off-type plants. Learn how to recognize and test for habituation, and discard habituated material. Avoid tissue culturing TP-prone cultivars—leave those for cutting propagation. And finally, maintain mature specimens for display, reference, and as a source of explants.

TISSUE PROLIFERATION AND RELATED LITERATURE

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Shrub Rose Breeding and Evaluation at the Minnesota Landscape Arboretum

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INTRODUCTION

At the Minnesota Landscape Arboretum (MLA), where minimum winter temperatures of -25 to -30F are typical, the number of repeat-flowering shrub roses hardy enough to survive a winter without protection is limited. Those that show slight to moderate levels of cane injury after a Minnesota winter are typically from one of three groups: hybrid rugosas, and Explorer and Parkland roses from Agriculture Canada. The number of disease-tolerant, hardy repeat-flowering roses is smaller yet.

The Woody Ornamental Research Program at the MLA has taken a two-pronged approach to increasing the number of hardy, disease-tolerant shrub roses for gardeners in the northern tier of the U.S. Existing cultivars that have not yet been trialed in Minnesota are being planted and evaluated to identify those that will perform well. A hybridization program to develop new cultivars is also under way.

EVALUATION

Floral traits, rebloom, plant size and habit, disease incidence, insect incidence, and winter hardiness are monitored during evaluation studies. Roses are evaluated every 10 to 14 days over several growing seasons.

Floral Traits. Floral traits monitored are the color, form, diameter, and fragrance of mature, fully open blooms. Inflorescence size, or the number of blooms in a single cluster, is also measured.

To evaluate rebloom, the growing season is divided into three periods: June, July, and August/September periods. Bloom during each of these periods is recorded as slight, moderate, or heavy.

Plant Size and Habit. At the end of the growing season, each plant's height and width are measured and a plant form (dense, open, suckering, spreading, arching, rugosa, climbing, and groundcover) is assigned.

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Disease Incidence. Roses being evaluated are not protected with fungicides, which allows differences in disease incidence among cultivars to be observed. The incidence of blackspot, powdery mildew, leaf spots, and rust are recorded as none, slight, moderate, or heavy for each cultivar. An estimate of defoliation is also recorded.

Insect Incidence. The occurrence of aphids, mites, rose stem borer (*Agrilus aurichalceus*), and the mossy rose gall (caused by *Diplolepis spinosa*) are monitored.

Winter Hardiness. Winter hardiness evaluations are done by observing cane injury in early spring as vegetative buds are swelling. There are a range of cane injury patterns seen. The descriptors we use are:

None: No injury is seen. Canes are hardy to the tip.

Tip: Cane tips are injured, resulting in less than 10% of the crown being injured.

Snow: Canes die back to the snowline.

<1/2: Injury results in dieback of 50% or less of the plant crown. Dieback among individual canes within any one plant varies from none to complete kill to the ground.

>1/2: Injury results in dieback of more than 50% of the crown. Dieback among individual canes within any one plant varies from none to complete kill to the ground.

Base: Every cane is killed to the ground. In spring, new canes grow from the plant's crown.

An ultralow freezer has been used during lab studies to quantify mid-winter hardiness levels of some cultivars and species. This is done by removing cane segments from the freezer at every 3 to 5F drop in temperature, incubating the material, and visually inspecting it for brown discoloration in the xylem or cambium. The lowest temperature at which half of the stem sections of a cultivar are uninjured is interpreted as the mid-winter hardiness level.

Shrub rose hardiness was also the focus of Laura Minsk's research while she was working on her master's degree at the University of Minnesota several years ago. The ultralow freezer technique was used to periodically measure the hardiness of seven shrub cultivars from September through April. This gave a profile of hardiness for each cultivar that could be compared to the typical minimum winter temperatures over the same time period. This work along with the correlations that we see between temperature patterns and winter injury patterns indicate that most cane injury in shrub roses occurs during late fall and early winter during the acclimation phase.

The rose cultivars evaluated initially were those in the shrub rose garden at the MLA. The 196 plants evaluated were a combination of old garden roses, shrub roses, and species roses. Evaluation data was taken between 1988 and 1992. This information is being published by the Minnesota Agricultural Experiment Station and will be titled *Roses for the North*. The publication can be ordered as MR-6594 from the Minnesota Extension Service Distribution Office, 20 Coffey Hall, St. Paul, MN, 55108. The publication's cost is $11.95.

The majority of roses in the second evaluation study are the shrub roses developed at Iowa State University by Dr. Griffith Buck. His best known rose is *Rosa* 'Bucbi' Carefree Beauty™. Dr. Buck's goal was to develop repeat-flowering shrub roses with enough cane hardiness to survive winters with minimum temperatures of -20F.

Seventy-two of his 87 cultivars have been located, and most of these have been reidentified, propagated, and planted. One year of evaluation has been completed. Dr. Buck's roses are very floriferous and after one mild winter, most appear to be crown hardy in Minnesota. Disease tolerance is variable but there are some with very high levels of blackspot resistance.

HYBRIDIZATION

The first shrub rose evaluation study provided a wealth of information to base a hybridization program on. Parental material spans many of the rose classes. Species roses, cultivars not too far removed from their species ancestors, and a few repeat-flowering cultivars are being used to incorporate hardiness. There are several roses native to eastern North America, such as *R. virginiana, R. carolina, and R. palustris*, that are hardy tetraploids but have not been used in breeding programs prior to this. Hardy, non-native species such as *R. pimpinellifolia* and *R. amblyotis* are being used. Rugosa roses are extremely hardy but sterility barriers occur very quickly when they are crossed with roses from other classes. A better way to take advantage of the hardiness of *R. rugosa* is through *R. kordesii,* as was done in the development of many of the Explorer roses from Agriculture Canada.

Disease resistance is a difficult trait to work on in a rose breeding program. There is little known about the genetic control of disease resistance in roses, and information on disease tolerance or resistance is typically based on how a plant performs in the field. Factors such as microclimate, culture, cultivar/pathogen race relationships, and inoculum level create variation in the disease levels seen in the field. When these variables aren't controlled, the level of disease incidence for any one cultivar varies over time and location. Ideally, there should be controlled screening techniques in place to eliminate this variation. But, until controlled screening techniques are developed, field tolerance is what will be used.

A range of diseases infect roses. The most common and serious, from an aesthetic standpoint, are foliar diseases. Blackspot, with its ability to defoliate, is of primary concern in the MLA's breeding program. Many species roses show high levels of field tolerance to blackspot. A number of old garden roses, especially among the albas, damask, and gallicas, are blackspot tolerant. There are also cultivars among the Explorer series and among Dr. Buck's roses that are blackspot tolerant.

Incorporating cold hardiness and disease resistance into repeat-blooming roses takes time. The breeding program at the MLA is the traditional one of emasculation, hybridization, growing and planting seedlings, evaluation, roguing of the bad plants, and selection, propagation, and reintroduction into the breeding program of the good seedlings. This process takes several years. Remontancy is a recessive trait, which means that a hybrid of a repeat-flowering rose and a one-time bloomer will most likely be a one-time bloomer and will not begin blooming until 3 years of age. Repeat-flowering plants will appear in the second generation. Disease resistance and cold hardiness appear to be quantitative traits, which makes breeding and selecting for these traits more complex and time consuming. Trying to combine all of these traits into an attractive plant takes multiple generations. At 5 years of age, the MLA breeding program is still in its infancy. Cultivar/species hybrids that are hardy, disease resistant, and carry a repeat-flowering gene have been produced and have been used in crosses with repeat-flowering cultivars over the past 2 years. Seedlings resulting from these crosses are being grown on for planting and evaluation.

The Effect of Growth Regulators on Growth and Overwinter Survival of Rooted Cuttings

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INTRODUCTION

Successful cutting propagation of many woody plant taxa is limited by poor overwinter survival in the first propagation year (Smalley and Dirr, 1986). Plants which fail to survive the winter after rooting are often characterized as having had budbreak inhibition or bud dormancy following rooting. Application of the auxin rooting hormone, indole-3-butyric acid (IBA), to the cutting base has been shown to inhibit budbreak (Hartmann et al., 1990). Sun and Bassuk found that although IBA increased percent rooting and root number in*Malus* MM 106, it delayed and reduced axillary budbreak in rooted cuttings.

It has been hypothesized that growth inhibition in rooted cuttings results in insufficient carbohydrate reserves for sustaining the cuttings during winter and early spring, and for inducing insufficient cold hardiness (Smalley and Dirr, 1986). Smalley and Dirr found that cuttings of *Acer rubrum* 'October Glory' which broke bud had significantly more carbohydrates than cuttings which did not grow. Nevertheless, many cuttings that did not grow overwintered successfully. They concluded sufficient carbohydrate reserves may be more important than achieving budbreak to insure overwinter survival (Smalley et al., 1987).

As there is ample evidence that hormones are involved in the onset and breaking of dormancy (Hartmann et al., 1990), studies have also addressed the effectiveness of exogenously applied hormones in overcoming budbreak inhibition and poor overwinter survival. Loach and Whalley successfully promoted budbreak in *Berberis thunbergii*with application of gibberellic acid, GA_3, where extended photoperiod and supplemental CO_2 failed to promote budbreak; however, the breaks were irregular and "etiolated" in appearance (Loach and Whalley, 1975). Maynard and Bassuk found that $GA_{4/7}$ was more effective than GA_3 in stimulating shoot growth of *Stewartia pseudocamellia* rooted cuttings (Bassuk, 1992).

Thidiazuron (N-phenyl-N' -1,2,3-thidiazol-5-ylurea) (TDZ), a plant bioregulator with cytokinin-like properties, has also been used to break bud dormancy and release lateral buds in apple (19).

The objective of this research was to assess growth and overwinter survival of rooted cuttings after application of several post-rooting treatments designed to achieve as much growth as possible in the propagation year. *Acer rubrum* 'October Glory', *A. rubrum* 'Red Sunset', *Hamamelis vernalis, H. virginiana,* and *Stewartia pseudocamellia* were selected for the study because of their difficulty in overwintering after rooting (Dirr and Heuser, 1987; Smalley and Dirr, 1986).

MATERIALS AND METHODS

Plant Materials. Softwood shoots were taken from mature stock plants of *A. rubrum* 'October Glory', *A. rubrum* 'Red Sunset', *S. pseudocamellia*, *H. vernalis,*

and *H. virginiana* over the period of May 27 to June 8, 1992 by the method described by Maynard and Bassuk (1985, 1987) except that IBA was not applied to the Velcro bands. All cuttings were treated with a 10-sec quick dip of 5000 ppm IBA 50% aqueous ethanol and rooted under mist. After 7 to 9 weeks, cuttings were transplanted to 4-in. (10.2 cm.) pots in a soil: peat: perlite medium (1 : 2 : 1 by volume) and then placed in a greenhouse with 21/15C (70/60F) day/night temperatures and 16-h photoperiods. Plants were fertilized weekly with Peter's 20N-10P-20K at a rate of 200 ppm up to October 25, 1992.

Post-Rooting Treatments. Three weeks after potting up, all plants were assessed for bud break and then randomly assigned to one of the five following plant growth regulator (PGR) treatments:

- STS: Foliar spray application of 1% silver thiosulfate (STS) prepared according to the method of Reid et al. (Perkins, 1994)
- STS GA: Foliar spray application of STS treatment followed 10 days later by a foliar spray application of gibberellin, $GA_{4/7}$ 250 ppm (ProVide, Abbott Laboratories, North Chicago, Illinois) .
- TDZ: Foliar spray application of thidiazuron 50 ppm (Nor-Am Chemicals)
- TDZ GA: Foliar spray application of thidiazuron followed 10 days later by a foliar spray application of $GA_{4/7}$ at 250 ppm.
- H_2O: Foliar spray of water

Each foliar spray contained 1 ml liter^{-1} Tween 20 surfactant. All plants were sprayed until run-off occurred.

Ten weeks after the rooted cuttings were potted up, long day treatments ceased and all plants were exposed to short days and fluctuating, cool temperatures 10/4.4C (50/40F) day/night to insure that they hardened-off and dormancy was established.

Carbohydrate Analysis. Once dormant, (characterized by fall color and leaf drop) rooted cuttings were measured for total new shoot growth. Next, a sample of three plants was taken in each of three growth categories (no budbreak; budbreak yet no growth, budbreak and growth) for every growth accelerator treatment group. Samples were analyzed for total non structural carbohydrates according to da Silveira, Teles and Stull (1978) of the roots and shoots expressed as a percent of the dry weight (% TNC).

Winter Storage. On December 21, 1992, rooted cuttings from all treatments were divided into two winter storage locations. Half the plants were located in a constant 3C (37.4F) cooler. Half the plants were stored in outdoor glass covered cold frames with fluctuating and freezing temperatures. On March 21, 1993, plants were removed from cold storage to the greenhouse and assessed for survival.

Statistical Analysis. The experiment was a completely randomized complete factorial design. Data was analyzed by logistic regression and general linear model.

RESULTS AND DISCUSSION

Plant Growth. Growth in all species except 'October Glory' red maple was significantly increased when GA was applied as a follow-up treatment. STS and TDZ showed little effect on their own, with TDZ occasionally causing mild growth inhibition (Table 1).

Table 1. Comparison of amount of shoot growth (cm) as affected by plant growth regulator treatment.

Species	Growth regulator				
	Water	STS	STS-GA[1]	TDZ	TDZ-GA
Stewartia pseudocamellia	3.5	6.0	11.0[2]	4.5	9.0[2]
Acer rubrum 'Red Sunset'	8.5	9.0	15.0	5.0	8.5
Hamamelis vernalis	14.5	15.0	17.0	11.0	15.0
H. virginiana	7.0	11.0	13.0	5.0	7.5

[1] STS-GA = STS treatment followed by $GA_{4/7}$ 10 days later; TDZ-GA = TDZ treatment followed by $GA_{4/7}$ 10 days later

[z] All treatments with GA follow-up (STS-GA and TDZ-GA) vs. no GA follow-up were significant at .02 or better level.

Carbohydrates. There were no significant differences in the total nonstructural carbohydrates, expressed as percent dry weight, in the root tissue of *S. pseudocamellia* for cuttings which grew vs. cuttings which did not grow (Figure 1). *Hamamelis vernalis* and *H. virginiana* both showed significantly higher percent total nonstructural carbohydrates in the root tissue of cuttings which grew than the root tissue of cuttings which did not grow, and *A. rubrum* 'October Glory' cuttings demonstrated a similar trend. *Acer rubrum* 'Red Sunset' cuttings were not analyzed for % TNC. The % TNC in the root tissue of *S. pseudocamellia* cuttings that did not grow were greater than the % TNC of the root tissue of the other species by at least 93%. Analysis of % TNC in the whole plant tissue (roots and shoots combined) was similar to the analysis of % TNC in root tissue alone (Perkins, 1994).

Survival Results. Winter storage in a 3C (37.4F) cooler resulted in significantly higher percentage of survival for every species than winter storage in the cold frame with fluctuating and freezing temperatures (Fig. 2). 'October Glory' was least affected by the fluctuating conditions; percent overwinter survival was only 7% lower than the cooler stored cuttings. *Hamamelis virginiana* and *S. pseudocamellia* were most harmed by cold frame conditions. One *Stewartia* cutting survived out of 395, and only 14% of the *H. virginiana* cuttings survived in the cold frame. *Hamamelis virginiana* was the only species to exhibit poor survival in the cooler (58%).

***Acer rubrum* 'October Glory'.** Overall survival was high for *A. rubrum* 'October Glory' cuttings. Increased shoot growth significantly increased the survival rate of *A. rubrum* 'October Glory' (Tables 2, 3) and was more critical to survival for cuttings exposed to fluctuating temperatures.

***Acer rubrum* 'Red Sunset'**. Increased shoot growth was not critical for survival of *A. rubrum* 'Red Sunset' cuttings in either winter storage location (Tables 2, 3). Survival rates were high for cuttings stored in the 3C cooler, but the cuttings were not sufficiently cold hardy to survive well in the fluctuating and freezing cold frame environment.

Hamamelis vernalis. Similarly, increased shoot growth significantly increased survival rates of *H. vernalis* for cuttings in both winter storage locations. Without shoot growth, survival rates were very poor, 38% in the 3C cooler and 14% in fluctuating temperatures (Tables 2, 3). Overall, *H. vernalis* cuttings exhibited high survival rates in the 3C cooler (Table 2).

Hamamelis virginiana. Shoot growth significantly increased survival of *H. virginiana* cuttings in both winter storage locations (Tables 2, 3). However, there was a great disparity between cutting survival rates in the 3C cooler and cutting survival rates in fluctuating temperatures. Cuttings in the 3C cooler which grew between 10 and 20 cm had 96% survival. Those that didn't grow had only 37% survival. Shoot growth for cuttings exposed to fluctuating temperatures only increased survival rates from 5% to 21%.

Stewartia pseudocamellia. Shoot growth was not critical for survival of *S. pseudocamellia* cuttings (Table 2, 3)—97% survived in the cooler regardless of growth, and 1% survived in the cold frame regardless of growth.

Table 2. Percent overwinter survival as affected by amount of shoot growth in 3C storage.

Species	Amount of shoot growth			
	0 cm (%)	1 - 10 cm (%)	11 - 20 cm (%)	21 - 30 cm (%)
Acer rubrum 'October Glory'	84 a (87)†	98 b (285)	-- (0)	-- (0)
A. rubrum 'Red Sunset'	86 NS (28)	98 NS (40)	100 NS (23)	-- (0)
Hamamelis vernalis	38 a (29)	83 b (120)	93 b (294)	96 b (113)
H. virginiana	37 a (139)	59 b (147)	96 c (69)	-- (0)
Stewartia pseudocamellia	93 NS (440)	100 NS (50)	-- (0)	-- (0)

Within species, numbers in rows followed by different letters are significantly different at the .05 level . Differences tested by logistic regression.

† Numbers in parentheses represent the sample size (n).

Was Growth Important for Survival? *Acer rubrum* 'October Glory', *H. vernalis* and *H. virginiana* cuttings all had higher overwinter survival rates for cuttings

which grew *Acer rubrum* 'Red Sunset' showed a similar trend, but *S. pseudocamellia* did not exhibit increased survival with growth. Several studies support the finding that growth improves overwinter survival. In a study by Loach and Whalley, extended photoperiod and CO_2 enrichment promoted growth and increased overwinter survival in *Betula pendula* and *Berberis thunbergii* (Loach and Whalley, 1975). Drew et al. used extended photoperiod to induce budbreak and growth of *Quercus* cuttings and found that 100% of cuttings which grew survived (Drew et al., 1993). Goodman and Stimart also found that growth improved survival when *A. palmatum* and *Cornus florida* cuttings were fertilized with nitrogen, but growth was not necessary for survival when nitrogen fertilizer was withheld (Goodman and Stimart, 1987). All species in this study received 20N-10P-20K fertilizer, at a rate of 200 ppm, once a week for 4 weeks. Nitrogen fertilization did not limit the survival of cuttings that did not break bud because, depending on winter storage environment, or response to plant growth regulators, fertilized cuttings which did not break bud survived the winter in high percentages for all species except *H. virginiana*.

Table 3. Percent overwinter survival as affected by amount of shoot growth in fluctuating cold frame.

	Amount of Shoot Growth			
Species	0 cm %	1 - 10 cm %	11 - 20 cm %	21 - 30 cm %
Acer rubrum 'October Glory'	71 a (155)†	94 b (486)	-- (0)	-- (0)
A. rubrum 'Red Sunset'	52 NS (23)	55 NS (71)	-- (0)	-- (0)
Hamamelis vernalis	14 a (37)	67 b (433)	-- (0)	-- (0)
H. virginiana	5 a (108)	21 b (169)	-- (0)	-- (0)
Stewartia pseudocamellia	1 NS (343)	0 NS (50)	-- (0)	-- (0)

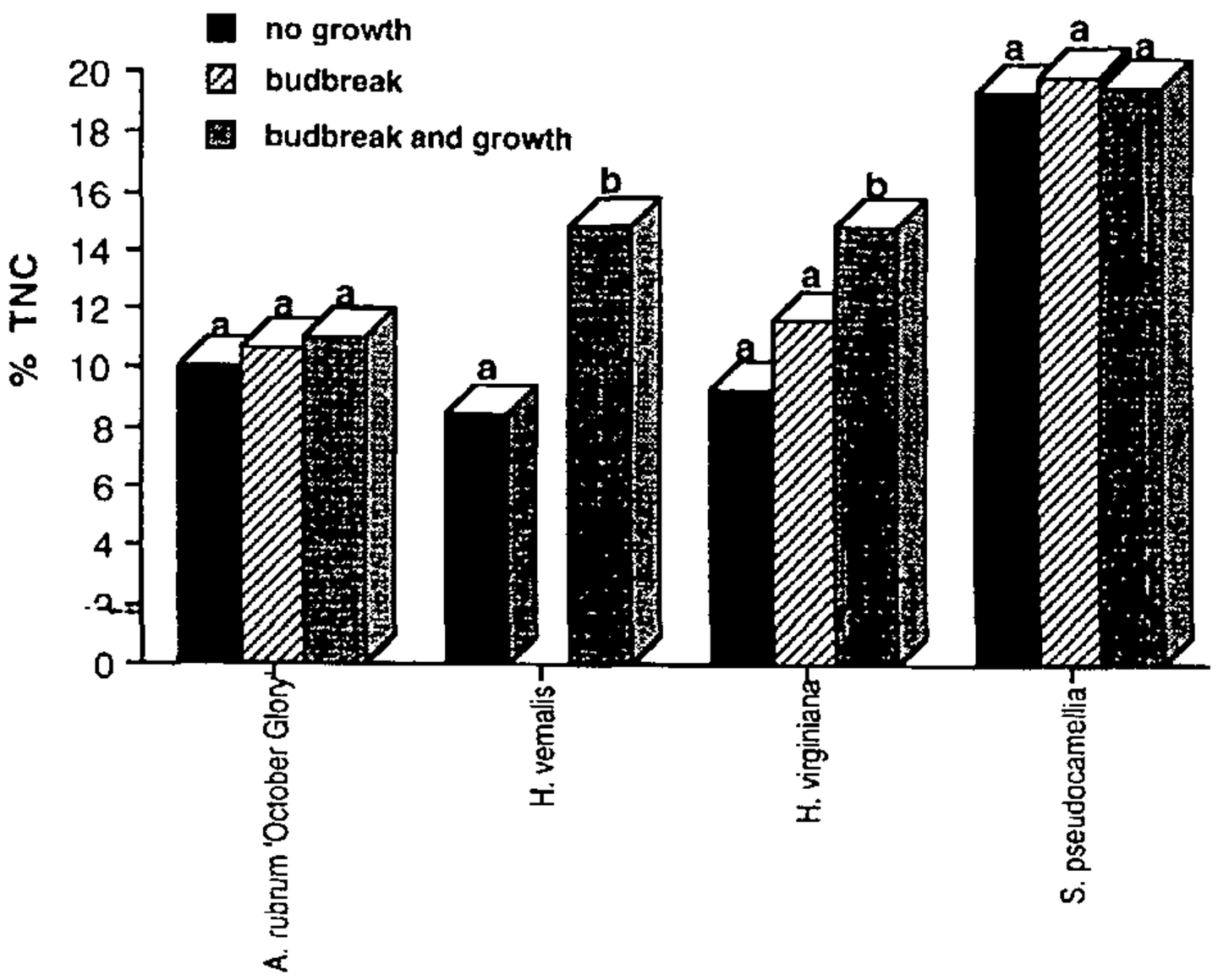
Within species, numbers in rows followed by different letters are significantly different at the .05 level. Differences tested by logistic regression.

† Numbers in parentheses represent the sample size (n).

Did Growth Result in Increased Carbohydrate Reserves? Both *H. vernalis* and *H. virginiana* support the hypothesis that increased growth after rooting results in increased carbohydrate reserves, and increased carbohydrate reserves are necessary for insuring winter survival. *Acer rubrum* 'October Glory' exhibited a similar trend, although increases in carbohydrates were not statistically significant. Carbohydrates were not anlayzed for *A. rubrum* 'Red Sunset' cuttings. *Stewartia pseudocamellia* cuttings did not have higher carbohydrates in cuttings which grew. For *S. pseudocamellia* cuttings which did not grow, carbohydrate reserves comprised at least 93% more of the dry weight of a cutting than any other species tested. This

indicated that carbohydrate reserves, after rooting, were not critically low for *S. pseudocamellia* cuttings.

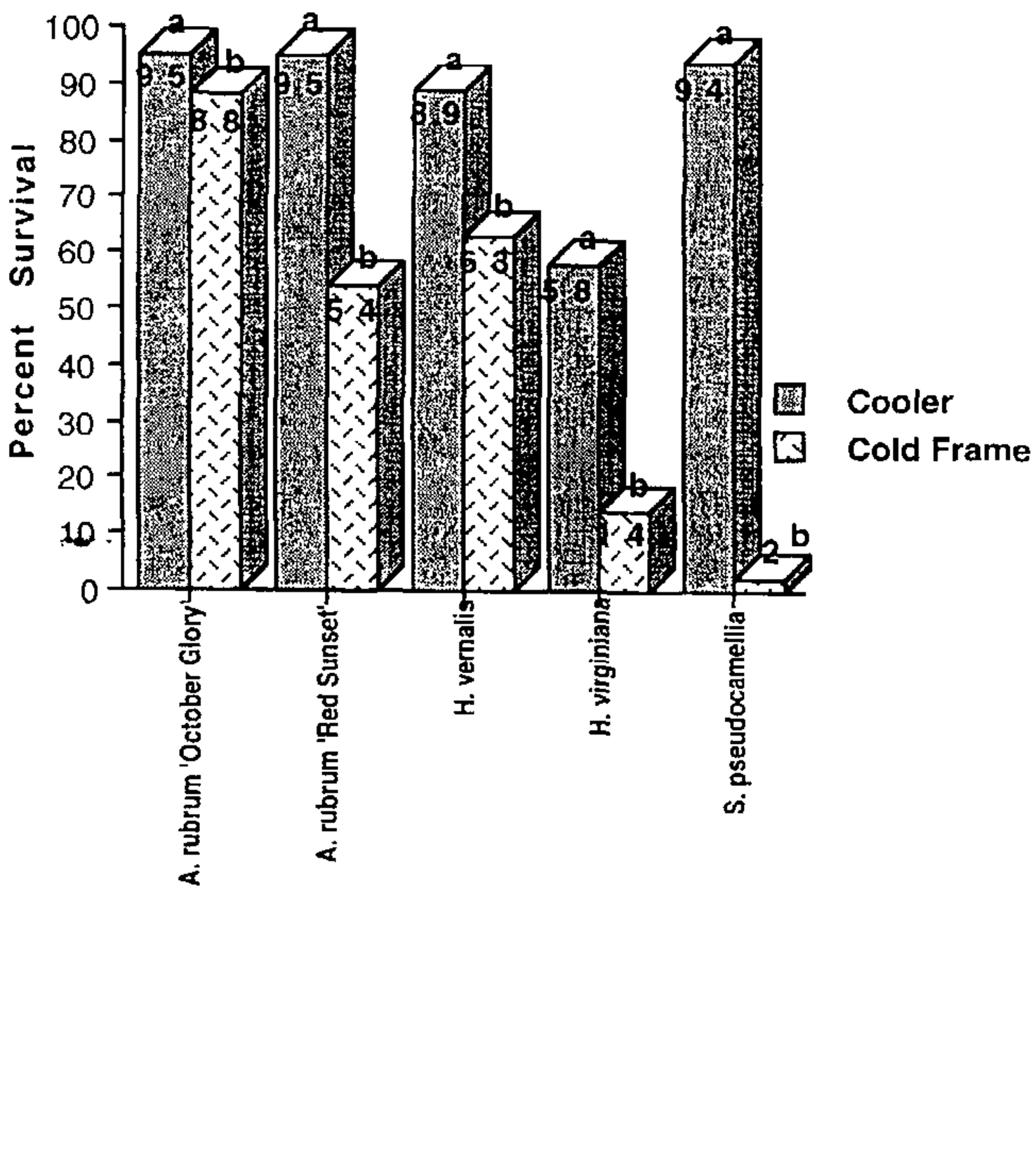
Smalley et al. reported similar results with *A. rubrum* 'October Glory' (Smalley et al., 1987). In their study, *A. rubrum* 'October Glory' cuttings which did not break bud had high survival rates, but had carbohydrate levels similar to *A. rubrum* 'October Glory' cuttings that did break bud. This result indicated that carbohydrates were not necessarily low in cuttings that did not break bud.



	Sample Size Analyzed for Each Species			
Amt. of Growth	A. rubrum 'October Glory' (n)	H. vernalis (n)	H. virginiana (n)	S. pseudocamellia (n)
No growth	9	1	14	8
Budbreak (< 1 cm growth)	9	0	7	14
Budbreak and Growth (> 1 cm growth)	15	15	15	5

Figure 1. Changes in % TNC with growth. Growth effect tested by general linear model, P=.05. Within species, columns with same letters are not different at the P=.05 level. See tables for sample sizes and mean separation by orthogonal contrasts.

Did Plant Growth Regulators Increase Growth? Post rooting plant growth regulators did not increase the growth of *A. rubrum* 'October Glory' cuttings, STS and TDZ did not increase growth of *H. vernalis*, but application of $GA_{4/7}$ to the leaves and buds after rooting and after application of STS or TDZ increased growth, as it did for *A. rubrum* 'Red Sunset', *H. virginiana*, and *S. pseudocamellia*. This result indicated



SPECIES	Winter Storage Location: 3° C. COOLER (*n*)	COLD FRAME (*n*)
A. rubrum 'October Glory'	388	283
A. rubrum 'Red Sunset'	96	94
H. vernalis	556	470
H. virginiana	367	277
S. pseudocamellia	490	395

Figure 2. Comparison of overwinter survival in two winter storage facilities. Winter storage location effect tested by Logistic Regression, P=.05. Within species, columns with different letters are signficantly different at the P=.05 level. See table for sample sizes.

that $GA_{4/7}$ alone should be investigated as growth enhancing treatment. McConnell and Herman reported increased growth of softwood cuttings with GA_3 treatments, but not overwinter survival (McConnell and Herman, 1980), and Loach and Whalley reported increased, but irregular and weak, growth with GA_3 treatments on *Betula pendula* and *Berberis thunbergii* cuttings (Loach and Whalley, 1975). In this study, growth induced by $GA_{4/7}$ was from the apical bud and neither irregular nor weak.

Despite the fact that growth was not necessary for insuring survival of *S. pseudocamellia*, added growth in the first year may be desired simply because it would give *S. pseudocamellia* cuttings, generally characterized by one flush of growth in a season, a head start on development.

Although TDZ did not effectively increase growth for any species in this study, a general statement about the response of cuttings to post rooting foliar spray application of TDZ should be noted. TDZ was selected as a plant growth regulator because Wang et al. reported that TDZ effectively increased lateral budbreak and bud development in *Malus domestica* (Wang et al., 1986). In this study, TDZ did break bud dormancy, but did not increase the amount of growth for any species. Overall, TDZ treated cuttings had weaker extension shoots, and did not have a central leader.

Did Cold Hardiness Affect Survival? In the case of *A. rubrum* 'October Glory', *A. rubrum* 'Red Sunset', and *S. pseudocamellia*, cold hardiness was the most critical factor for survival. All three plants had extremely high survival (95%, 95%, and 94%, respectively) when stored in the 3C cooler regardless of growth, and significantly lower survival (88%, 54%, and 2%, respectively) in the cold frame regardless of growth. Until it is determined exactly what winter conditions are intolerable for rooted cuttings, mild winter storage conditions are essential. Research is needed to determine rooted cutting cold tolerance for all the species.

Lastly, when treatments successfully increased cutting growth, hardening off may require a longer period of time than cuttings with less growth or no growth. In this study, STS GA treatment effectively increased growth of *A. rubrum* 'October Glory', but had very low survival (Perkins, 1994). This poor survival, despite growth, is likely due to insufficient cold acclimation.

CONCLUSIONS

What Conclusions can be Drawn Concerning Growth and Overwinter Survival? Not all plants that exhibit budbreak inhibition and poor overwinter survival fit the hypothesis that rooted cuttings are carbohydrate depleted and must break bud and grow to survive the first winter. Some cuttings are not carbohydrate depleted by rooting and therefore not carbohydrate enhanced by budbreak and growth. These cuttings survive without growth if their cold hardiness capacity is not exceeded.

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Use of Paclobutrazol to Regulate Flower Bud Initiation and Stem Elongation in *Rhododendron catawbiense* 'Boursault'

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INTRODUCTION

For years, researchers have been experimenting with the plant growth regulator paclobutrazol to control stem elongation in rhododendron. This presentation, however, will attempt to demonstrate the feasibility of using paclobutrazol in a large-scale production setting.

Use of the Bonzi® formulation of paclobutrazol, marketed by Uniroyal Chemical Company, was initiated at Prides Corner Farms in 1991 by Dr. Martin Gent, a research scientist at the Connecticut Agricultural Experiment Station in New Haven, Connecticut. Dr. Gent's work at Prides Corner Farms and at his experimental plots in Hamden, Connecticut, prompted us to pursue the use of Bonzi in our production system. *Rhododendron catawbiense* 'Boursault' was selected as a cultivar that would benefit from applications of Bonzi, due to its typical growth habit of growing tall and setting very few flower buds. In a typical year, untreated 'Boursault' grown in a 2-gal container will produce flower buds on only about 5% of the plants, and those plants that do flower will usually have only one flower bud per plant. In addition, the vegetative growth of these plants is very vigorous and generally results in a tall, open plant structure. Why even grow such a cultivar? 'Boursault' roots easily from vegetative cuttings and its vigorous growth produces a large, husky liner. The stems are strong and upright, so the plant does not tend to lean as much as some other cultivars when grown in a container. The lack of flowering, however, has been a serious drawback, since a rhododendron will sell most readily when it is flowering. Therefore, our goal was to develop a system that would allow us to treat 'Boursault' efficiently on a large scale. We needed to produce 2-year-old plants in a 2-gal container that would consistently have at least two to three flower buds per plant and maintain an attractive, compact form.

MATERIALS AND METHODS

When first experimenting with Bonzi on a small scale, a backpack sprayer was used to apply a spray treatment directed at the stems of the rhododendron. Bonzi as a foliar spray penetrates into plant stems and is translocated to the terminal where it has a growth regulatory effect. The amount of solution (and therefore the amount of paclobutrazol), was fairly accurately monitored for each plant. While this was effective and produced excellent results, it was also very time consuming and physically demanding.

Starting in 1994, we utilized a large capacity spray tank, a P.T.O.-driven diaphragm pump, and a 300 ft length of 1/2-in. spray hose terminating with a super-fine 0.5 gpm Fogg-It nozzle. With this system, the spray solution for an entire day is made all at once, so the concentration is consistent all day long, without the variability that can easily occur when making numerous smaller batches. This technique is very efficient in terms of labor cost, and it can be calibrated to give consistent, accurate

applications. The nozzle produces a wide angle spray pattern and good air turbulence which applies the spray to all stems of a plant. Because foliar absorption does not effectively occur, the spray must be directed at the stems of the plant to uniformly wet each shoot. The spray applications were made in middle to late June, after the first flush of growth had hardened off, and before any growth of the second flush. At this time, a 2-gal 'Boursault' is 10 to 12 in. tall and has enough plant surface to hold on to approximately 2 to 3 ounces of solution when sprayed as described.

We have used a solution of 20 ppm of 0.4% Bonzi. This concentration equals 0.619 mg paclobutrazol per ounce of spray solution. A 2-gal plant that receives 2 to 3 ounces of solution will therefore get 1.24 to 1.86 mg of paclobutrazol. This is well below the 100 ppm label recommendation. Ranney, et al. (1994) in a study done with Bonzi on *R.* 'Roseum Elegans' in 1992 at North Carolina State University, noted that foliar sprays were much less effective than drench applications in reducing shoot growth, and had no effect on flower bud initiation. This was based on foliar applications of 50 to 200 ppm. Our results with *R. catawbiense* 'Boursault' in 1993, 1994, and to a lesser extent in 1995 indicate that in New England, a desirable response can be achieved at the 20 ppm foliar application rate.

RESULTS AND DISCUSSION

When comparing untreated control plants to plants treated in June 1994, the effect of the paclobutrazol was very evident. The typical untreated 2-gal 'Boursault' was 18 to 20 in. tall, quite open in growth habit, and had no flower buds (Fig. 1). The height of the plant was due to not only a long second flush of growth, but also a vigorous third flush in late summer. Treated plants, however, displayed both reduced vegetative growth and greatly enhanced flower bud development (Fig. 2). A darker green color of the foliage was also evident, and many plants had multiple

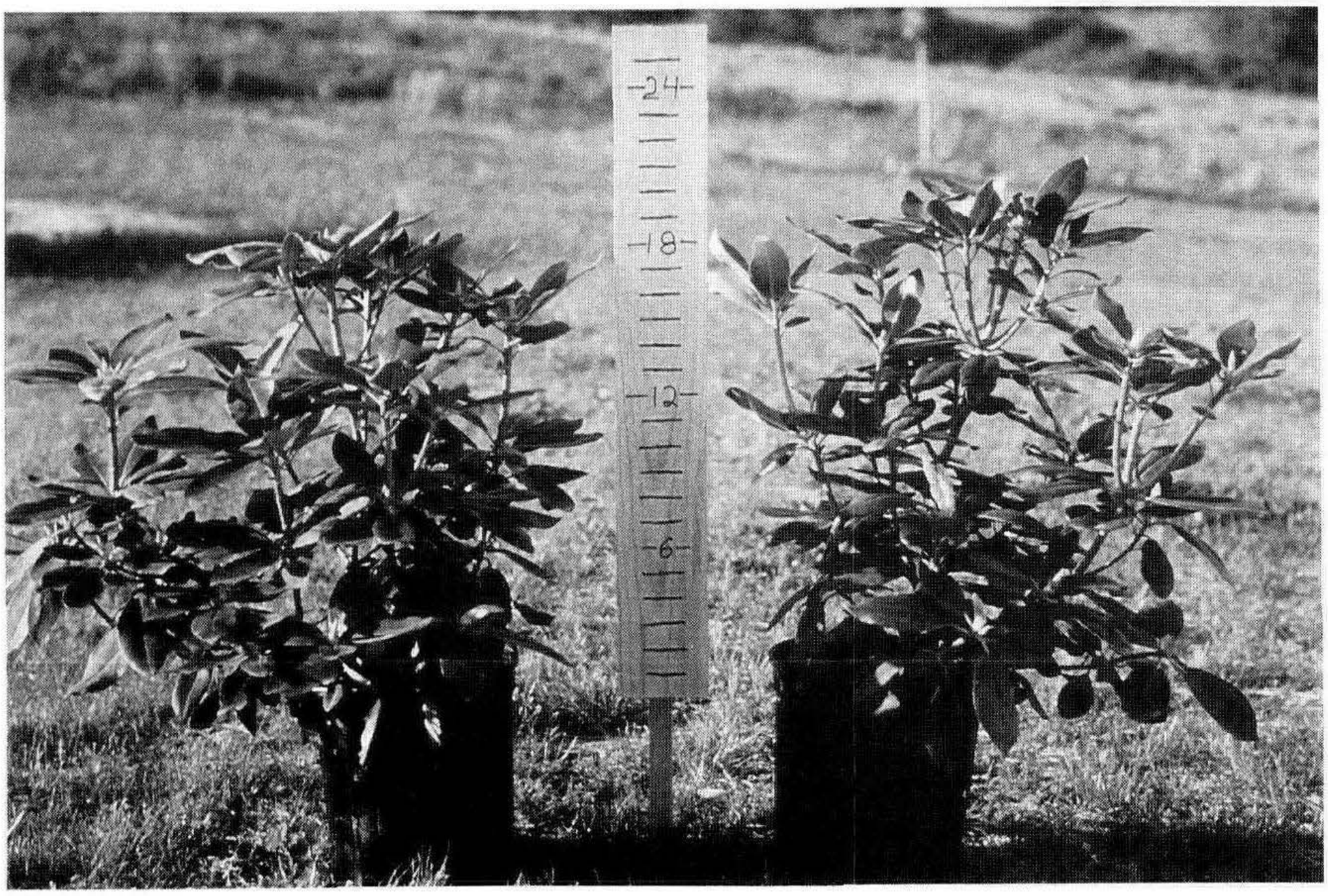

Figure 1. Typical untreated 'Boursault', tall with no flower buds.

flower buds on one shoot. The second flush was reduced from 4 to 5 in. on untreated plants to 1/2 to 1 1/2 in. on treated plants. A flower bud was then set on this second flush, and very little third flush growth occurred. The comparison became even more dramatic when the treated and untreated plants were viewed side by side (Fig. 3).

By early June, the treated plants supplied us with a gorgeous display of lavender flower clusters followed by the typical light green new growth. This first flush is important to note, because one of our concerns was the long-term effect of paclobutrazol on subsequent growth. On our treated plants, the first flush developed normally from dormant buds just below the flower bud, with little reduction in length. In some cases, we found as much as 7 in. of growth from the first flush. It should also be noted that we found no evidence of foliar phytotoxicity or deformity.

The results of our Bonzi applications of June 1995 were less dramatic then the previous year. Many of our 'Boursault' did not show the full desired response. Approximately one-half of the crop had reduced growth for the second flush, and subsequently flower buds were initiated. However, both the percentage of plants flowering and the number of buds per plant were significantly less then 1994. Most of the crop, including many plants which developed flower buds, had a fairly strong third flush as well. This is not desirable, as the foliage of this late growth tends to hide the flowers the following year. This third flush, though present, was at least suppressed and shorter than that found on our untreated plants, all of which had a vigorous third flush in 1995. In summary, about one-half of the crop in 1995 showed a long untreated first flush, a short second flush with a flower bud induced by the Bonzi treatment, and a reduced third flush developing from one to three vegetative buds just below the flower bud (Fig. 4).

The remaining one-half of the plants treated in 1995 displayed even less response to the paclobutrazol. Many had reduced second flush growth but only one or two

Figure 2. 'Boursault' treated the previous year, with numerous flower buds and compact growth.

Figure 3. Comparison of untreated plants on left to treated plants on right.

flower buds per plant. A discouragingly large portion of the crop, probably 30% to 35%, had no flower bud development at all. While these plants did have noticeably reduced second flush growth, as well as shorter stem length in the third flush, they had no flower buds. It could be argued that these plants, even without buds, are more marketable than the taller, less compact untreated plants. While this may be true, the treatments in 1995 were less successful than we had anticipated.

Figure 4. Short second flush with flower bud and reduced third flush.

There are four factors which have been identified as possibly contributing to the incomplete and inconsistent response in 1995. After the application was completed, the amount of paclobutrazol applied and the number of plants treated were used to compute the average dose per plant. It was found to be lower than the 1994 application, with each plant receiving only approximately 1.0 mg paclobutrazol. The date of application in 1995 was only 5 days later than the date of application in 1994, however, this crop may have been physiologically more mature and closer to the onset of the second flush. Another factor could have been the high temperature reached by the spray solution as it flowed slowly through

the 1/2-inch spray hose that lay on black plastic for up to 300 ft. The sun heated the solution in the hose to a very warm temperature by the time it got to the nozzle. Without knowing what temperature the solution had reached, a representative of Uniroyal Chemical Company could not say whether or not a breakdown of the paclobutrazol had occurred, or to what extent. Lastly, the very warm temperatures we experienced in southern New England in August 1995 may have been the largest factor. We had 12% more growing degree days in August 1995 than we did in August 1994. According to the Bonzi label, temperature can be the overriding factor in determining the amount of Bonzi needed to produce desired results, with higher rates needed during warmer months. The warmer than normal temperatures may have been enough to cause this crop to outgrow the effect of the paclobutrazol application.

In order to further study the response of 'Boursault' to applications of Bonzi, a group of plants from the 1994 crop were potted into 3-gal containers and held an extra year. Plants that had not received any growth regulator in either 1994 or 1995 were quite tall, measuring 24 to 26 in. They had a spreading, open growth habit and no flower buds. Plants treated in 1994 but not 1995 had flower clusters in the spring of 1995 and compact growth. This compact stature was then hidden by longer shoots of unregulated growth in 1995. A plant that was induced to form three flower buds in 1994 now has only two flower buds, despite the fact that the plant is 1 year older. Upon close inspection, it was often noted on plants treated in 1994 that the shoots of the first flush of growth in 1995 were shorter than shoots on untreated plants. This latent effect of the Bonzi treatment was only evident on the first flush. A normal second and third flush occurred without any reduction of growth.

Another category was plants treated in 1995 only. These were tall plants, averaging 20 to 22 in. in May 1995 due to the vigorous growth the previous year. Treating these plants with Bonzi this year produced numerous flower buds and totally suppressed the third flush.

Finally, plants treated in both 1994 and 1995 continued to display tight, compact growth and many flower buds. The dark green foliage and 18-in. height along with continued flower bud development made these plants very desirable. Once again, reduced first flush of growth was typical, followed by a second flush and a flower bud on top of that.

CONCLUSION

It is clear that paclobutrazol can be an effective tool in the production of *R. catawbiense* 'Boursault'. Although the results of our Bonzi application in 1995 were not as we had hoped, we have perhaps learned more this year about this aspect of our production system. Our 20 ppm rate may need to be increased to 30 ppm next year. We can now feel confident that a moderately higher rate will not have any negative effect on our crop. A slightly higher rate would help assure that even in another hot summer, we should see more of the results that we are trying to achieve.

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Grafting on Bare-Root Stock of Small Standard Trees

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I will discuss and describe the grafting on bare-root understock of small standard trees of the following:

Understock	Scion
Caragana arborescens	*C. arborescens* 'Lorbergii'
	C. arborescens 'Pendula'
	C. arborescens 'Walker'
	C. frutex 'Globosa'
	C. tragacanthoides
Syringa reticulata 'Ivory Silk'	*S. vulgaris* cultivars
	S. meyeri 'Palibin'
	S. microphylla 'Superba'
Prunus americana	*P. ×cistena*
Prunus cerasifera (with interstem of *P. nigra*)	*P. triloba* 'Multiplex'
Salix viminalus	*S. caprea* 'Pendula'
	S. integra 'Hakuro Nishiki'
Euonymus europaeus	*E. fortunei* Emerald Gaiety®
	E. fortunei 'Vegetus'
	E. fortunei 'Canadale Gold'
	E. fortunei 'E.T. Gold'
	E. fortunei 'Sunrise'
	E. fortunei 'Sunspot'
	E. alatus 'Compactus'
	E. nanus var. *turkestanicus*
Malus MM111 (with interstem *M. ×adstringens* 'Hopa')	*M. sargentii* 'Tina'
	M. 'Sir Galahad'
	M. 'Lolipop'
Cotoneaster bullatus	*C. apiculatus*
	C. dammeri 'Coral Beauty'
	C. dammeri 'Eichholz'
	C. ×hessi
Ulmus 'Dodoens'	*U. glabra* 'Camperdown'
Morus alba	*M. alba* 'Pendula' fruiting
	M. alba 'Chaparral' fruitless

All understocks are field grown, fall dug, cleaned up (but not root pruned till grafting time), put in bins (with roots packed in bark), and stacked in a cooler. Most understock are frozen to -2C all winter with humidity maintained. An exceptions is *E. europeaus* which is propagated from softwood cuttings and pot grown to 1.5 to 1.8 m in 1 year. These euonymus are overwintered in a double

polyhouse (almost frost free). The *Salix* stems are cut from a stock block in late winter and stored for 1 month in bundles wrapped in polyethylene.

At the end of Feb., the packed bins are removed from the -2C temperature storage and allowed to thaw slowly at 15C. The understocks are usually cut 1.25 m height and the roots are pruned as little as possible.

Scions are gathered at this time on frost-free days and stored at 0C in black plastic bags.

Three types of grafts are utilized:

- Whip graft with most cultivars;
- Whip and tongue on *Caragana* stems;
- Triangle (we call it) or inlay graft on plants where the understocks is 2 or 3 times larger in caliper than the scion.

We try to fit scions as close as possible to the stem caliper and match the cambium on at least one side if they do not match. Grafting rubber strips are used for tying, finished with a loop hitch for easy removal. The *Salix* are grafted on unrooted stems and tied with polyethylene tape. Tight rubber strips seem to damage the scions.

Completed grafts are dipped in wax which covers the total scion and graft union. The wax is melted in a special wax pot at a temperature of 65C. (The wax is made in Canada by Dilmont in Montreal: distributor is Timm Enterprises, Trafalgar Road in Oakville, Ontario).

Grafted stems are transported to our Bouldin & Lawson Honcho potter adapted for potting these trees. The potting medium is peat and sand (1 : 1, v/v) and it is packed around the roots. The potted grafts are then transported to a double polyhouse covered with white (50%) plastic on the outside and a clear layer of plastic on the inside. A minimum temperature of 8C is maintained by a propane space heater. The polyhouse is about 30 m long and equipped with two household fans to keep the air mixed. The sun and spring-like weather will soon increase the temperature to 25C with the space heaters gradually running less and less. After 6 weeks callous is evident.

Suckers on the stems are removed by hand (glove covered) up to the last branches under the scion which are retained to help keep the sap flowing to the grafted scion. Insecticides are applied at this time with a fungicide used during periods of dull weather.

Venting is done very sparingly at first, unless the inside temperature goes over 33C. After 8 to 10 weeks, all suckers on the understocks are removed. More air is given and by 10 weeks the plastic is removed and replaced by 50% shadecloth. The grafts receive full sun light for approximately 2 weeks prior to field planting.

The new scion growth on the grafts is cut back to 15 cm above the graft union and the grafts are planted in well prepared land with a tree planter. Grafts are staked using galvanized stakes with the grafting rubber strip removed at this time.

The *Salix* grafts are container grown with drip irrigation. A stake is pushed through the bottom of the pot into the soil beneath to keep them from blowing over.

Most grafts are sold with a 2-year head—except for the *Euonymus* which are sold with a 3-year head.

SUMMARY

Successful grafting depends on these factors: good healthy understock, good healthy fresh scionwood, proper environment, proper carpentry suited for the species, staged removal of suckers, good cultural practices during the process—watering, spraying, and oh yes, we do not fertilize the pots (the potting medium is a mix with some super phosphate added). We tried Osmocote top dressing and almost lost a crop because heat in the polyhouse gave a fast release. Irrigation saved them.

Aseptic Germination of *Trillium erectum* and *Trillium grandiflorum* Seed

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INTRODUCTION

Trillium species are a delightful group of spring-flowering woodland plants for the shade garden. The North American species are frequently more showy than the Himalayan and Northeast Asian forms. They are long-lived, easy-care plants when sited properly. Hence, they are much sought after by sophisticated temperate-zone gardeners in both the Northern and Southern hemispheres. *Trillium* species would be an excellent perennial nursery crop if they could be easily propagated in volume. And therein lies the problem. They are slow to flower from seed, taking up to 3 to 7 years to build a large rhizome (food storage organ) if one is able to germinate the seeds. Seeds of some species have been reported to exhibit double-dormancy. Division is also a slow, but not impossible, process. Several species are classified as threatened or endangered in the wild, which is the source of many plants marketed today.

Work was undertaken several years ago to develop a method for propagating native hardy forms of the genus *Trillium* using micropropagation techniques. I expected that this approach could generate a more rapid increase in clonal plant material than traditional nursery notching and division techniques, and would be more appropriate than collecting plants from the wild.

The initial question asked in this learning process was: What is the easiest method to obtain a large quantity of aseptic plant material to use as an experimental vehicle for further research? Pence and Soukup (1986) reported considerable difficulty with contamination when attempting to use buds from mature*Trillium* rhizomes excised from garden-grown plants for micropropagation. My own experience with using buds from rhizomes of the genera *Hosta, Sarracenia*, and *Astilbe* confirmed the reported decontamination difficulties. In response to the query, I selected aseptic germination of seed (the explant) as the course of action for testing.

MATERIALS AND METHODS

Freshly picked green (unopened) seed capsules were the targeted source of seed in order to reduce the amount of contamination from the natural environment. Seeds from friends, commercial sources, and plant society seed exchanges were used in subsequent experiments. A moderate quantity of *T. erectum* and *T. grandiflorum* seed was readily available in a local private garden where they were growing profusely, having been brought in from a farm in upstate New York many years earlier. Timing of seed collection became a major concern. Ants are an important means of seed distribution in some native*Trillium* species because they are believed to be attracted by the aril as a food source. An aril is a fleshy attachment to the seed. The ants quickly remove seed from split capsules to their nests.

Capsules were watched for ripeness and collected just as they were turning from green to red in late July. Within 24 h of being collected the capsules were washed in a 10% bleach/detergent solution in distilled water for 20 min, placed in a plastic bag

with a moist (not wet) paper towel, and stored at about 40F (5C) for 30 to 45 days before being started in culture.

Knutson's C medium, a nutrient-lean orchid medium, was chosen for the initial germination experiment because the extra nutrition of a Murashige and Skoog (MS) medium (Arditti and Ernst, 1984) was not deemed critical in the beginning cycle for seed germination. Pence and Soukup (1986) had also reported that reduced-strength MS medium was useful for some rhizome culture. The Knutson's C medium was augmented for the first transfer cycle in culture with zeatin at 1.0 mg liter^{-1}. Zeatin is a powerful natural phytohormone (plant growth regulator) in the cytokinin class, which influences several plant functions (Donnelly and Vidaver, 1988). When MS medium was used in later experiments for the first culture cycle, it was also augmented with zeatin at 1.0 mg liter^{-1}. Agar was added at 8 g liter^{-1}, while the medium was adjusted to pH 5.5.

After the initial 30- to 45-day cold/dark treatment, the seeds were recleaned with an alcohol dip for 1 min followed by two 20-min washes of 10% bleach/detergent. Seeds were then placed into plastic egg culture containers holding 16 ml of Knutson's C medium, 4 to 14 seeds per egg, depending on the experiment and seed quantity available. The plastic eggs are made of autoclavable polycarbonate divided in half horizontally with a flat bottom. Their advantages are that they are easy to access with forceps, easy to handle in the lab, and confine any contamination to small quantities of materials.

Culture containers received cold/dark treatment in a refrigerator—18 eggs to a Magenta tray placed into a plastic bag sealed to reduce dehydration. For subsequent warm/dark treatment, the trays of containers in bags were moved to a growing room, which was maintained at 70F (21C) to 84F (29C) with relative humidity held to between 60% and 80%. For warm/light treatment, the trays with eggs were removed from plastic bags and placed on a rack 4 in. under standard white fluorescent tubes on a 16 h light/8 h dark cycle.

When seed was obtained from sources where it was not freshly collected, i.e., received at least 3 months after harvest, it was dry. The seed had been treated to the vagaries of handling by plant society seed exchanges and commercial seed purveyors, and sitting in a desk drawer of another researcher and later refrigerated. In each case, seed of 11 species obtained in subsequent seasons was several months old and dry. It is fair to assume that all the seed received was neither stored in cool conditions nor kept in air-tight containers.

RESULTS

Freshly collected seed of both *T. erectum* and *T. grandiflorum* in the initial experiment germinated after the following treatment:

- Dark/cold 30 to 70 days cold storage
- Dark/cold 60 to 90 days in culture
- Warm/dark 90 to 120 days in culture

Containers were moved to warm/light as roots from germinating seed were observed. At the end of 10 months all seed that had germinated had extended at least one shoot, usually with the now broken seed coat still attached to the tip. This was followed by the extension of a second shoot within 45 to 120 days—a pattern typical for both species.

Final results at the end of this initial experiment:

	T. erectum	*T. grandiflorum*
Eggs per culture containers	2	18
Seeds per egg	9	5
Total seeds	18	90
Seeds germinated after 10 months	13	35
Germination rate (%)	72	41

Other variables tested in subsequent experiments were species, nutrient media, plant growth regulator, and length of cold/dark and warm/dark periods. A total of 750 seeds of nine other species from several sources were tried, using the plant growth regulator gibberellin, MS medium modified for hosta (Kyte, 1987), and Knutson's C medium. Because the seed was not fresh in every subsequent experiment, it was soaked for up to 42 h to hydrate it. None of the seed germinated.

DISCUSSION

Reasonable germination of *T. erectum* and *T. grandiflorum* seed was achieved in 10 months, providing aseptic cultures of rhizomatous plant material for further experiments on multiplication and transplanting plantlets from culture. Contamination only became a problem when the cleaning process was shortened or sterile technique failed.

The exact seed dormancy and germination process for all species in the genus *Trillium* may not yet be completely understood. One can proceed on the basis that, at least for *T. erectum* and *T. grandiflorum*, they are not doubly dormant and it is possible to obtain germination aseptically in one growing season. By ignoring conventional wisdom that dictates two seasons to germinate seed that is doubly dormant, a sequence can be used for *Trillium* similar to modern nursery practice with the native woody plant *Chionanthus virginicus*. One skilled researcher-propagator regularly produces *C. virginicus* seedlings during one winter season by accelerating the cold and warm periods.

The use of dry seed in the experiments was a risky approach, given the known reluctance of some *Trillium* to germinate, even when using fresh seed. Contributing to the failure of the dry seed could have been an overly long period (more than 3 to 6 h) of water soak, which may have caused the seed to over imbibe with subsequent damage to internal tissue (See Deno, 1993 for further thoughts on *Trillium* seed germination).

A cursory survey of the horticultural literature immediately available to the author failed to turn up definitive rules for handling *Trillium* seed. Botanic gardens, arboreta, commercial firms, plant society seed exchanges, and those who donate to them could benefit from standard procedures for handling and germinating *Trillium* seed. This could increase the rate of germination and make commercial propagation more attractive.

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Grafting on Roots

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INTRODUCTION

Root pieces have a number of advantages over regular understocks. They are among others things, readily available when harvesting nursery stock, can be dug from original plants, are compatible with plants from which they originate, and prevent abnormal growth habits that can occur with seedlings. The disadvantage is, root pieces that can be used as root cuttings will generally produce shoots if used, but are the only choice for grafting of taxa that can not be produced any other way.

Root pieces are harvested when plants have ripened sufficiently so that they could be dug bare-root. After harvesting, roots should be packed in moisture-retentive material and stored at 0C. They could be cut into pieces at this time to facilitate accurate counts. At no time should roots be permitted to dry.

Size of root pieces optimally should be from 6 to 15 mm thick, their length can be between 10 and 20 cm depending on the pot size if they need to be potted. Branched roots are best. Roots that need added temperature to heal are potted and placed into a grafting case 3 to 4 weeks before grafting is to commence—temperature should be 18 to 20C. This procedure promotes heavy rooting. Roots that do not need heat are taken directly from cold storage and grafted and waxed. Grafting for either method is by a side graft. Scions should be from one to five buds in length depending on the particular plant. Rubber grafting strips are used to tie the grafts. If heat is required the grafts are placed back into the grafting case with the unions covered by a moisture-retentive material. The case can stay closed until callusing commences—usually between 4 to 6 weeks. Top growth will also have started by this time and the plants need to be hardened gradually with the temperature not exceeding 20C. After the plants have fully hardened, the grafting strips are removed and the grafts are planted into larger pots or grown on in open ground. It is important that the root part of the graft is covered when planting.

OBSERVATIONS AND TRIALS

Observations and trials, that I have made with plants grafted on roots.

***Aralia elata* 'Variegata'**. This plant is a bud sport and in my experience it can not be rooted. Graft this cultivar on *A. elata* roots in winter, pot, and keep at 20C. In addition it is possible to wax the grafts and keep cool until field planting. There is less suckering if grafts are planted deep and in a heavy soil. A patch bud should be used.

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Grafting on Roots

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INTRODUCTION

Root pieces have a number of advantages over regular understocks. They are among others things, readily available when harvesting nursery stock, can be dug from original plants, are compatible with plants from which they originate, and prevent abnormal growth habits that can occur with seedlings. The disadvantage is, root pieces that can be used as root cuttings will generally produce shoots if used, but are the only choice for grafting of taxa that can not be produced any other way.

Root pieces are harvested when plants have ripened sufficiently so that they could be dug bare-root. After harvesting, roots should be packed in moisture-retentive material and stored at 0C. They could be cut into pieces at this time to facilitate accurate counts. At no time should roots be permitted to dry.

Size of root pieces optimally should be from 6 to 15 mm thick, their length can be between 10 and 20 cm depending on the pot size if they need to be potted. Branched roots are best. Roots that need added temperature to heal are potted and placed into a grafting case 3 to 4 weeks before grafting is to commence—temperature should be 18 to 20C. This procedure promotes heavy rooting. Roots that do not need heat are taken directly from cold storage and grafted and waxed. Grafting for either method is by a side graft. Scions should be from one to five buds in length depending on the particular plant. Rubber grafting strips are used to tie the grafts. If heat is required the grafts are placed back into the grafting case with the unions covered by a moisture-retentive material. The case can stay closed until callusing commences—usually between 4 to 6 weeks. Top growth will also have started by this time and the plants need to be hardened gradually with the temperature not exceeding 20C. After the plants have fully hardened, the grafting strips are removed and the grafts are planted into larger pots or grown on in open ground. It is important that the root part of the graft is covered when planting.

OBSERVATIONS AND TRIALS

Observations and trials, that I have made with plants grafted on roots.

***Aralia elata* 'Variegata'**. This plant is a bud sport and in my experience it can not be rooted. Graft this cultivar on *A. elata* roots in winter, pot, and keep at 20C. In addition it is possible to wax the grafts and keep cool until field planting. There is less suckering if grafts are planted deep and in a heavy soil. A patch bud should be used.

***Corylus avellana* 'Contorta'**. This cultivar can be grafted in winter on *C. colurna* to prevent suckering, potted, and kept at 20C or wax after grafting, coldstored, and planted out in spring. The scion should contain two to three buds.

***Malus* species and Cultivars**. While *Malus* can be produced by cuttings and tissue culture the majority of plants are still produced by budding or grafting on seedling rootstock. This practice while economical for the producer does not provide the consumer with the best product. Such grafted plants will generally sucker from the understock usually because the plant grafted is less vigorous. If grafting is practiced on own roots a considerable amount of aftercare is avoided. Root grafts with *Malus* can either be given a warm period during callus development, or waxed and then cold store.

Paeonia suffruticosa. Cultivars are grafted in August as soon as buds are fully developed. Use one bud scions with the leaf removed except for a short piece of the petiole and graft on *P. lactiflora* cultivar roots. Heel the grafts into a sand and perlite medium in a closed case—the buds should be covered, and the temperature maintained between 20 and 24C. After healing, cold store until spring and pot or plant out. Using peat as covering material will cause rotting of the scion bark.

Grafting Oaks. A side graft with well-ripened scions of three to five buds is made and then potted and placed into a grafting case. Oaks heal well with temperatures of 20 to 24C. As soon as the grafts are healed they should be hardened off. The emerging leaves are very sensitive to moisture and care should be taken to prevent rotting. After the grafts are well healed, they can be repotted or planted out after danger of frost is over.

- ***White Oak Group***. *Quercus robur, Q. alba*, and *Q. macrocarpa* seem to be quite compatible within the species and even on *Q. robur*. *Quercus robur* f. *fastigiata* does not always show the characteristics of the original plant. Instead of the normal tight columnar growth a more open wavy growth is exhibited when grafted on some seedlings of *Q. robur*. By using roots from the typical grafted form I believe that this growth deformity can be avoided.
- ***Red Oak Group***. Since my trials only involved roots from either the original tree or plants that were successfully grafted, I had no problems with graft take. However, there is a problem with graft incompatibility when grafting on seedlings.

  Santamour (1992) in one of his papers to this society states that there are three lignin-enzyme groups that are only compatible with each other. Unless the understock and scion are of the same group, failure of the graft will eventually occur.

  I believe that by using the original tree root or roots from a successful graft this problem can be avoided and no typing of plants needs to be carried out.

  With *Q. rubra,* while there are few if any growth variations propagated, there is considerable interest in the forestry industry to produce superior seed trees. Root grafting works well with this species.

Quercus palustris has a number of growth habit variations and some have been patented, but they have not been listed for sale for a while. I wrote to Bill Flemer at Princeton Nurseries on this subject and he replied that they used to bud the *Q. palustris* cultivars 'Sovereign' from Cole's Nurseries and 'Crownright' a selection of their own. Good stands were obtained when budding in August. Later 15% of 'Sovereign' and 10% of 'Crownright' showed incompatibility with overgrowth on the graft union.

A new culitvar 'Green Pillar' has so far not shown incompatibility problems. My trials with 'Sovereign' using roots from a successful grafted plant worked well when grafted onto each other.

CONCLUSION

I hope that this paper gives you a practical approach, grafting on roots, for the propagation of some difficult-to-propagate plants.

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Vegetative Propagation of Rare and Unusual Conifers: An Alternative Approach

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INTRODUCTION

Vegetative propagation of rare and unusual conifers from stem cuttings serves diverse needs. At botanic gardens and arboreta these plants are grown for botanical study, ex situ conservation, and/or horticultural evaluation, and commercial distribution. Often, vegetative propagules are the first or only type of propagules available since, unlike viable seed, stems and shoots are available to collectors year round (i.e., whenever they may have the good fortune to locate the plants—especially when dealing with plants growing as small, isolated populations in remote areas). Vegetative propagation allows propagation of physiologically mature tissue resulting in whole, mature plants—which can greatly accelerate cone production in cultivation, either for taxonomic studies or seed production. Vegetative propagation may also be used as a back-up method when both seed and vegetative material are limited.

By definition, propagules of rare and unusual taxa are generally scarce and need to be multiplied before plants can be included in collections or distributed to other gardens or nurseries. In addition to the scarcity of the material itself, there is often an analogous lack of information as to how best to propagate the rare plant by vegetative means—either because it is new to cultivation, or it has not been routinely propagated to date using varied vegetative techniques. When propagation recommendations for rare conifers are available, they may be detailed for some taxa, but limited in critical detail, or even absent for others untreated at the time of publication (Fordham and Spraker, 1977). Reports may be of techniques that have been used successfully in a different climate (with different ambient light intensities, relative humidities, available substrate contents, etc.). Yet, the very scarcity of the material precludes the use of traditional, controlled, replicated comparisons of diverse propagation techniques to determine optimal methods. When faced with limited material of unfamiliar conifer taxa, an awareness of the plant's habitat can guide the selection of propagation treatments, increasing success rates significantly. This paper discusses and gives descriptive examples of this general approach.

AN ALTERNATIVE APPROACH

Amentotaxus, Austrocedrus, Callitris, Calocedrus, Cephalotaxus, Cupressus, Dacrydium, Fitzroya, Fokienia, Glyptostrobus, Keteleeria, Microbiota, Microstrobos, Phyllocladus, Podocarpus, Pseudotaxus, Saxegothaea, Taiwania, Thujopsis, and *Torreya* are some of the coniferous genera with rare or unusual species that can be propagated successfully by rooting stem cuttings (space constraints prevent discussion of all of these taxa but selected examples are discussed in the following section). Standard techniques may yield some success but I have found that minor but informed changes to routine procedure resulted in significant improvements in

percent rooting and/or survival of rooted cuttings—improvements that may be critical to success in bringing the plant into cultivation.

When dealing with unfamiliar taxa, applying a few discriminately selected treatments to several small lots of cuttings offers the best likelihood for success. Rather than subject all of a limited quantity of wood to standard production techniques convenient in existing facilities, be prepared to alter season of harvest, media, bottom heat, and mist regimes to optimize propagation. For best results, adapt the system to the apparent requirements of the plant.

The challenge then becomes how to select a range of only a few treatments likely to succeed when dealing with limited quantities of wood—i.e., when traditional comparison studies of controlled, replicated treatments are impossible. Treatments selected after consideration of native habitat and specific growth and development characteristics have been determined can optimize results. In addition to the standard propagation literature, references and publications on habitat and biology for specific plants therefore become important sources when selecting propagation treatments. Avoid limiting treatment choices to only those detailed in existing propagation literature, i.e., avoid accidentally assuming any limitations imposed by an earlier technology and understanding of the plant's biology. A treatment that seems promising today in relation to current knowledge of plant habitat may be very different from any attempted in the past, yet it may ultimately be the one most successful in your region. The examples given below illustrate the general concepts of this approach as applied to selected rare and unusual conifers.

GENERAL METHODS AND EXAMPLES

The following list of examples illustrates how attention to the characteristics of a given plant's habitat in nature may optimize vegetative propagation of rare conifers by rooting of stem cuttings. Due to the small sample sizes necessitated by scarcity of propagation material, statistical analyses could not be performed on these results. Results, therefore, have been reported descriptively and any conclusions reached were necessarily circumstantial—as are any conclusions reached using small, unreplicated sample sizes. Results, however, showed useful trends, such that treatments which included the primary characteristics of a plant's native habitat always gave best results. For each example plant, a brief description of the plant, its primary habitat characteristics, and optimal propagation treatments, are given.

All cuttings were rooted in greenhouses using a range of standard treatments, depending on the plant. Comparisons were made of small quantities of cuttings allotted to each unreplicated treatment group (ca. 6 to 12, depending on availability). Not all plants were subjected to all treatment possibilities (see individual descriptions). Comparisons were made between season of cutting harvest (winter, after significant frost, vs. summer, after spring growth flush, or late summer, after some hardening); moisture retentive quality of the rooting medium (moisture retentive, perlite and peat [1 : 1, v/v] vs. well-drained, perlite and peat [3 : 1, v/v]); and degree of relative humidity as effected by intermittent mist regime (frequent, 6 sec every 6 min, vs. infrequent, 6 sec every 20 min). All winter harvested cuttings received bottom heat and no summer harvested cuttings received bottom heat. So that differences in rooting response would more likely be due to differences in environmental conditions, rather than an effect of hormone treatments, all cuttings were treated with KIBA at moderate concentrations in alcohol-free preparations (5000 to

8000 ppm, depending on the plant). All comparisons were made at one of two sites: either in Jamaica Plain, MA (USDA Zone 6b: Arnold Arboretum) or Raleigh, NC (USDA Zone 7b: North Carolina State University Arboretum). Cuttings were kept in treatments for 16 to 20 weeks, depending on the plant, after which time cuttings were lifted and percent rooting for each treatment was calculated. Cuttings were considered to be successfully rooted when at least one primary root was greater than 5 cm long. No comparisons between species were made.

Athrotaxis selaginoides is an evergreen tree native to a small area of Tasmania where it grows in a cool, moist, montane environment of very even moisture. Comparisons were made of winter and summer cutting harvests, and frequent and infrequent mist regimes, using a moisture-retentive medium. Highest percent rooting was obtained with winter-harvested cuttings and the frequent mist regime (i.e., cool, moist conditions).

Austrocedrus chilensis is an evergreen tree found growing in Chile and Argentina in the Andes region up to about 1500 m. It grows in both moderately moist and moderately dry areas, reaching the edges of the dry steppe in Argentina. Comparisons were made of summer and winter cutting harvests, moisture retentive and well-drained media, and infrequent and frequent mist regimes. Highest percent rooting was obtained with summer-harvested cuttings in either the well-drained medium with the frequent mist regime, or in the moisture-retentive medium with the infrequent mist regime (i.e., warm, with moderate moisture).

Cephalotaxus fortunei is a species of plum yew native to China. Plum yews are evergreen conifers superficially resembling true yews (*Taxus* spp.) but with significantly different reproductive biology and landscape performance. The genus is found in both cool and warm temperate climates in a diverse range of conditions. *Cephalotaxus fortunei* is found growing in nature in humid, warm-temperate and subtropical, low to middle elevation, understory habitats, on diverse moist substrates. Comparisons were made of summer and winter cutting harvests, moisture-retentive and well-drained media, and infrequent and frequent mist regimes. Highest percent rooting was obtained when cuttings were harvested in summer and rooted in the moisture-retentive medium under the frequent mist regime (i.e., warm, moist environment).

Fitzroya cupressoides is an evergreen tree reaching great heights in its native South America—analogous to those of *Sequoia*. *Fitzroya* is found growing in cool (not cold), moist, exceptionally uniform climates at middle to high elevations in Chile and Argentina. Comparisons were made of summer, late summer, and winter cutting harvests, and frequent and infrequent mist regimes, in a moisture-retentive medium. Highest percent rooting was obtained with late summer-harvested cuttings in the moisture-retentive medium under the frequent mist regime (i.e., uniformly moist environment with cooling conditions).

Fokienia hodginsii is an evergreen tree native to warm temperate and subtropical southeastern China with unique flattened foliage. Comparisons were made between winter and summer cutting harvests in moisture retentive medium with a frequent mist regime. Highest percent rooting was obtained with the summer cutting harvest (i.e., warm, moist conditions).

Keteleeria davidiana is an evergreen tree resembling true firs (*Abies* spp.) in appearance, native to southeastern and southwestern China. It is found growing in relatively hot areas with significant dry periods as well in areas with moderate

moisture. Comparisons were made between summer and winter cutting harvests, moisture-retentive and well-drained media and frequent and infrequent mist regimes. Highest percent rooting was obtained with the summer harvest, using the well-drained medium and infrequent mist regime (i.e., warm, relatively dry conditions).

Saxegothaea conspicua is a large evergreen shrub or tree, native to South America where it grows in the cool, moist areas of Chile and Argentina at middle elevations. Comparisons were made between winter and summer cutting harvests, and frequent and infrequent mist regimes, in a moisture-retentive medium. Highest percent rooting was obtained with the winter cutting harvest and the frequent mist regime (i.e., cool, moist conditions).

Thujopsis dolobrata is an evergreen tree that grows for many years as a low shrub before eventually developing a leader and attaining heights of 15 to 20 m. It is quite shade tolerant and is found growing on deep, moist soils in central and northern Japan. Comparisons were made of winter and summer cutting harvests, moisture-retentive and well-drained media, and frequent and infrequent mist regimes. Best results were obtained with the winter cutting harvest, using the moisture-retentive medium, and the frequent mist regime (i.e., cool, moist conditions).

CONCLUSION

Vegetative propagation of rare and unusual conifers from stem cuttings benefits from a systematic approach to both the art and science of propagation. Determining successful propagation techniques becomes difficult when limited quantities of wood preclude traditional, replicated studies with a broad range of many treatments. Under these circumstances, informed selection of a few key treatments that account for the environmental conditions found in a plant's indigenous habitat can optimize results. Information on plant distribution and habitat therefore, becomes an important resource for this approach.

In general, English language regional floras can be especially helpful. Secondary references (e.g., Krussman) often cite primary references that give more detailed information on habitat. Manuals and expedition collection journals often publish the greatest detail on the specific microclimatic conditions associated with a given taxon. Another invaluable, but less accessible resource consists of the collection data recorded on herbarium specimens housed in research-oriented herbaria (such as those maintained at the Royal Botanic Garden, Edinburgh; Royal Botanic Garden, Kew; Harvard University Herbaria; and regional herbaria in the countries of origin). Selected references useful for uncovering specific information on given conifer habitats are listed following the literature cited.

Finally, conifer cuttings have the unique attribute of retaining viability for a much greater period of time than those of other plant groups. As a result, it is possible to successfully root conifer cuttings that have been subjected to a second round of treatments even when the first has failed to induce rooting. Green, vigorous cuttings can be lifted, the callus trimmed and/or wounded, and cuttings restuck in fresh medium. Cuttings can then be subjected to a different set of potentially more favorable treatments and conditions. This attribute, unique to conifers, is especially valuable when dealing with limited quantities of wood of rare conifers. This persistent approach recently led to the successful rooting of stem cuttings of the rare species *Torreya jackii* at the Arnold Arboretum. When rooting stem cuttings of rare

conifers, persistence combined with informed selection of propagation treatments is often rewarded with success.

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Propagation of Hinoki Cypress Cultivars

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Chamaecyparis obtusa cultivars are used very much in the landscape because they can tolerate both shade and sun conditions. In Japan where plants grow to 60 ft or more they are a source of important lumber products, while the slower growing and dwarf cultivars are used in the landscape.

Propagation of this species is easy. At Bald Hill Nurseries, Inc. we propagate cultivars of *C. obtusa* by cuttings and by grafting.

CUTTING PROPAGATION

The propagation method using cuttings is as follows:

- Cuttings 8 to 10 in. are gathered from established plants in December or January. They are then trimmed down to about 3 in. wide by 7 in. long with the bottom 3 in. of branches removed. A 1-in. wound on one side is made, then a 45 degree cut is made on the basal end. The cuttings are then quick dipped (5 sec) in Wood's (1 : 6, v/v) and when they are almost dry they are then dipped in Hormodin #3.
- The double-dip method promotes better rooting in that using a single stronger solution seems to cause burning or a large callous that does not produce roots. Cuttings are stuck in a sand-filled bench with bottom heat. Cuttings are kept moist by hand watering when the sand begins to dry, usually once a week, and misted by hand daily. Cuttings that have not rooted by May can be restuck with rooting occurring by late summer.

GRAFTING

The propagation method by grafting is as follows:

Cuttings of *C. obtusa* 'Plumosa Retinispora' are taken in early November. The cuttings are trimmed to 8 in. long, foliage is cut back to 2.5 to 3 in. in width, and the stems are stripped on the lower 3 or 4 in. Prepared cuttings are dipped in Hormodin #3 powder and stuck in sand-filled benches with bottom heat. 'Plumosa Retinispora' cuttings are treated the same as *C. obtusa* cultivar cuttings during rooted. By June 1st they should be rooted.

Rooted cuttings are potted in 2-1/4-in. pots using loam instead of potting mix. The potted cuttings are then placed in outdoor sand beds and the pots are covered with sand up to 2 in. above the rim of the pot. They are shaded with 50% lath shade, watered, and cared for in the usual manner.

The potted liners are lifted out of the sand beds before the freeze, brought into a propagating house, and placed under the benches until they are grafted. We start our grafting after January 1st.

Collection of *Chamaecyparis obtusa* cultivar scions. If collected in cold weather (30 to 40F) they are submerged in water for 15 min to thaw them out. We prepare our scions 6 to 8 in. long, remove any growth 4 in. from the bottom, cut foliage

back to 3 to 4 in., and shake to remove any dead foliage from the scion. After preparation they are counted, put in plastic bags, and then placed in the cooler until needed.

The potted understocks are prepared by wiping the pots and stems. The understocks are put in cedar flats—45 to a flat. The scions are taken from the cooler, removed from the plastic bag, and spread on a table for 2 h before grafting.

A veneer graft is made and tied with a rubber strip. As the grafts are completed they are placed, standing up, in a plastic tent. The bench of the plastic tent has 3 in. of wet peat moss on which the grafts are placed side by side. They can even be double stacked if you are short of space. No wax or peat moss is needed to cover the union. Once the tent is filled it is sealed. After about 3 weeks the grafts are examined and should be completely calloused.

After the grafts are fully calloused, the plastic is loosened at the bottom to allow air into the tent. The grafts are aired this way for 3 to 4 days after which the plastic is raised from the sides. After an additional week or two the grafts are placed on an open bench. The pots are submerged in moist peat to a level where the peat covers about 2 to 4 in. of the base of the union.

GROWING ON

Rooted cuttings and grafts are planted in 1-gal containers. Our mix consists of sand, peat moss, and aged bark mulch (1 : 1 : 1, by volume). We incorporate a high N plus minor elements fertilizer—22N-4P-8K, 8 to 9 month controlled-release type.

Although grafting is still the faster way to produce *Chamaecyparis obtusa* cultivars, the propagator has the option of sticking cuttings if more scions than understocks are available or if grafting is not possible.

Fasciation in Plants

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The typical fasciated plant produces a large flat, ribbon-shaped stem. Any growing plant part can become fasciated including stems, flowers, fruits, and roots. However, the most observable and spectacular fasciations occur in rapidly growing vegetative and flowering stems. Here, the change in size and shape of the stem leads to an increase in the number of leaves and flowers along the flattened stem. I have observed normal flowering lily stems with 13 to 15 flowers, while nearby, fasciated stems produced 45 flowers bunched together across the stem (Fig. 1).

The word, fasciation, comes from the Latin word, *fascia*—to fuse. So in a broad sense, the fusion of plant parts can be considered a form of fasciation. This fusion of plant parts has been the driving force behind evolution and it is interesting to think of degrees of fasciation as the normal condition of modern plant species.

The primitive flower form is represented by having many leaf-like petals. The star magnolia (*Magnolia stellata*) is a good example of a primitive flower. Flowers are

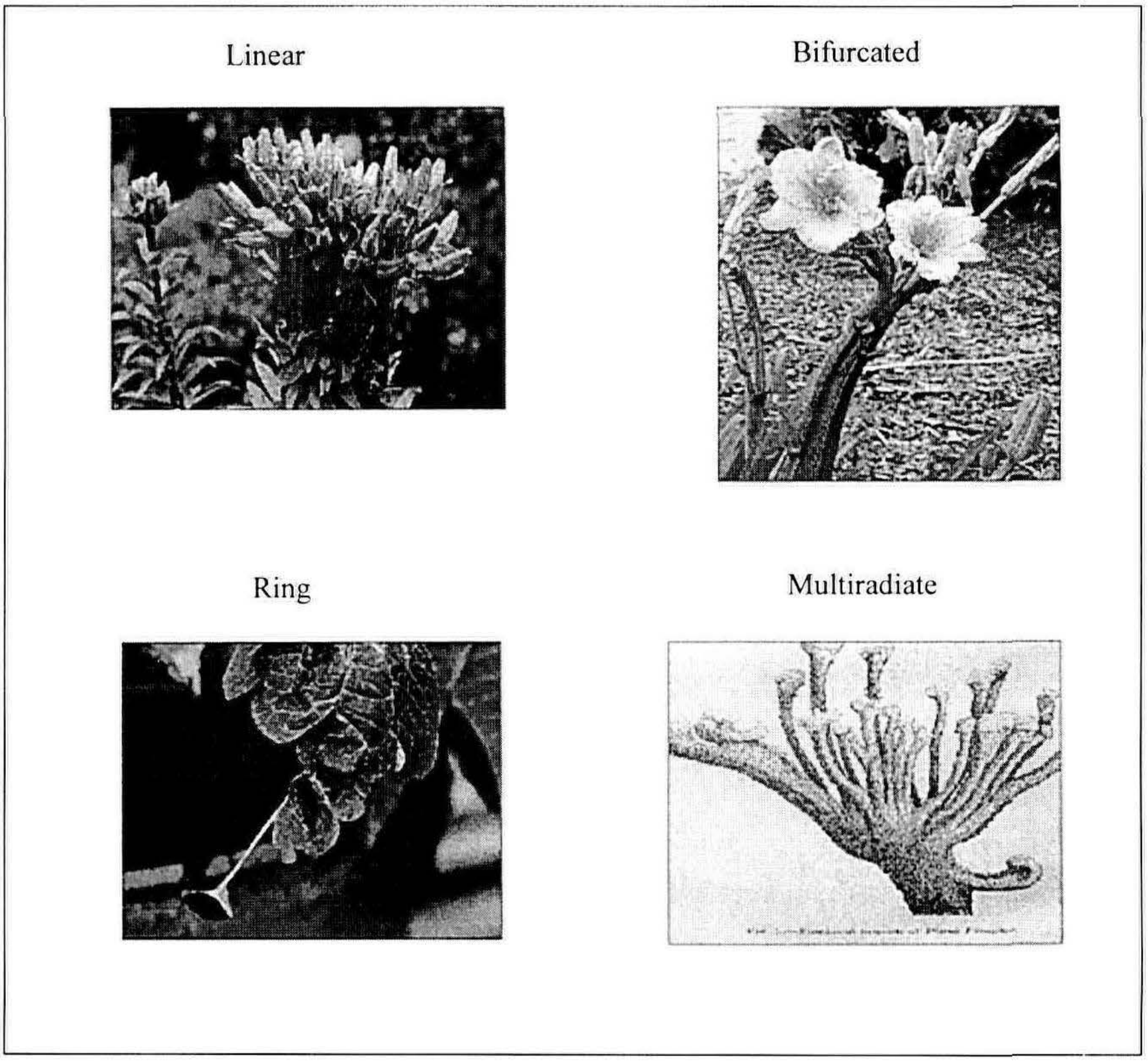

Figure 1. Types of fasciation.

thought to have evolved from leaves that modified, folded, and fused to become the typical modern flowers containing sepals, petals, anthers, and a pistil. Highly evolved flowers show fusion, modification, and usually a reduction in the number of petals of the flower. It can be argued that the evolution of flowers and the resultant complexity displayed in flower forms is the result of fasciation. Consider the fused petals of the flowers in the Heath family which include the cup-shaped flowers of mountain laurel (*Kalmia latifolia*) and the bell-shaped flowers of Japanese pieris (*Pieris japonica*). Are these examples of fasciations? At least one gene has been isolated from snapdragon (*Antirrhinum*) that is related to flower form and petal fusion that gives the typical, zygomorphic ("dragon") flower appearance. Studies are also underway that are looking for genes responsible for petal fusion in *Petunia* that should extend our understanding of the mechanisms for flower form.

A more convincing case for a role in fasciation during evolution is found in the development of fruit types. Two striking examples are illustrated in the familiar fruits of apple and strawberry. The portion of these fruits eaten is actually receptacle tissue. A receptacle is a part of the flower stem. In these cases, the receptacle continues to grow and elongate. The apple receptacle swells and grows until it completely surrounds the seeds inside the fruit. Strawberry seeds (actually the small nut-like fruits) are distributed on top of the swollen red receptacle. Strawberry fruits can be found that are typically fasciated with broad flattened fruit tips. The old strawberry cultivar, 'Fairfax', consistently had a percentage of large, fasciated fruits when the environmental conditions were favorable.

The most extensively studied example of fasciation in modifying a fruit's shape is in the tomato. Originally, the wild-type tomato fruit contained only two locules. A locule is the seed chamber inside the fruit. The cherry-type tomato is an example of this original condition. Through extensive breeding and selection, all the large commercial tomato cultivars are fasciated. This results in an increase in the number of locules leading to larger fruit. The extreme example is the fasciated 'Beefsteak' tomato that can have over 200 locules in a single fruit. The flower parts (particularly the style) show a typical fasciated condition well before the fruit develops. For tomato, plant breeders have characterized the genes responsible for fasciation and utilize the fasciated condition for increasing tomato fruit size.

Fasciations have fascinated botanists for centuries. One of the first descriptions of fasciated plants is found in the 16th century herbals. Descriptions and an illustration of a fasciated pea called the "tufted", "Scottish", or the "mummy" pease (old English for pea) can be found in John Gerarde's "The Herball or Generall Historie of Plantes" and in John Parkinson's "Paradisium". The mummy pea is a selection that breeds true from seed for the fasciated character when self-pollinated. The appearance of the mummy pea is unique with a typical fasciated stem and all the flowers bunched together at the top of the stem rather than flowers produced in the leaf axils as occurs in normal peas.

Interestingly, the mummy pea figured prominently in the classic genetic experiments with peas conducted by Gregor Mendel (the father of genetics) in 1866. Fasciation was one of the seven characters selected for crosses in pea that led to the illustration of the Mendelian concept of dominant and recessive traits. He found that fasciation was a homozygous recessive trait in pea giving the expected 3 to 1 ratio of normal to fasciated plants from the cross between normal and fasciated parents.

Astonishingly, the classic paper written by Mendel went unnoticed and unappre-

ciated by his contemporary scientific colleagues, who were preoccupied with the Darwinian concept of natural selection. The manuscript was independently rediscovered, 35 years later by three scientists. One of these scientists was Hugo de Vries, a geneticist from Holland who extensively studied the genetics of fasciation in the genus *Oenothera* (primrose).

The prominent 19th century botanist, Julius Sachs (the father of botany) was also fascinated with fasciations. He conducted experiments with bean plants to induce fasciation. Sachs showed that by removing the growing point above the cotyledon from rapidly growing bean seedlings, the resultant shoots that developed from the cotyledonary buds would be fasciated. His inquiries were meant to provide insight into a question posed a century before by Carl von Linnaeus (the father of taxonomy). Linnaeus proposed that fasciations were the result of several growing points fusing to form the typical ribbon-shaped stem.

In 1840, Moquin-Tandon suggested an alternative to the Linnaean hypothesis on the origin of fasciations. He proposed that fasciations were the result of a change in the original growing point to form one large growing ridge. Subsequent anatomical investigations have shown that fasciations can arise from either route. Most of the naturally occurring fasciations studied arise from a single growing ridge, while many artificially induced fasciations show multiple, fused growing points.

Typical stem fasciations can be classified as linear, bifurcated, multi-radiate or stellate, and ring fasciations. Linear fasciations are the typical flat, ribbon-shaped stems. They can be very spectacular. It is common for the stem to begin normal symmetrical growth, then gradually become progressively more flat as the growing point becomes very broad. Commonly, the growing point becomes 2 to 6 in. wide at the tip, however, in some fasciated cristate cactus, the growing ridge can reach several feet wide.

Bifurcated fasciations are linear fasciations that split to produce a "Y" shaped, double, ribbon fasciation. In the multi-radiate fasciation, the stem is split into 3 or more short branches. The least common fasciation in nature is the ring fasciation. Here the growing point folds over and fuses to form a funnel shape. This is a fairly common form of fasciation in plants being grown in tissue culture. The potential for fasciation in tissue culture can be quite high, possibly because of the high levels of growth regulators supplemented in the culture medium.

Fasciations can be produced in plants for a number of reasons. The most interesting is the apparent mutation that occurs in certain plants. In many cases, these mutations are spontaneous and can become an inherited trait. Mendel was able to very nicely explain the inheritance of fasciation in the "mummy" pea as a homozygous recessive trait explaining why seed collected from this fasciated pea produced almost exclusively fasciated plants. For gardeners, the most familiar inherited fasciation occurs in the flower of the cockscomb celosia (*Celosia argentea* var. *cristata*). The colorful, contorted growing ridge that constitutes the celosia's flower is an excellent study in fasciation. In celosia, this trait is heritable and also the size of the fasciated stem and flower is easily influenced by the environmental growing conditions.

The environment has always played an important role in the expression of heritable fasciation making genetic studies difficult. Environmental conditions that favor rapid growth will also favor the expression of fasciation. Particular day lengths have also been implicated in inducing fasciations. However, not all fasciations are

induced by mutations or genetically controlled. Many fasciations are induced simply by environmental conditions.

The most common, nongenetic cause for fasciation is damage to the growing point caused by insect, disease, or physical injury. This type of fasciation was demonstrated nicely by Loiseau in 1954. In experiments using tiny glass needles to physically damage the growing point of impatiens, there were fasciations produced in about 30% of the damaged plants. Fasciations in garden asparagus have been attributed to physical damage or pressure exerted on the growing point as it pushes through the soil. In the evening primrose (*Oenothera*), fasciations can be caused by damage to the growing point by the egg laying activity of a moth. Similar documentation can be found implicating gall wasps, caterpillars, and mites for inducing fasciations in a variety of plant species.

Most recently, with the advent of pesticides, herbicides have been the inadvertent cause for some fasciations. The most common damage occurs when low levels of herbicides of the 2, 4-D type are used for broadleaf weed control in lawns. Any drift of these chemicals into nearby vegetable or flower gardens can cause herbicidal symptoms in sensitive plants. One of these symptoms can be a distortion of growth similar to fasciation.

In most cases, it is not known whether the fasciations that occur in woody plants are heritable. However, the fasciated character can be maintained by vegetative propagation through cuttings or grafts. Cultivars with the typical fasciated stem occur in several of the conifers including (*Cryptomeria japonica* and *Chamaecyparis obtusa)*. You will find these listed under descriptive cultivar names like 'Cristata', 'Torulosa', and 'Monstrosa'. Also, the witches brooms that occur in many species of conifers have been correctly or incorrectly termed fasciations. A witches broom usually forms as a mass of short shoots grouped together in the top of a tree. These shoots do not have the typical flattened stems associated with stem fasciations, but can be considered a multi-radiate form of fasciation. Many of our dwarf conifers have been selected from cuttings taken from witches brooms.

Interest in fasciations have persisted for centuries and although fasciations have only proven to have commercial importance in a few species of ornamental and fruit crops, I think the rich history surrounding fasciations will prove rewarding to anyone willing to stop and observe these garden abnormalities.

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Inexpensive IBA Root-Promoting Solutions

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INTRODUCTION

Nursery propagators regularly stimulate cuttings to root using indolebutyric acid (IBA) dispensed in powder (talc) or liquid formulations. Commercial liquid rooting preparations are readily available in a wide range of concentrations and are easier to dilute to meet the rooting requirements for cuttings of different species (Dirr, 1981; Dirr and Heuser, 1987). IBA solution may induce better rooting than powdered IBA and at high concentrations [≥1% (10,000 ppm) IBA] may also stimulate rooting of many difficult-to-root species (Chong and Daigneault, 1986).

TRADITIONAL LIQUID HORMONES

Most commercially available liquid rooting hormones are prepared by dissolving crystalline IBA in solvents—also referred to as "carriers"—such as ethyl or isopropyl alcohols. These solvents are expensive, may require a special permit to purchase, and large quantities may have to be kept locked up. For instance, pure (99%) isopropyl alcohol may be purchased in Ontario upon special order from a drug store. However, "drinkable" ethyl alcohol (ethanol) can only be purchased from liquor stores over-the-counter (40% alcohol), with a doctor's prescription (65% alcohol), or with special government permit (94% or more alcohol). "Non-drinkable", denatured laboratory grade (95%) ethanol can be purchased from a chemical supply company and does not require a permit to purchase or store. Denatured alcohol is poisonous and, if consumed mistakenly or otherwise, can result in death!

Some commercial root-promoting solutions contain solvents or hormone formulations which may cause excessive callusing or extensive basal burning (injury) to some cuttings (Barnes, 1988; Chong and Daigneault, 1986; Dirr, 1981). Under certain circumstances, the concentration of alcohol-based hormones may change during use due to evaporation of the alcohol.

GLYCOLS

Glycols are common constituents in many types of commercial antifreezes. According to Dirr (1981), polyethylene glycol is a good IBA solvent and is the least toxic of all commonly used solvents, except water. Barnes (1988) stimulated cuttings to root with IBA dissolved in glycol-based commercial antifreezes.

Chong et al. (1992) compared the rooting response of nine evergreen and five deciduous woody taxa after cuttings were treated with 0.1%, 0.3%, or 0.8% IBA in talc, or with 0%, 0.5%, 1.0%, 1.5%, or 2.0% IBA dissolved in 95% laboratory-grade ethanol or undiluted plumbing antifreeze containing 45% propylene glycol. The evergreen cuttings were taken from last season's growth and rooted during the winter under greenhouse fog regime. The deciduous cuttings were taken from current season's growth and rooted under mist during the summer. Rooting evaluation was based on the mean percent rooting of cuttings, mean root number (based on cuttings which rooted), and mean root length (based on the longest root).

There were large differences in the rooting response of taxa to carriers and/or IBA concentrations. However, as exemplified by data for one evergreen (*Taxus ×media* 'Densiformis') and one deciduous species (*Elaeagnus angustifolia*) (Fig. 1), IBA dissolved in plumbing antifreeze produced rooting in most taxa comparable to those of the ethanol-IBA combination. Root numbers of all taxa increased (linearly or curvilinearly) with increasing IBA concentrations, as did percent rooting in six of the nine evergreens and four of the five deciduous taxa. Talc formulations were similar, or were typically less effective, than IBA in solution at comparable concentrations.

NEW PRODUCTS

Encouraged by these results, Chong and Hamersma (1995) examined related commercial products that could be just as effective, such as car radiator antifreeze and windshield washer fluid. The costs and availability of these products in Ontario are compared in Table 1.

Table 1. Comparative costs of various solvents in Ontario.

Solvent	Source	Cost for 4 litres
Ethyl alcohol (ethanol)	*Liquor Control Board of Ontario*	
	65% prescription, 500 ml @ $16.95	$135.60
	40% over-the-counter, 1.14 L @ $27.50	96.49
	Chemical supply company	
	95% denatured, laboratory grade	43.00
99% isopropyl (rubbing alcohol)	Drug store	14.42
Pure methyl hydrate (methanol)	Drug store	5.53
Plumbing antifreeze (45% propylene glycol)	Hardware department	4.99
Car radiator antifreeze (95% ethylene glycol)	Auto department	6.49
Windshield washer fluid (47.5% methyl hydrate)	Auto department	1.49

Car radiator antifreeze contains 95% ethylene glycol plus small (unspecified) amounts of antioxidants and other rust inhibiting additives. Windshield washer fluid (-40°C) contains 47.5% methyl hydrate plus small (unspecified) amounts of detergents and dyes. Methyl hydrate (methyl alcohol, methanol) is an alcohol closely related to ethanol. Ethanol is a fermented alcohol. Methanol is made from natural gas or coal, and thus also referred to as wood alcohol. It was quite conceivable that these commercial products, used as IBA solvents, might be toxic to cuttings perhaps due to the additives and dyes present in these products. Before any nontraditional solvents, such as these, could be widely used by nursery propagators, their efficacy had to be fully determined.

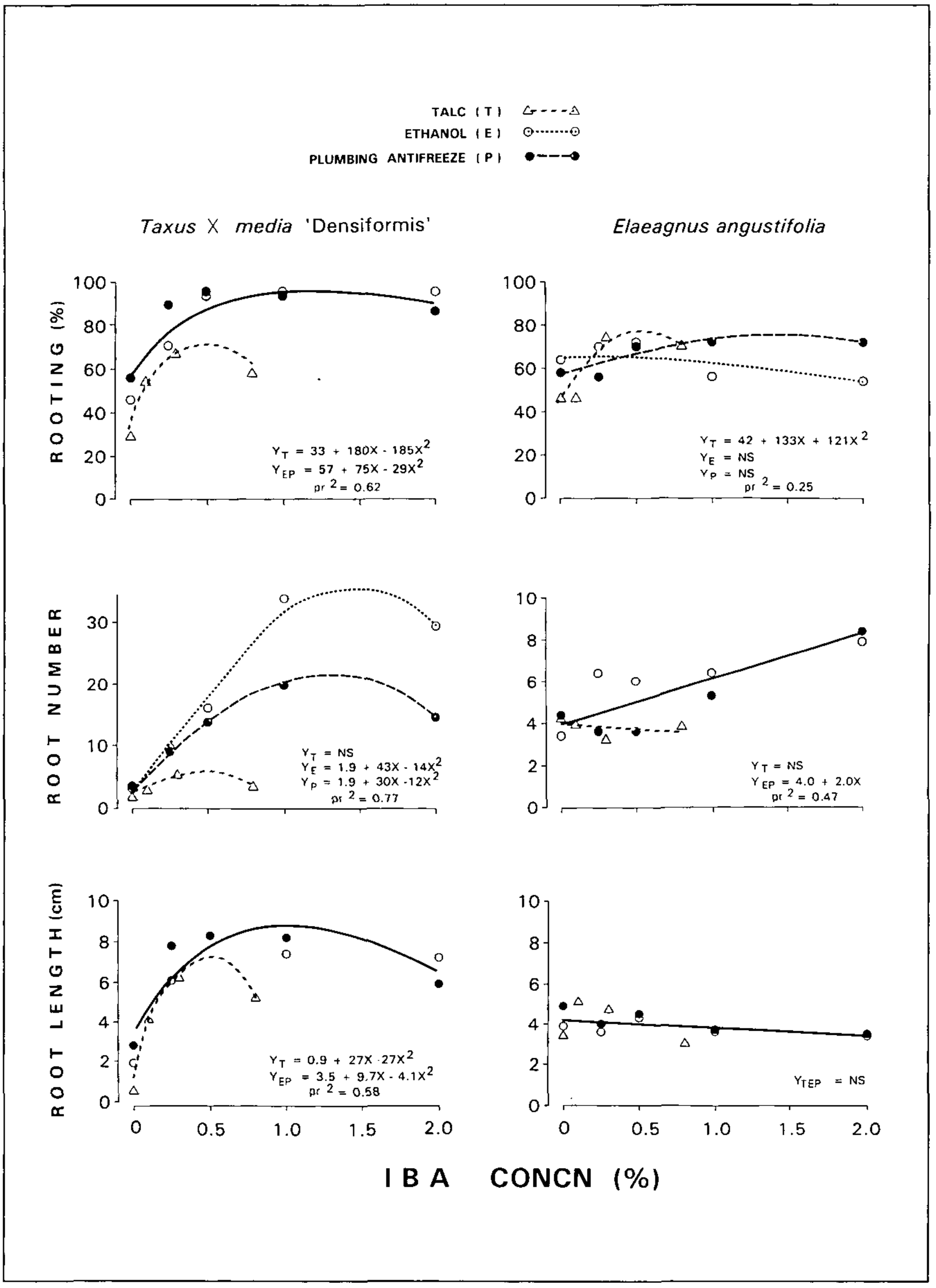

Figure 1. Rooting response of two nursery species to solvents and IBA concentrations. The regression for each carrier is represented by Y_T (talc), Y_E (ethanol), and Y_P (plumbing antifreeze). Y_{EP} and Y_{TEP} indicate nonsignificance among regressions ($P<0.05$) for the two or more solvents represented in the subscripts, and are shown graphically as solid lines. NS indicates that the slope, curvature, or both were nonsignificant ($P<0.05$). pr^2 represents the coefficient of determination after removing replication effects.

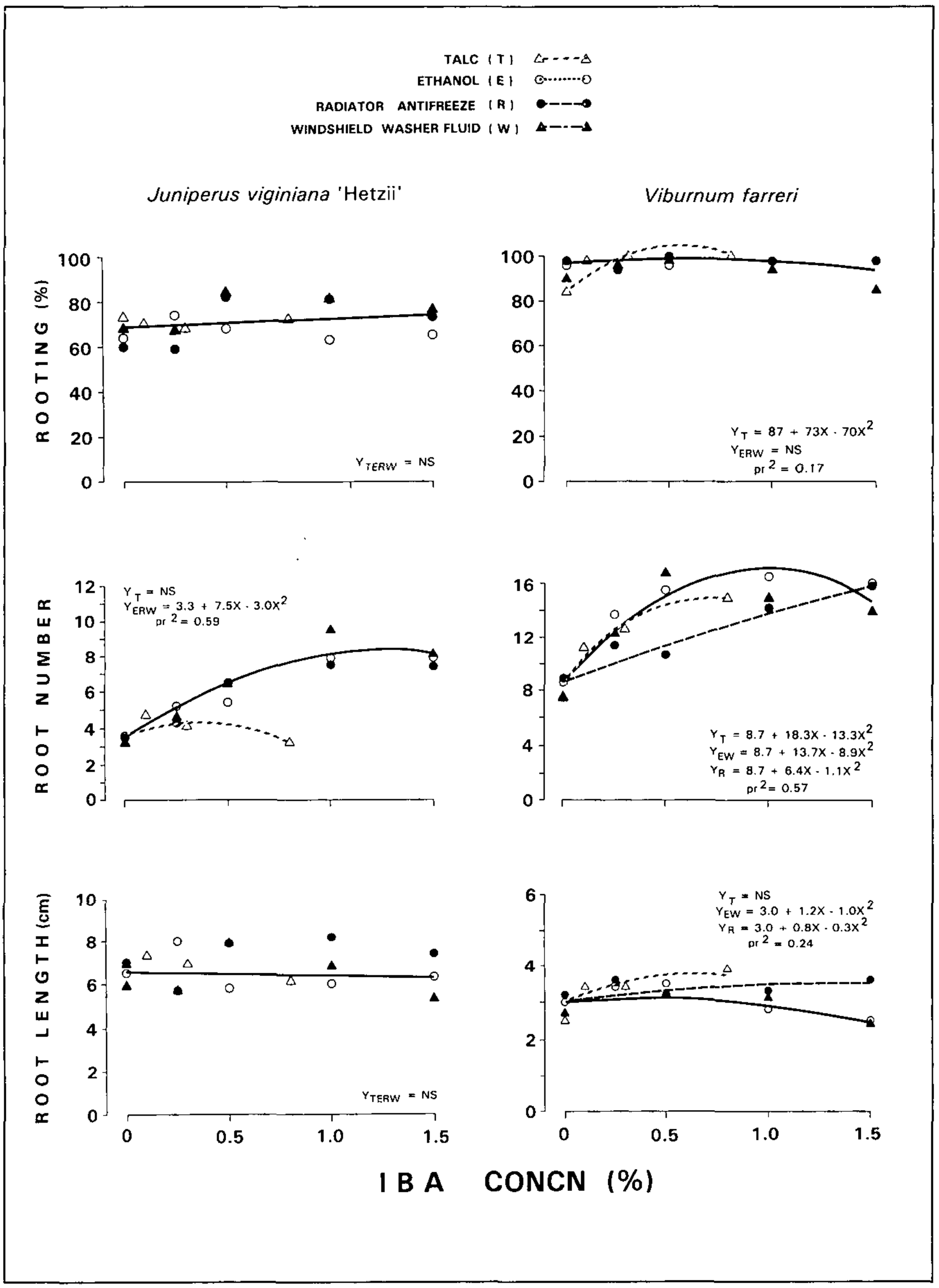

Figure 2. Rooting response of two nursery species to solvents and IBA concentrations. The regression for each carrier is represented by Y_T (talc), Y_E (ethanol), Y_R (radiator antifreeze), and Y_W (windshield washer fluid). Y_{EW}, Y_{ERW}, and Y_{TERW} indicate nonsignificance among regressions ($P<0.05$) for the two or more solvents represented in the subscripts, and are shown graphically as solid lines. NS indicates that the slope, curvature, or both were nonsignificant ($P<0.05$). pr^2 represents the coefficient of determination after removing replication effects.

In these investigations, four evergreens and four deciduous taxa were treated as described above with talc IBA, or with 0, 0.25, 0.5, 1.0, or 1.5% IBA in ethanol, car radiator antifreeze, or windshield washer fluid.

As exemplified by data for one evergreen (*Juniperus virginiana* 'Hetz') and one deciduous species (*Viburnum farreri*) (Fig. 2), the results indicated "near-similar" root-promoting effects of ethanol, car radiator antifreeze, and windshield washer fluid and confirmed results with plumbing antifreeze (Fig. 1).

CONCLUSION

Within each of many taxa tested, rooting differences, if any, due to solvents were generally small and/or commercially insignificant. Consequently, propagators can use ethanol, plumbing antifreeze, car radiator antifreeze, and windshield washer fluid and expect comparable results. These non-traditional solvents are inexpensive and are readily available.

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Plug Production of Bedding Plants within a Nursery Production Program

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INTRODUCTION

Bailey Nurseries has built itself a fine reputation for its bare root trees and shrubs. Over the years it has diversified to keep up with the changing markets. In the last decade, the trend in the nursery business has been an increased demand for containerized woody and perennial plants. To satisfy customer needs, a large expansion into these areas was undertaken and a larger propagation facility was needed.

Cuttings would need to be rooted not only for the field liners or sold as liners but for container-grown plants as well. In order to meet this demand, the Nord farm was bought in 1980. Since 1981, 90 polyhouses and a 45,000 ft^2 Van Wingerden gutter-connected range have been built. Still expanding, we are currently constructing a 1.5 *acre Hanois Nordic range.*

Back in the early 1980s when the first 20 polyhouses were built at the Nord farm, a small percent of these were used for propagation year round. The others were used solely for softwood cutting propagation. The rooted cuttings would be dug in the fall and be placed in cold storage and graded that year. This meant that those houses would remain empty until the following spring—the challenge was on to find the most effective use for those houses.

It wasn't long before a couple of interesting ideas were floating around. One of those ideas came from a couple of Bailey salesmen whose customers had asked them if they knew of a good source for bedding plants. Their original supplier was downsizing and not able to supply the amount these customers needed. The second related idea was given to Rod Bailey by a farmer friend that wanted to know if the nursery would start some vegetable liners so he could grow mass quantities of peppers and tomatoes. Thus the bedding plant program was implemented.

It didn't take long to get the ball rolling. With help from a Ball Seed Company seed representative, and the propagation farm staff and local growers, an intense effort was made to make the bedding plant production a successful operation at Bailey Nurseries.

THE TRANSITION

How do you take a staff of woody plant propagators and make them greenhouse growers? In this industry you're usually one or the other. It took a lot of research, brainstorming, team effort, and networking. We had to simulate the same growing conditions in a real greenhouse range as best we could using polyhouses. Over the years, through trial and error, we have been able to achieve this goal. We have an excellent reputation for the quality of bedding plants we grow.

PLUG PRODUCTION

Seeding of annuals and perennials has come a long way in recent years. The advent

of the plastic plug tray would mean better quality transplants, more even germination, and less labor for transplanting. Technology of seed selection and development has improved, especially with annuals, over the years.

The first year a local greenhouse grower seeded the flats for us. We germinated the seed in our main shop. Then they were sent by heated truck to the polyhouse to grow on until transplant stage. The next year a chamber was built and the seeding and germination was done on site. The plugs were still grown on in polyhouses until 1990 when the Van Wingerden gutter-connected greenhouse was built. This house, like any house we were to build from then on, would have to be compatible for both our bedding plant program and our woody propagation needs.

The plug flats are filled with a commercial-plug mix on our Javo flat filler. They next go by conveyor to the seeding machine and then on to the top coater. If the cultivar we are seeding needs a cover of vermiculite or plug mix they will be given the proper amount of covering. The last stage is the water tunnel. The media will get just moistened before going on carts into our fog chamber.

Each culitvar may have its own germination requirements of light, temperature, etc. Once in the chamber we monitor the amount of fog. Too much and the media gets too wet. Too little and the seed will not get enough moisture during germination or the medium will dry. The object is to keep even moisture and temperature. The carts are put into lighted stalls. Lights give you more flexibility to get the largest percentage of germination in the chamber without the plants stretching. Each cultivar is different so we make detailed notes on how long we can leave that cultivar in the chamber and at what stage to take it out. The stages are: (1)just cracked (the radicle is out and going down into the media),(2) the cotyledon emerging, and (3) number of days after the cotyledon emerges.

Some plants such as snapdragons, alyssum, and marigolds tend to stretch fast so you would take these out with the cotyledon just emerging—about 2 to 3 days. Others, such as petunias and impatiens, do not stretch as fast and can be left in until cotyledons are expanded straight up—about 4 to 5 days. Begonias take a long time to start germinating and may stay in for up to 12 days.

When the plugs are ready to come out, the carts will be put into a heated trailer. The trailer will be taken to the plug house.

THE PLUG HOUSE

The plug house is a Van Wingerden (43,000 ft^2 gutter connected type).

We are able to heat and fill the bays one at a time. The bays have plastic curtains between them. To open up the next one we drop the curtain and heat that bay.

The wire-mesh benches each have a black bench cloth covering for more even heat distribution and more even drying. Polytubes run under the benches and are connected to a forced air heater—this arrangement provides the bottom heat. Four of these in each bay. Two auxiliary heaters supply heat for ambient air. Most greenhouse ranges use hot water pipes permanently installed under the benches. Since we do summer softwood propagation in this house we cannot have a permanent structure above the sand beds. The polytubes are easy to roll up when finished being used. So we sacrifice a little on the uneven heat we get from forced air.

The newly germinated seedlings will be placed on the benches. We maintain the proper temperature for each type. They will be acclimated by applying mist for 1 to 2 days until germination is complete. The six I.T.S. computerized booms are capable

of misting and irrigating in almost unlimited combinations. Plant types that damp-off easily are sprayed with a fungicide drench.

The plugs have different requirements according to the stage they are in.

- Stage 1. The germination stage, discussed above.
- Stage 2. We apply a low-phosphate fertilizer 13N-2P-13K CaMg to keep plants from stretching. Even while I am misting plugs to finish germination I have found a constant but low level of fertilization is very beneficial as nutrients can be leached easily from the small plug.
- Stage 3. In this stage the true leaves are out. At this point 100 ppm of fertilizer can be applied to strengthen the plants. It is still low enough in phosphorous to prevent stretching. We want to keep the plant as compact as possible. One method is growth regulators. The other way is to combine high light and negative diff. We leave the HID light on for 22 h. The more light the shorter the plants. Negative diff works this way: plants will generally put on their biggest "stretch" of growth during the morning hours during sunrise. Research has shown that if you reduce your nighttime temperatures just 5F starting 1 h before sunrise and ending 3 h later, then increase to normal daytime temperature, this will help eliminate top growth on most cultivars. Therefore, low fertilization, high light, and negative diff = less growth regulators.
- Stage 4. This is the holding stage. We want to tone the plant. This means lower temperature to harden any soft growth. Reduce fertilizer until the plant begs for it! We might fertilize every other watering. On flowering types we want to see flower bud initiation before plugs are to be transplanted. The reason for this is simple. If we get flower bud initiation, then after transplanting, the plants will not grow out of control by producing a lot of unnecessary foliage. This makes it much easier for the growers who will take care of the finished plant. High light through all stages helps achieve this!

In review, we need to produce a high quality plug that is short and compact, has a strong root system, flower buds initiated, and is disease and insect free.

Through the plug season (Jan to May) we will fill up all the benches in four out of six bays in the Van Wingerden gutter-connected range at least once. That's approximately 17,000 #512 plug trays and 3000 #200 plug trays. We do an additional 1000 #72 trays of seed and 2500 #72 trays of cuttings.

All cuttings and any plants bought in will immediately go into an isolation house to be grown on, rooted, and inspected before going in any other house.

TRANSPLANTING THE PLUGS

It is important that the plugs are transplanted at the proper time. Holding the plugs too long will increase the chances for the plugs to deteriorate, such as decreased vigor, stem rot, and the plant literally stalling out its growth. We have recently acquired a mechanical transplanter. To make the most of the machine the plug quality really needs to be good with a quality root system and short top growth. If the plants are too tall they tend to fall over. The plugs will be transplanted into their

final packs—4 packs, 6 packs, and 3½-in. and 4½-in. pots. From there they go into each available polyhouse. In each house the sand beds are leveled and a ground cloth is put over the sand for the trays to rest on.

As space opens up in the Van Wingerden gutter-connected range we will fill it up with pack material. Usually 3½-in. and 4½-in. pots go into the two bays with no benches. Then the benches are filled as we consolidate the remaining plug flats. As soon as the temperatures are warm enough during the day we push the benches outside and put transplanted flats on the ground. At night if temperatures are too cold the benches get pushed back in over the crop on the ground until the next morning. This utilizes the maximum amount of space. Hanging baskets are hung in each bay and in the driveway, so we basically have three crops at a time in this range.

One grower is assigned to a certain set of houses and is responsible for knowing their specific crop requirements. This includes shipping dates so plants are at the desired stage. They will then control the rate of plant growth, as outlined in our growers manual by controlling temperature, fertilizer, and water, along with informing our pest department of any problems they see.

CONCLUSION

How has the experience of growing bedding plants helped us improve our nursery propagation and growing techniques? As mentioned before, Bailey's was originally only growing bare-root stock. All propagation was done in sand beds. Now we found we can get a better quality juniper liner when we root these in #50 trays using soilless medium. Softwood cuttings that we can sell 1½ years from the field are planted mid summer from cuttings stuck that spring in flats.

Since we have a fog chamber with lights we were able to buy in unrooted tissue culture cuttings and root them in flats placed on carts. We've changed our methods over the years but that's how the idea got started.

The juniper cuttings we stick in flats are now put on raised benches with bottom heat, same as the plugs. Also, these houses and many softwood cutting propagation houses have the roll up side vents for better temperature and humidity control. This reduces diseases, such as *Phomopsis* blight on juniper.

Keeping the foliage dry on annuals at night is very important in preventing foliar disease. We have applied this same procedure with our softwood cuttings. Each taxa is treated so that no excess moisture will remain on the foliage over night.

Since the mist booms we use on our plugs in the Van Wingerden gutter-connected range are very versatile, we can use this house for rooting many plants where only small quantities are needed and be able to meet the mist requirement of each type. If a faster rooting type is ready to go off mist we can still mist the cuttings on either side.

We have found that the availability of information produced by the greenhouse industry is very up to date. Much of it pertains to media, fertility, and pesticides that can be of value to the industry in general.

In bedding plant production the effects of changes in pH and fertility such as high salt levels occur very rapidly. Because of this we are more aware now of the necessity to monitor this in all our production.

The addition of the bedding plant program at Bailey Nurseries has helped us improve our overall growing practices and maximize the use of our facilities.

FACILITIES AND EQUIPMENT

Seeding. (Note: Items 3-6 are linked by conveyer so handling is minimal).

1) ***Plug tray.*** We use #512, #200, #72 rounds, # = number of plugs/ tray.
2) ***Plug mix.*** Proper media for maximum aeration/porosity.
3) ***Flat filler.*** We use a Javo for plug flats and small pots.
4) ***Seeder.*** Many kinds available, we use a Blackmore.
5) ***Top coater.*** For seeds that require a covering of vermiculite or plug medium.
6) ***Water tunnel.*** To moisten media before plants enter the germination chamber.

Germination/Sweat Chamber.

- Well insulated, temperature controlled
- Fog - We use air-over-water method
- Lighted stalls - (optional) Some growers feel they can control germination better with lights, others will simply sweat the seeds then finish the germination on the bench.

The Plug House. Van Wingerden 43,000 ft^2 gutter connected.

- Divided into 6 bays, 4 of which have roll out benches.
- High intensity discharge lights above benches.
- Bottom heat—we use polytubes under the benches.
- Traveling irrigators—six I.T.S. computerized "smart" booms.
- Drip irrigation with hanging baskets.
- Bench cloth covers each wire-mesh bench section to put flats on for better heat distribution and more even drying.
- Q Com environmental-control system to monitor temperature, light, wind, humidity, etc. This system will control heat, cooling/ venting, or any other equipment that affects growing conditions.

POLYHOUSES

- Overhead heaters and cooling fans with polytubes.
- Ground tarps—to cover sand beds in propagation houses.
- All polyhouses built in the last 3 years have roll up side vents.
- Drip irrigation hanging basket lines.

Germinating Difficult Herbaceous Perennial Seeds

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Many perennials have a reputation for being difficult to germinate. It is not the complexity of the process, but rather the lack of information about germination requirements of particular seeds that leads to this misunderstanding.

I am going to discuss some of the basic issues that impact the germination of seeds in genera that are often perceived as intimidating, but are nevertheless very worthwhile growing.

A number of factors can affect the germination process. In many cases, it is not a single factor, but a combination of factors that produces success. The most frequent obstacles to germination are:

1) Impervious seed coat.
2) Lack of long-term viability or complex requirements due to age of seed.
3) Different conditioning requirements.
4) Different temperature requirements at germination.

Specific requirements often apply to many members of a family of plants. For example, many legumes have impervious seed coats. These need to be physically abraded in some manner. Seed from the Umbelliferae and Ranunculaceae generally needs to be fresh when sown in order to achieve high germination percentages. As with most matters related to plants, these generalizations are only useful to a point. There is always variation within a given group.

Plants with hard seed coats are actually very quick to germinate and often need no conditioning other than breaking the seed coat in order to allow moisture to pass through.

Baptisia species are a group of plants with this requirement. There are many good species, some of which are uncommon. Seed is often unavailable or obtainable only in small quantities.

In order to obtain maximum germination, seeds are soaked for 24 h after which any seeds that have absorbed enough water to increase in size are removed and planted. A small notch is filed in the seed coat of the remaining seeds, and these are then soaked an additional 24 h, then planted. This procedure usually results in a high germination percentage within a week.

An alternative method is to abrade the seed between two sheets of sandpaper, although when seed is scarce, the filing method produces a higher germination percentage.

A requirement for many genera is freshness of seed. In these cases it is important to have a seed source that will ship seed in a timely manner. In many cases, it is quite worthwhile to grow stock plants in order to have a reliable supply of fresh seed. Some worthy plants falling into this category are *Aconitum, Clematis, Cimicifuga, Paeonia, Glaucidium, Helleborus*, and *Thalictrum*; all members of the Ranunculaceae. Some plants from other families where freshness of seed is important are *Corydalis, Astrantia, Adonis*, and *Kirengeshoma*.

The very definition of freshness is highly variable. For many seeds, freshness can

mean refrigerated storage after harvest, followed by sowing within a month or two. For others sowing must occur immediately after harvest. These include *Aconitum, Glaucidium, Helleborus, Anemonopsis, Astrantia,* and *Adonis*.

Conditioning is necessary for all seed germination. This is the process by which physical or chemical treatments are used to overcome delay mechanisms in seed. Many of these treatments require alternate periods of time when the seed is exposed to different temperature regimes, usually under moist conditions.

Deno (1993) has run tests on thousands of species and provides useful information on different conditioning requirements in his book, *Seed Germination Theory and Practice.*

These tests provide much practical information as shown in the germination requirements of *Cimicifuga racemosa*. This is a plant that blooms late in the summer with seed ripening in early fall. One might come to the conclusion that since *Cimicifuga* seed ripens just before the onset of winter, it needs a period of cold-conditioning to start the germination process. In fact, this seed first requires a period of time under moist conditions at room temperature, followed by a time period at 40F under moist conditions. It then germinates at 40F. *Cimicifuga* is in the Ranunculaceae and seed freshness has an impact on germination percentage also.

Fresh seed is placed in a plastic bag with a small amount of moist medium and stored at room temperature for 3 months. The bag is then placed in refrigeration at 40F for 2 to 3 months after which germination will commence in the bag. Seed is then removed from the bag and spread out in a flat of soil mix and grown on in a cold frame. This method saves us one year in production time.

It should be noted that we are growing in Zone 5. In areas with milder fall weather, there may be a long enough period of warm weather to condition seed outdoors in one season.

Some other plants that require conditioning at 70F followed by a period at 40F are *Adonis*, some *Clematis, Corydalis, Helleborus*, and *Paeonia*.

The largest group of seeds have relatively simple needs and require one cold period of about 3 months. They will then germinate when the temperature rises. This is especially true when seed is fresh.

However, some seed requires three or more conditioning periods to germinate. In our experience, *Podophyllum hexandrum* and *Veratrum* species require two 3 month cycles of 70F, and two 3 month cycles at 40F. To make things a bit more challenging once the seeds germinate, they produce a set of leaves, then proceed to sit for another year without growing appreciably.

Two plants which we grow, *Kirengeshoma palmata* and *Meconopsis betonicifolia*, require only one conditioning period at 40. Germination begins at this temperature, and it is important to keep the seedlings growing at or near that temperature until they are well established, probably 6 to 8 weeks.

While it is relatively easy to grow young plants of *Meconopsis* under controlled conditions, the real challenge is to find suitable locations for growing it outside, unless you are located in Vermont or New Hampshire.

In our climate *Kirengeshoma* is quite hardy, but the length of the season is insufficient for ripening seeds on plants grown outdoors. We find it worthwhile to keep a stock plant in a container which can be moved into a greenhouse when necessary for the express purpose of ripening seeds. Making this extra effort guarantees a reliable supply of fresh seed.

It is often the combination of previous knowledge of a given plant, with our experience in germinating its seed, and perhaps most importantly with what we know of the plant's natural habitat that results in the discovery of an efficient germinating procedure. For it is when we succeed in our attempts to mimic those natural conditions that we can overcome dormancy in the seed, and are rewarded with germination.

LITERATURE CITED

Deno, N.C. 1993. Seed Germination, Theory and Practice. 2nd edition. State College, Pennsylvania.

Propagation and Production of Wildflowers.

Heather McCargo
P.O. Box 203 Brooklin, Maine 04616

INTRODUCTION

The topic of this paper is propagation and production of wildflowers. It is based on the work I did from 1990 to 1995 as propagator at Garden in the Woods, the botanic garden of the New England Wild Flower Society in Framingham, Massachusetts. The nursery at Garden in the Woods was established to propagate plants for the garden's collection, to conduct research on propagation and cultivation techniques for native species, and to produce plants for sale to the general public. Every year approximately 16,000 pots of nursery-propagated native plants (mostly herbaceous wildflowers) are sold from this facility to support the Society's various education and conservation programs.

When I became propagator, I wanted my nursery practices to reflect the Society's mission of native plant conservation. In my mind, this means plant propagation that preserves the genetic diversity inherent in wild native plants and cultivation practices that are conserving of natural resources. I see traditional nursery practices which emphasize vegetative propagation of "superior clones" and a reliance on sterile peat-based soil mixes nourished with petroleum fertilizers as counter to this mission. Instead, I focused most of my propagation on seed germination out of doors in flats or raised beds, and I developed an inexpensive compost-based potting mix that eliminated the need to use peat moss and fertilizers made from fossil fuels.

SEED PROPAGATION

Because much of our native flora has been overlooked by the nursery trade, many species have not been altered by plant domestication and breeding. Hence these plants can be propagated the way they do in nature—from seed. Seed propagation of wild flowers has several advantages:

- Plants grown from seed exhibit a wide range of genetic diversity, unlike plants which are vegetatively propagated and are genetically identical to the parent plant. Genetic diversity in wild plant populations enhances a species' ability to adapt to changing conditions. This is particularly desirable for plants that are used by

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ecologists and designers for habitat restoration, where the hope is that once established, the plants will grow and reproduce with minimal human interference. Much of the interest and demand for wildflowers today is for this kind of use. To fill this niche as propagators, we need to think in terms of maintaining biological diversity in plants produced by the nursery trade so they have the best chance of adapting to changing environmental conditions. Vegetative propagation of "superior clones" may have a role for plants destined for ornamental gardens, but not for natural landscapes.

- Seed is generally inexpensive. Often a large number of seeds can be collected from one or several stock plants yielding many plants for sale. Cuttings or divisions from the same stock plant often yield much fewer plants. Also, if the seed is being collected from wild plants, the impact of removing a small percentage of the seed from a healthy wild population is minimal.
- Seed propagation does not require expensive or sophisticated facilities. Seeds can be germinated outdoors in beds or flats. Seed that needs cold stratification are taken care of by the freeze and thaw of our northeastern winters, and seed which must be sown fresh will not be thrown off their natural cycle by the artificial climate of a greenhouse.

There are several procedures that I follow based on the germination requirements for various species:

No Pretreatment Required. Seeds that need no pretreatment can be stored dry in the refrigerator and sown outdoors in early spring. Examples include: *Aquilegia canadensis*, *Arisaema triphyllum*, *Asclepias tuberosa*, and *Solidago* spp.

Cold Stratification. Seeds that need cold stratification to germinate can be sown outdoors in late fall. Examples include: *Anemonella thalictroides*, *Cornus canadensis*, *Dodecatheon meadia*, and *Sarracenia purpurea*.

Fresh Seed. Seeds which need to be sown immediately upon ripening. If the seeds are allowed to dry out, they usually will not germinate. Most of these species seeds ripen from late spring through late summer and germinate the following spring. Examples include: *Actaea* spp., *Caltha palustris*, *Clintonia* spp., and *Hepatica* spp.

In some instances, species which disperse their seeds quickly or are carried off by ants are easiest to handle by letting seed drop into a growing bed and then later transplanting the seedlings into pots. Examples include: *Mertensia pulmonarioides* (syn. *M. virginica*) and *Sanguinaria canadensis*.

Some species take 2 years to germinate. Examples include: *Polygonatum* spp., *Smilacena racemosa*, *Trillium* spp., and *Uvularia grandiflora*.

Alternating Warm and Cold. Some species need a warm moist period of approximately 3 months before cold stratification to germinate. They are sown outdoors in spring and germinate the following year. Examples include: *Cimicifuga racemosa* and *Lilium canadense*.

After sowing, all seed flats are covered with a thin layer of coarse sand. This helps prevent the seeds from splashing out in the rain. Responding to the local environ-

ment, seeds sown outdoors will germinate when soil temperatures are optimum for each species, which can vary from the cool and frosty temperatures of early spring to the heat of early summer. The generally good air circulation out of doors (as opposed to in a greenhouse) reduces or eliminates the incidence of damping off and other problems such as fungal gnats. Because some species can take a year or more to germinate, I am careful to keep the flats weeded. If rodents are a problem the flats can be covered with wire screen. Seedlings are potted, often several to a pot, when they start to crowd the seed flats. If there is an oversupply of a species, they can be successfully held in the flats until needed. While some of the species which are slow to germinate and grow, such as *Trillium*, may be artificially accelerated with hormones or tissue culture, this outdoor method is simple and free of pest and disease problems. For a busy propagator, this method has many advantages.

COMPOST-BASED POTTING SOIL

Many modern horticultural practices are polluting to the environment and wasteful of limited natural resources. This has a negative impact on biological diversity in wild ecosystems. Therefore, I sought alternatives to the nursery practices that I saw as unsustainable, i.e. the widespread use of peat moss which is an extremely slow-forming old-growth product and fossil-fuel bases fertilizers which are not renewable and can be polluting to manufacture.

As an experienced organic gardener, I know that most plants flourish when grown in compost and that healthy plants are often resistant to pests and diseases. As a primary ingredient in a potting soil, compost can replace both the peat moss as a source of organic matter and chemical fertilizer because it slowly releases nutrients to the plants. Compost also contains beneficial microorganisms which aid plant growth and help defend against harmful plant pathogens.

A commercially produced compost made from chicken manure, fruit refuse, and wood pulp that is hot composted to kill weed seeds and screened to make a uniform product is used. It has a pH of 6.5 which is ideal for many plants. To this mixture a small amount of vermiculite and perlite—to lighten the mixture—and varying amounts of sand—depending on the moisture and drainage needs of each species—is added. Coarse sand is very beneficial to many natives grown in pot culture, even when using a commercial potting mix. A typical mix is compost, vermiculite-perlite, and sand (1 : 1 : 1, by volume). When a more acidic mixture is needed rotted pine bark is added. When I am growing bog plants such as sundews and pitcher plants, I still use sphagnum peat moss, which has the correct pH and nutrient levels for these plants.

This composed-based mixture has worked well. Plants are healthy and strong from seedling to maturity, and pests and disease in the seed flats and potted plants have been negligible. It also is less expensive than the peat and fertilizer mixture we had previously been using.

CONCLUSION

I have been very satisfied with this low-tech system of wildflower production. Along with cheaply producing thousands of healthy plants and a clean environment, the nursery is a rich and diverse place for a variety of beneficial creatures, such as birds, insects, and earthworms. This makes nursery work an enjoyable outdoor experience. I think these practices could be successfully used by larger commercial nurseries.

New Perennials to Propagate

Pierre Bennerup
Sunny Border Nurseries, P.O. Box 483, Kensington, Connecticut 06037

The perennials I have chosen to present today should be on every perennial growers list. Although relatively new, they are not B.I.O. plants, (meaning "Botanic Interest Only," to quote John Elsley of Wayside Gardens, Hodges, South Carolina).

First is the Galaxy Series of Achilleas. This group was originally hybridized by Heinz Klose in Germany by crossing *Achillea millefolium* with *A. taygetea* (Bot. Ed. note: the species *taygetea* is not a valid name) and *A. filipendulina*. The resulting crosses and back-crosses have yielded colors from pure white to shades of yellow, pink, salmon, red, and bronze. In combination with each other or with other border perennials, they are nothing less than dazzling. They bloom off and on from late spring to fall. They are easy to propagate and grow from division or tip cutting in early spring or any time during the growing season a week or two after they have been severely dead-headed. In general, these plants should be dead-headed because they are fertile and the seeds will be variable. If you don't wish to maintain the individual cultivars of this series, they can easily be done by mixed seeds.

Angelica gigas. *Angelica* is actually a biennial or monocarpic plant. Its only known wild location is on an army base in South Korea. Rumor has it that Barry Yinger negotiated a live mine field on that base in order to collect seeds from this rare species. Its mahogany stems and bronze-red flowers make a bold statement in the perennial border. Germination of seed is fairly straight forward but the seeds must be collected and sown as soon as possible after ripening since they are short-lived. The plant will take sun or part shade and tolerates all normal growing conditions in our climate. It performs well in Zones 3-8.

Baptisia pendula. *Baptisia pendula* (also known as *B. lactea*) is a 30- to 36-in. vase-shaped plant which has purple stems, lime green leaves, and milky-white flowers in late May and June. It has a very architectural look throughout the growing season and makes a dramatic center of focus in the garden. Unlike other *Baptisia* species, the seed pods hang down, thus the species name *pendula*. It can be propagated by tip cuttings in the early spring but is more commonly done by seed. Like many members of the pea family (Fabeacea), the seeds have a tough cellulose coating and may benefit by some form of scarification but they don't require winter stratification. The plant is not fussy and has no disease or pest problems to my knowledge. It will take full sun or part shade and is hardy from Zone 4 to 9.

Lobelia cardinalis. *Lobelia cardinalis* 'Ruby Slippers' is probably a cross between *L. cardinalis* and *L. siphilitica* 'Alba' back-crossed to *L. cardinalis*. The result achieves a sparkling ruby-red as compared to the blood red of the native cardinal flower. For unknown reasons it tends to bloom later than the species and is one of the only bright reds blooming in our garden in Sept. to Oct. Propagation by tip cutting or division is easy in the early spring. Like most cardinal flowers, it prefers moist, loamy soil and will prosper in full sun or part shade. It is hardy from Zone 4 to 8.

Salvia verticillata. *Salvia verticillata* 'Purple Rain' has smokey purple spikes from late spring to hard frost. It will bloom even more heavily if the spent spikes are dead-headed regularly. Unlike the better known *S. nemorosa* types, 'Purple Rain' tends to be rather lax of habit, making it perfect for tumbling over the front of the border or softening the lines of harsher or more linear-foliaged plants. Its delicate, pastel shade blends well with almost any color and lends an aura of subtlety to the summer border. This cultivar propagates easily by tip or lateral cuttings during most times of the year but when the plant is blooming it should be dead-headed before cutting. 'Purple Rain' is virtually trouble free. It is tolerant of most garden conditions but need full sun to perform at maximum. It is safe in Zone 6-9 and usually all right in Zone 5.

Propagation of *Daphne ×burkwoodii* 'Carol Mackie'

John Padua
Cobble Creek Nursery, RD 2 Box 3850, Bristol, Vermont 05443

Daphne ×burkwoodii 'Carol Mackie' is a beautiful landscape plant with variegated foliage and fragrant light-pink flowers. It grows 3 to 4 ft high and 4 to 6 ft wide. This plant has proven to be quite winter hardy in Vermont, at least to -40F, and grows well in full sun or part shade. There are apparently two or more clones being sold as 'Carol Mackie' in the trade. My discussion will be on my experience with the clone that originated in Vermont in the late 1960s as a branch sport on *Daphne ×burkwoodii* 'Somerset'.

I began growing and propagating 'Carol Mackie' in 1982. The first summer that I took cuttings I got better than 90% rooting. These plants grew like weeds in the field for the next few years. It was easy to get excited about such a nice new plant growing so well. The *Daphne* gods must have been with me on that first crop! For the next few years rooting results were erratic and I experienced some difficulties growing the plant, especially in containers. We have since worked out some of the problems, but 'Carol Mackie' can still be frustrating to root and grow. I would like to share some of my observations, successes, and failures.

We take most of our cuttings between mid July and mid August. Our experience has been that cuttings taken earlier than this are generally too soft and rot at the base. I look for the new growth to harden a bit, but still be growing at the tip. The bark near the base of the cutting should be starting to turn a light brown color. The wood of *Daphne* is quite tough and stringy so it is important to have a very sharp pruner or knife to take the cuttings. The stock plants that we use are 3- to 6-year-old field plants with vigorous growth that have received good soil fertility. To prepare the cuttings we pinch out the growing tip and strip the leaves off of the bottom third of the cutting. Ideally we strip the lower leaves with one quick downward pull. This doesn't always work. Some batches of cuttings, usually the softer ones, need to have their leaves plucked off individually because the petiole does not separate cleanly from the stem and we end up stripping off too much bark. Our cuttings are about 4 in. long.

Sanitation is very important since *Daphne* cuttings are prone to fungus problems under mist. We disinfect flats, benches, and work areas with a 10% bleach solution. Isopropyl alcohol is used on pruners and hands. Our rooting medium is super course perlite and medium grade vermiculite (1 : 1, v/v). We try to use a flat that is at least

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3 1/2 in. deep so that the base of the cutting is well off the bottom of the flat where the medium is wettest. We dip the cuttings in powdered rooting hormone with 3000 ppm IBA. We try to give the cuttings adequate space so that the leaves do not touch. We use a Mist-a-Matic system for intermittent mist. Our propagating house is a 14-ft-wide polyhouse with whitewash for light shading. We do not have heat in the house so night temperatures fluctuate. Daytime temperatures run around 90 to 100F on sunny days. The mist is set so that it comes on for a few sec about every 10 min during the heat of the day. The 'Carol Mackie' cuttings would probably root better with less mist, however, we need to set the mist to accommodate a wide range of deciduous shrub cuttings we are rooting at the same time. Excessive mist causes leaf drop and stem rotting. For this reason we pull the flats of cuttings from the mist early in the rooting stage at about 3 weeks. The flats stay in the same house and are hand misted as needed and gradually weaned from the mist as they root further. Transplanting begins 5 to 6 weeks after the stick date. The rooted cuttings are potted into either 3-in. peat pots or 2-3/8-in. × 5-in. tree bands. Deep square pots or peat pots are used because 'Carol Mackie' roots will grow to the bottom of a round plastic pot and circle around. This creates serious problems later in the production cycle. We use a well-drained medium of a commercial peat lite mix with coarse sand added. The transplants go directly outside under burlap or shade cloth for a few days to help acclimate the plants to the full sun. Liquid feeding, which began as soon as the cuttings started to root, continues until about mid September. Cuttings that are stuck later than mid August remain in the flats until the following spring. We overwinter our cuttings and transplants in either an insulated coldframe or in a root cellar. Winter survival rates have been variable over the years. I believe that *Daphne* 'Carol Mackie' would overwinter best in refrigerated cold storage or a greenhouse with minimum heat where the temperature could be kept fairly constant at about freezing. Since we have neither of these facilities, we try to come as close to those conditions as possible.

The following spring the transplants are potted into a true 1-gal container or lined out in the field. Container production is tricky. The soil mix needs to be very well drained, the pH slightly acid to neutral, and the soil needs to dry out between waterings. The field plants grow vigorously in well drained soil with the proper pH. They transplant well in spring, late summer, and fall.

One of the problems that we have experienced with *Daphne* 'Carol Mackie' is that an occasional branch will revert back to green leaves. These can simply be pruned out. More serious problems involve the structure of the plant. Weak branch crotches tend to split easily, especially under snow and ice loads. The main trunk can become weak and floppy, which is usually the result of a circling or one-sided root system. Stem dieback, caused by *Nectria* or *Fusarium*, usually enters through a wound or branch split. I have not seen any insect problems on 'Carol Mackie'.

Although 'Carol Mackie' can be frustrating and the results erratic, we have been able to get our rooting percentage up to around 80% the past two seasons. The important things to remember for successful rooting and growing of are: start with healthy vigorous stock plants, take the cuttings at the proper stage of growth (not too soft), use a well-drained medium, be careful with mist and water management, soil pH should be slightly acid to neutral, and give cuttings and container plants adequate winter protection. With these things in mind and a little luck, this plant can be propagated and grown successfully and profitably.

Pesky Problem with Propagation of *Acer palmatum*: *Pseudomonas*

Nancy Jo Vermeulen
John Vermeulen & Son, Inc., Neshanic Station, New Jersey 08853

I would like to broaden the assigned topic of my paper from the propagation of *Acer palmatum* 'Red Feather' to include the production of *A. palmatum* cultivars in general, specifically a pesky disease problem we have experienced for several years.

In preparation for this paper I could not find any reference to *Pseudomonas* in any of our Proceedings nor in any of the books in our library. It appears to be a relatively recent disease affecting Japanese maples and because of the extent to which it affects the success, or lack of it, of our grafted Japanese maples crops it needs to receive much more attention. I hope by this paper to generate that attention, hopefully leading to successful preventive measures.

Pseudomonas, also known as "black stem", is a soil-borne bacteria which consists of several strains. Our first evidence of the disease in our program dates back about 8 years. We graft our maples in February on understocks which are potted the previous spring. Most of these were what we call low grafts (about 1 to 1-1/2 in. above the soil level) and are plunged into a peat/perlite medium in greenhouse benches after grafting. The remaining are top grafted, either 12 or 20 in. high. The graft union is covered with a mixture of part beeswax and paraffin.

In our first experience we lost a good portion of the bench crop from what appeared to be a blackening of the bark of the understock at the base. This was also observed in its vascular system when the uncallused scion was removed. Top grafts were not as affected. In the 2 years following we continued battling the problem before hearing from others who were having similar experiences, subsequently diagnosed as resulting from *Pseudomonas*.

As a result of many discussions with others it was determined that the disease is translocated in a moist warm environment such as the peat/perlite medium we were plunging them into. The top grafts were not plunged but set on benches or the floor. It appeared that the exposure to circulating air and their not being plunged kept the disease from spreading. At one point we thought the disease entered through the scionwood but now have determined it's in the understock.

With this understanding it was necessary to learn how to treat it. We found that the University of Oregon has done the most extensive research on *Pseudomonas* because of the extensive propagation of Japanese maple in the Northwest. Treatments that were recommended relied on the use of Cocide (copper hydroxide) and Agristrep (streptomyacin). Treatment begins immediately after potting of understocks in the spring. Treatment begins with a combination of Cocide and Agristrep sprayed as a drench followed by a second application 1 week later. This is followed by alternating applications of each pesticide every 2 weeks until dry warm weather, which for us is about late June. The spring program is repeated when cool, moist weather returns (about September) and continued until understocks are brought into the greenhouse. At the time the grafts are plunged in the medium they should be watered in with the addition of the Cocide/Agristrep combination.

After we started this program we noticed a marked improvement in the percentage of healthy successful grafts. However, we still see the presence of some *Pseudomonas* so we are not satisfied that it is 100% effective. This may be because we have recently learned that there is evidence of strains of Pseudomonas that are resistant to this treatment. So the question still remains: **JUST WHERE ARE WE WITH THIS DISEASE?**

An Oregon nurseryman, who believes that prevention is fundamental to growing disease-free plants has apparently found a way to produce *Pseudomonas*-free seedlings by growing in plugs without exposure to native soils. Understocks which we have purchased from him seemed to have proven him correct.

This experience leads me to believe that a fundamental basic knowledge of plant science and plant diseases is necessary for everyone in our industry, especially plant propagation. This will lead to proper preventive practices which will in turn yield healthier plants and better crops.

Rooting Lilacs from Softwood Cuttings

C. Peter Nickerson
Robert Baker Nurseries, 1700 Mountain Rd., P.O. Box 434, West Suffield, Connecticut 06093-0434

I'd like to begin my talk on lilac rooting with a little history. Prior to 7 years ago, French hybrid lilac cuttings were taken the first week of May from a stock block or containerized material. Very soft cuttings were taken and treated with IBA (indole-3-butyric acid) in talc or with an IBA solution [water and alcohol, (1 : 1, v/v)]. Results were very uneven and the continued growth of the liners was uncertain, at best.

As demand for lilacs from our customers increased, tissue-cultured lilac liners were purchased to supplement the lining-out stock propagation was generating. Cuttings were made from these young plants and we were very successful in rooting the cuttings from these juvenile micropropagated liners. I wondered if the higher rooting percentages would continue through successive generations. Because additional tissue-cultured liners were purchased for a second spring, I was able to compare the results from these plants with cuttings from second generation tissue-culture liners. Our rooting results were quite good. Most of the 20-plus cultivars tried rooted over 80%, whether the cuttings were from micropropagated liners or second-generation micropropagated liners. The juvenility of the parent plant from which the cutting was made seemed to be the most important factor.

As far as actual propagation of lilac cuttings, we start of course with our young liners. They are kept at 35 to 40F most of the winter. As their leaves fall in late autumn, we blow the leaves off the plants and onto the greenhouse floor, where they can be raked up and disposed of. The plants are pruned to about a 2-in. height. In mid February, the night time heat is increased to 55F. The liners begin to grow and by late March, the new growth is long enough to use for cuttings. Enough length of stem is removed to allow a two-leaf and one-node cutting to be made. We try to finish our wood gathering by 10 AM so the cuttings are fresh and turgid.

The cuttings are made in a work room next to the sticking greenhouse. After being prepared, they are dipped in one of two IBA preparations. For French hybrids, we

After we started this program we noticed a marked improvement in the percentage of healthy successful grafts. However, we still see the presence of some *Pseudomonas* so we are not satisfied that it is 100% effective. This may be because we have recently learned that there is evidence of strains of Pseudomonas that are resistant to this treatment. So the question still remains: **JUST WHERE ARE WE WITH THIS DISEASE?**

An Oregon nurseryman, who believes that prevention is fundamental to growing disease-free plants has apparently found a way to produce *Pseudomonas*-free seedlings by growing in plugs without exposure to native soils. Understocks which we have purchased from him seemed to have proven him correct.

This experience leads me to believe that a fundamental basic knowledge of plant science and plant diseases is necessary for everyone in our industry, especially plant propagation. This will lead to proper preventive practices which will in turn yield healthier plants and better crops.

Rooting Lilacs from Softwood Cuttings

C. Peter Nickerson
Robert Baker Nurseries, 1700 Mountain Rd., P.O. Box 434, West Suffield, Connecticut 06093-0434

I'd like to begin my talk on lilac rooting with a little history. Prior to 7 years ago, French hybrid lilac cuttings were taken the first week of May from a stock block or containerized material. Very soft cuttings were taken and treated with IBA (indole-3-butyric acid) in talc or with an IBA solution [water and alcohol, (1 : 1, v/v)]. Results were very uneven and the continued growth of the liners was uncertain, at best.

As demand for lilacs from our customers increased, tissue-cultured lilac liners were purchased to supplement the lining-out stock propagation was generating. Cuttings were made from these young plants and we were very successful in rooting the cuttings from these juvenile micropropagated liners. I wondered if the higher rooting percentages would continue through successive generations. Because additional tissue-cultured liners were purchased for a second spring, I was able to compare the results from these plants with cuttings from second generation tissue-culture liners. Our rooting results were quite good. Most of the 20-plus cultivars tried rooted over 80%, whether the cuttings were from micropropagated liners or second-generation micropropagated liners. The juvenility of the parent plant from which the cutting was made seemed to be the most important factor.

As far as actual propagation of lilac cuttings, we start of course with our young liners. They are kept at 35 to 40F most of the winter. As their leaves fall in late autumn, we blow the leaves off the plants and onto the greenhouse floor, where they can be raked up and disposed of. The plants are pruned to about a 2-in. height. In mid February, the night time heat is increased to 55F. The liners begin to grow and by late March, the new growth is long enough to use for cuttings. Enough length of stem is removed to allow a two-leaf and one-node cutting to be made. We try to finish our wood gathering by 10 AM so the cuttings are fresh and turgid.

The cuttings are made in a work room next to the sticking greenhouse. After being prepared, they are dipped in one of two IBA preparations. For French hybrids, we

use Dip-n-Grow diluted 1 ounces/5 ounces (water) plus 1/2 teaspoon of the K-IBA (potassium salt of IBA). For other easier-to-root types like 'Miss Kim' and 'James McFarlane', we use Dip-n-Grow (1 : 9, v/v) by itself. The cuttings are stuck in sand flats in a pit house with 25% shade, frequent misting, and very little ventilation. Misting is gradually reduced and ventilation increased as cuttings begin to root, often within 3 weeks. The cuttings are periodically drenched with Banrot or sprayed with Greenshield to control diseases.

As the roots develop, we liquid fertilize with 200 ppm nitrogen on a regular basis. It is important to get them back into growth in order to get the best liner for the following spring. This is relatively easy with the March/April cuttings and more difficult with cuttings stuck in May. The rooted cuttings after hardening-off are potted into cell packs using a peat and sand mix (2 : 1, v/v). I should add that our water pH and carbonate levels are high enough that we can get away with using a low-pH medium like peat/sand. The pH rises as time goes by. The potted liners are watered, fertilized, sprayed, and sheared as needed.

This growing scheme works well for us because we can dedicate a large portion of a gutter-connected greenhouse to lilacs. Additionally, our lilac liners are not bedded out until early June (which gives us the opportunity to get the juvenile cuttings off the liners to be bedded out).

While we have been more successful rooting lilacs than in the past, there are still problems. Foremost is bacterial lilac blight, *Pseudomonas syringae*. We rotate sprays of Agristep and Greenshield along with a culling regime. As different cultivars become popular and others go by the wayside, we hope to maintain a high level of production to meet our market needs.

Propagation of Hydrangeas at Half Hollow Nursery

Bruce L. Amundsen
Half Hollow Nursery, P. O. Box 652, Laurel, New York 11948

INTRODUCTION

With the recent popularity of hydrangeas comes renewed interest in their propagation. Following is an overview of the most common methods currently used for popular taxa with specific techniques used at Half Hollow Nursery. Methods using seed, layering, tissue culture, and cuttings are discussed; propagation from cuttings is emphasized, since this technique is the easiest and most cost-effective.

METHODS OF PROPAGATION

Seed. Growing hydrangeas from seed is easy for most species since they have no dormancy and will germinate without pretreatment. The seed is small and therefore I suggest shallow sowing in the greenhouse during early winter using standard media at a temperature of approximately 70F. *Hydrangea anomala* ssp. *petiolaris* (climbing hydrangea) is one exception—germination is improved by cold stratification (moist chilling) for 2 to 3 months before sowing. Seed can be placed in a plastic bag with a damp medium, such as peat-lite, sealed, and refrigerated at around 40F for the stratification period.

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Layering. Although slow, this method may be useful where only a few plants are desired and if space for the mother plant is not limiting. Layering has been demonstrated for the following species: *H. paniculata* 'Grandiflora' (pee-gee hydrangea), *H. aspera* ssp. *aspera*, and *H. quercifolia* (oakleaf hydrangea). The French or continuous method has been used and will probably work with other species and cultivars. Propagation from cuttings is usually a faster method and therefore generally favored.

Tissue Culture. Several *H. macrophylla* (bigleaf or florist's hydrangea) cultivars and possibly others are propagated from tissue culture. Plants grown from tissue culture tend to be free from disease or pest problems which may accompany cutting-grown plants, and also tend to have a very bushy habit. This method is useful for rapidly increasing inventory of a new cultivar.

Cuttings. Because it is so simple and reliable for almost all hydrangea species and cultivars (with the possible exception of *H. anomala* ssp. *petiolaris*), I recommend this method over all others. By following a few basic procedures outlined here you should encounter no major problems.

Timing. Cuttings can be taken almost any time, from softwood to hardwood. Advantages of summer propagation are that no bottom or additional heat is necessary and a salable plant can be produced much faster. I have had best results taking softwood cuttings in June or July from current season's growth firm enough to snap. Cuttings should be collected in early morning when stock plants are fully turgid and then stripped to leave 2 to 4 leaves. Leaves should be left uncut if possible, but some larger-leaved types, such as *H. quercifolia*, may need to be trimmed. Cuttings should be taken approximately 4 to 6 in. long and kept moist until stuck. No wounding is necessary.

Hormone. Use of a hormone improves rooting, although concentration is not critical. Some authors call for a liquid dip in IBA or K-IBA at approximately 500 to 5000 ppm or dry dip in talc-based powder at 3000 to 8000 ppm. I use Wood's 1 : 20 (v/v) quick dip with good results.

Water Control. The literature recommends using mist, fog, or high humidity chambers (e.g. polyethylene plastic tents, cold frames, or burlap clouds). I use mist timed to keep foliage wet from dawn to dusk with as little runoff as possible. Gradually wean off or reduce mist as rooting starts, usually after around 4 to 6 weeks.

Medium. A well-drained medium, such as a peat-and-perlite-based mix, is essential for good aeration, rooting, and disease management. Cuttings rooted during the dormant season or under mist require a more porous medium than cuttings rooted during the summer or under fog. Under mist, I usually use a mix containing coarse perlite and peat moss (7 : 3, v/v) with no other additives. Prepared cuttings are then stuck in 50-cell Pro-trays (cells approximately 1.8 in. diameter, 2.5 in. deep, 2.25 in. on center). Although this is rather crowded for such large cuttings we are still successful despite our space constraints. If possible, however, I would recommend using trays with a wider spacing between cells.

After Care. After approximately 4 to 6 weeks, plants should start rooting and can be weaned from high humidity and hardened off. When roots appear and are

sufficiently large, fertilize lightly or transplant to a fortified mix containing a low level of fertilizer. Cuttings can be lifted at 6 to 8 weeks. Plants are pruned often to develop a desirable bushy form. We typically transplant around mid to late August into a mix containing fine composted pine bark and well-aged leaf mold (1 : 1, v/v) fortified (per cubic yard) with 5 lb dolomitic lime, 1 lb of triple super phosphate, and 2.5 lb (=1 lb N equivalent) of 20N-3P-10K slow-release fertilizer. Plants are transplanted to 18-cell trays (3 in. × 3 in. × 3.5 in. deep) and overwintered in a greenhouse at 40F. Cuttings should be checked often during rooting. Our success rate runs 84% to 99%. Among cultivars we propagate, *H. quercifolia* tends to be somewhat more difficult to root and has slightly higher losses than other hydrangeas.

Hydrangea anomala* ssp. *petiolaris. This plant is an exception among hydrangeas, being more difficult to propagate than other popular species. A summary of guidelines for producing rooted cuttings follows.

Timing. Softwood cuttings should be taken as early as possible—around May-June is best—before wood turns brown and flower buds begin to form. New leaves should not yet be fully expanded (i.e. around 1/2 size). Some authors recommend forcing and heavily pruning stock plants to produce a high level of juvenile growth. Others recommend taking cuttings with a small portion of the old wood. Double wounding is also recommended to improve rooting.

Hormone. A liquid dip containing 8000 to 10,000 ppm IBA is recommended; either Wood's from 1 : 5 or 1 : 8 (v/v), or a talc powder dip at 8000 ppm can be used.

Water Control. Either mist or fog can be used.

Medium. A very well-drained peat-, perlite- and/or sand-based medium is usually called for. It is important to maintain the root zone at 70 to 75F, using bottom heat, if necessary.

After Care. Bark splitting from freezing is a common problem, so dormant plants should be stored in a protected facility above 32F for the first winter and perhaps for the second winter as well.

CONCLUSION

Now in high demand, major hydrangea cultivars are generally easy to propagate. Although hydrangeas can be grown from seed, layers, and tissue culture, cuttings are easy to root and (using the basic steps outlined above) provide the most reliable way to produce common taxa.

Propagating hydrangeas: taxa grown and procedures used at Half Hollow Nursery

- Timing: June-July, softwood.
- Hormone: Wood's 1 : 20 (v/v) or 3000 ppm IBA powder.
- Mist: Leaves wet dawn to dusk.
- Medium: coarse perlite and peat moss (7 : 3, v/v).
- Cultivars:
  H. arborescens 'Annabelle'
  H. macrophylla 'Mariesii Variegata'
  H. macrophylla 'Nikko Blue'
  H. macrophylla 'Soeur Thérèse' (syn.'Sister Theresa')
  H. macrophylla 'Merrit Supreme'

H. paniculata 'Grandiflora'
H. quercifolia (oakleaf hydrangea) (a little more difficult than others listed)

- Rooting: 84% to 99%, 4 to 6 weeks.

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Korean Stewartia Propagation

Robert J. Gouveia
Jackson Nursery, Inc., Norton, Massachusetts

Stewartia pseudocamellia Koreana Group (syn. *S. koreana*), Korean stewartia, is a beautiful, easy-to-grow, small- to medium-sized tree. It has white camellia-like flowers in midsummer, striking autumn foliage, and attractive exfoliating bark. It was recognized with a Styer Award of Garden Merit in 1990.

At Jackson Nursery, we have tried to propagate this plant from seed but have achieved erratic results. The seed is doubly dormant and requires both warm and cold stratification. Thus we prefer to propagate Korean stewartia from cuttings. We have found that the procedure described below also works for other *Stewartia* species that need a dormancy period.

We take three-node cuttings from plants in the nursery, starting around mid-June and finishing in mid-July. Length is not particularly important as long as three nodes are available, but most cuttings average 4 to 6 in. long. We prefer to use terminal shoots.

We collect the cuttings in the morning and keep them in plastic bags until we can process them (usually, the same day). If for some reason we cannot handle the cuttings right away, we refrigerate them until we are ready. We strip the bottom set of leaves but have found wounding, pinching, and disinfection to be unnecessary.

Cuttings are treated with a 5-sec quick dip in about 2000 ppm indole-3-butyric acid [Wood's Rooting Compound : water (1 : 7,v/v)]. We then stick the cuttings into flats filled with two parts perlite and one part sand (2 :1, v/v).

We have rooted the plants in both a glasshouse and in outdoor propagation frames. We use no shading or bottom heat in either area; the plants do not seem to mind full sun. The cuttings receive intermittent mist, which varies according to the weather.

H. paniculata 'Grandiflora'
H. quercifolia (oakleaf hydrangea) (a little more difficult than others listed)

- Rooting: 84% to 99%, 4 to 6 weeks.

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We have rooted the plants in both a glasshouse and in outdoor propagation frames. We use no shading or bottom heat in either area; the plants do not seem to mind full sun. The cuttings receive intermittent mist, which varies according to the weather.

In general, during midsummer, we provide mist 2 sec per min between 8 AM and 8 PM. As the days get shorter, we reduce the misting schedule.

We do not fertilize the cuttings the season after sticking; nor do we incorporate any fertilizer in the rooting medium.

Rooting is generally complete after 60 to 90 days (mid-August to mid-October, depending on sticking date). We then gradually wean the cuttings from the mist system and water them only by hand. Our rooting percentage is generally quite high (80%).

Now comes the single most important step in successfully growing *Stewartia* from cuttings—overwintering. In November, we move the flats to a cool greenhouse covered with clear poly and leave them undisturbed until bud break the following spring. We water the plants only when monitoring indicates the need for it.

It is most crucial that the cuttings remain undisturbed until bud break. According to some authorities, *Stewartia* requires at least 100 h of temperatures no lower then 32F and no higher than 40F. We simply try to maintain the plants in this temperature range throughout the winter.

When the buds start to swell (usually around the end of February or the first week of March), we apply a soluble 20N-20P-20K fertilizer at 200 ppm. We repeat this application 10 days later. No insecticides or fungicides are necessary.

We then pot the rooted cuttings in 2-1/4-in. containers in a medium of peat and perlite (1 : 1, v/v) Alternately, a commercial medium (such as Pro-Mix) can be used.

Normally, we grow the trees in these pots until Memorial Day, then shift them into 1-gal containers. Plants can be overwintered and repotted into successively larger containers until they area scheduled for sale.

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Grafting Trifoliate Maples

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If a plant species is an excellent garden subject and no cultivars are in the trade it usually signals some problem with clonal propagation. Such is the case with the trifoliate maples.

Trifoliate maples have a compound rather than simple leaf, and are composed of three similar leaflets, one terminal leaflet with two attending laterals.

They were first introduced to the United States as early as 1891 when C.S. Sargent of Boston's Arnold Arboretum brought back seed of *Acer nikoense* from the mountains of Japan. Since then three more species of trifoliate maple have been introduced and are now among the most highly regarded landscape trees.

Japan and Central China are home to a species of trifoliate maple known as the Nikko maple. Originally named for the Japanese temple city of Nikko, the tree was once known as*Acer nikoense* but a nomenclature change has brought it to its present Latin name of*A. maximowiczianum*. It is a component of the cool-temperate forest, preferring moist and fertile soils near streams. In central China it grows with such genera as *Tilia, Carpinus, Betula, Fagus, Davidia*, and other species of*Acer*. Trees of 65 ft have been reported from the wild but most mature trees in cultivation are from 40 to 50 ft. A tree raised from Sargent's seed collection 100 years ago now measures 45 ft high with a broadly domed canopy of 40 ft. Its 2-foot-thick trunk shows a number of main branches close to the ground, the first at 3 ft, and these rise at a 45° angle upward to the canopy. The bark, when compared to the other trifoliate maples is a more subtle sell, being a tight medium gray, sometimes forming small plates and with curious vertical rows of bumps. The Nikko maple distinguishes itself most by its foliage as it has the largest leaves of the trifoliate group. Each leaf is made of three leaflets, with two-lateral leaflets near to a right angle to the terminal leaflet. These thick leathery leaflets are oblong-ovate in shape, deep green above, pale green below with the lower leaf surface and petiole having felty, silvery white hairs. The edges of these leaflets are slightly wavy and a few coarse teeth may be present. The size averages from 3 to 5 in. long and 1.5 to 2.5 in. wide although trees from China have been reported with 7-in.-long leaflets. This crisp fresh greenery is the main attribute of this species, especially, when it changes hue in mid-October, (all times are for Boston, Massachusetts). Luminous shades of scarlet and orange are made even more pronounced by the darkness of the gray bark. Oddly the underside of the leaf remains a duller color. The flowers are held in threes, each a 1/3 in. long with 10 chartreuse petals in two rings of five. While interesting on close examination it is really a flower only a botanist could love.

The plants in cultivation in the U.S. have been reported to come through winters with lows of -25F without damage. As a woodland native the Nikko maple will prefer fertile brown soils and a moist site. The proportions of*A. maximowiczianum* make it an ideal tree for suburban gardens for if grown as a specimen tree on a lawn it will keep in good scale to most houses and not attain too large a size.

The star of the trifoliate group is the renowned paperbark maple, *A. griseum*. Native only to the Central Chinese provinces of Hubei, Sichuan, Honan, and Shensi,

it was introduced into cultivation by the prolific plant hunter, E.H. Wilson, and it has come to be regarded as perhaps the best of his hundreds of plant introductions. He first found the plant in May of 1901 and he jotted in his field notebook "Hupeh's best maple". He later came to regard it as "China's best maple" and modern horticulturists may go even further. Wilson recorded the species on steep slopes of moist rich woodlands of Western Hubei between 4000 and 5500 ft. The maximum size of the tree was 60 ft with an 8-ft circumference but trees of 30 to 45 ft were more typical. Seed from these trees was collected for the Veitch Nursery of England in 1901 and for the Arnold Arboretum in 1907. Veitch raised a hundred plants from their seed and the Arnold Arboretum raised one seedling to pair with two plantlets Wilson had dug up in China and brought home to Boston.

Despite other collector's efforts, it seems that so far, Wilson's collections in 1901 and 1907 are the only introductions that have resulted in progeny and that all trees in cultivation are descendants of these. A genetic profile of Paperbark maple in cultivation comparing U.S. and U.K. populations would be a fascinating case study and would probably show a narrowing genetic base.

The bark of this Chinese species is unique in the maple family, a striking collage of textures and colors. The oldest bark, at the base of mature trees is often a interlocking puzzle of irregular plates of copper and smoky gray. Younger wood is sheathed in tight bark of a ruddy maroon-brown with patinas of orange brown and weathered bronzy olive surrendering curled shavings of cinnamon. The wood is hard, dense and at certain points looks sinewy. The effect of this singular stem is of a dense, aged, metallic pillar of exotic alloy.

The foliage of the paperbark maple is reddish brown when first unfurling in the spring but soon turns to a soft, deep green above, pale green and felty below. The margins of the leaflets are coarsely toothed with two to five large teeth to each leaflet's side. The foliage turns a striking, strong crimson in late October and early November, blending beautifully with the coppery bark. Flowers are similar in size and color to the Nikko maple but the petioles are less hirsute.

The oldest paperbark maple that we are aware of graces the grounds of Boston's Arnold Arboretum and is one of E.H. Wilson's original trio. Unlike other *A. griseum* trees in the collection, this specimen has a squat fat trunk that begins to branch at 3-1/2 ft. It has a broad dome, some 40 ft wide and is 25 ft high. It is a venerable and monumental tree, a piece of living sculpture that honors its collector far more nobly that any work from the artist's hand.

The paperbark maple is an ideally proportioned tree for lawn and specimen plantings as it doesn't attain a tall stature in these full-sun situations. It works particularly well alongside the red brick dormitories and lecture halls of our Smith College campus. But it would be superb as a focal point in a woodland or courtyard garden or, as a grove of 20, an unsurpassable luxury.

The woodland forests of Korea have very fine fall foliage color, mainly due to its nine maple species. *Acer pseudosieboldianum* has the most vivid colors, scarlets and reds, but a close second are two trifoliate species native to the mountains—*A. triflorum*, the three-flowered maple, and *A. mandshuricum*, the Manchurian maple.

The three-flowered maple ranges from South Korea, where Nicholson saw it at 600 m in the foothills of the Odae Mountains, north into Northeastern China with isolated disjunct stands in Shensi Province growing at 1700 m. It is a tree that

usually grows about 50 ft high but older trees in the wild have been recorded to grow as high as 70 ft. Nicholson collected seed in the Odae Mountains where the species was found next to a brook, on the edge of a forest of huge *Abies holophylla*, the Manchurian fir. A mile up the road was the ancient temple complex of Hwoamsa and on a crisp fall day in the mountain forests I found the beautiful tableau of Two Maples with Temple. To the front was a small tree of *A. pseudosieboldianum*, its branches covered in leaves of pink and brilliant cardinal red. The temple was small, with a sedate gray tile roof and covered two chambers facing an open middle. Intricately painted beam work and panels counterbalanced the somber roof and straightforward architecture. But behind it, fronting a screen of dark firs, was a glowing-orange, three-flowered maple, its lowest branches peeking through the alcove of the temple. Standing at 65 ft high with a basal trunk diameter of 3 ft it was far bigger than the tree downriver. The bark at the lower portion of the trunk was splashed in pale gray-green lichens, these contrasting pleasantly with the gray and buff colored bark.

Bark on trees in cultivation we have surveyed is a silvery-beige, flaking in small plates to reveal coppery-orange and even pinkish tones beneath. These trees were both over 60 ft high at 70 years of age and were more upright in habit than the Nikko maple. Unlike the Nikko maple, the three-flowered maple tends toward a single dominant trunk.

The trifoliate leaf is distinct from the others of the group due to its bristly upper surface (the lower has a hairy midrib). Leaflets are medium green above, paler beneath, and are up to 3.5 in. long and half as wide with two to four coarse teeth along the margin. In Boston it is usually in fall color during mid to late October and is a blend of pumpkin, yellow, and wines with orange being the dominant hue.

Table 1. Grafting success with trifoliate maples on sugar maple (*Acer saccharum*) understock.

	Graft type				
Acer species	Saddle	Side	Side whip and tongue	Cleft	Overall
1-year understock					
griseum	8/10 (80)[1]	7/10 (70)	3/10 (30)		18/30 (60)
triflorum	3/7 (42)	5/9 (55)	6/10 (60)	4/7 (57)	18/33 (52)
mandshuricum	0/6 (0)	0/11 (0)	0/9 (0)	0/4 (0)	0/35 (0)
2-year understock					
griseum			4/4 (100)		
triflorum			2/4 (50)		
mandshuricum			0/5 (0)		
overall (%) by graft type	11/23 (48)	12/30 (40)	15/42 (36)	4/11 (36)	

[1] The fractional number equals the number of successes over the total number grafted with the percentage success in brackets.

A hike from the Hwoamsa Temple complex to the highest point in the park, Mt. Pirobong at 1550 m, is a 2-1/2 km climb through sublime fall forest, an interplay of the blazing maple and solid somber green of fir. At 1150 m, a small grove of Manchurian maple, *A. mandshuricum*, was growing on a sharply steep, cool slope anchored in dry brown soil. Sharing the hillside were*Betula schmidtii, B. davurica, Viburnum wrightii, Magnolia sieboldii, Rhododendron schlippenbachii, R. brachycarpum, A. pseudosieboldianum, A. ukurundense, Astilbe koreanum,* and *Hepatica asiatica*. In this tight competitive canopy, the Manchurian maples were tall trees to 80 ft, with first branches at 35 ft, yet had a relatively thin trunk diameter of 1 ft. Toward the top of the mountain, 300 m higher, the canopy was squatter and more open and here the Manchurian maple was a round-headed tree of 35 ft. Bark was tight, slightly plating, and of a dark battleship gray color. The leaves of *A. mandshuricum* leaves have narrower leaflets when compared with its cousins, the two laterals held at a closer angle to the terminal and sometimes overlapping it. The oblanceolate leaves are a dark, glossy green above and pale green below with a long tapered tip and a margin of up to 20 small teeth. The leaves are carried in dense tufts at the ends of the branches and give this species a finer, more feathery texture. It was striking how much variation there was in the fall color of this species, especially when recalling those trees cultivated stateside. In the wild, a dull ruddy purple to soft maroon seems to be most common color and to these hues, undertones of pink, orange, and yellow blend. Among the yellows of birch and poplar in the high mountains, these reddening plumes were the standouts. In sharp contrast to these plants is the fall color of a specimen at Boston's Arnold Arboretum. Grown from seed sent by the St. Petersburg Botanic Garden in 1906, the tree grows in full sun and measures 55 ft high by 50 ft wide. It colors early, usually the first week of October displaying a superb soft rose color to the leaves. Once turned they last but a few short glorious days then drop too soon. Based on its fall color alone this striking tree is worthy of cultivar status.

Flowers of the Mandshurian maple are less prone to the chartreuse coloration of the other trifoliate maples, and can be a dull pink. But by late May, clusters of dark pink and chartreuse samaras are forming and these contrast beautifully with the soft green undersides of the leaves.

Of all the trifoliate maples, *A. mandshuricum* is probably the hardiest, growing near to the tops of frigid mountains in S. Korea, and surviving the brutal winters in Northeastern China. It can probably withstand temperatures of -25 to -30F.

A few varieties of trifoliate maples have been described in Chinese journals but are not now known to be in cultivation in any botanic garden. Originally described as a new species, *A. kansuense* was later reduced to a subspecies of the Mandchurian maple and is now known as *A. mandshuricum* ssp. *kansuense*. If this report is accurate, this maple, from the drier province of Gansu could be an interesting more drought-tolerant trifoliate maple.

Other obscure varieties include two of*A. triflorum*—var. *subcoriacea* differs from the species by the leaves being sparingly papillose on both surfaces and the variety *leiopodum* was described in 1934 from a specimen collected by G. Fenzel from a temple woods in Shensi Province in north central China. It is described as having smaller leaflets which are glaucous below and slightly pilose or nearly glabrous on the nerves and petioles. As Joseph Hers later collected *A. griseum* from the same mountain, we question whether the initial identity of the*A. triflorum* tree is correct.

Lastly, the Chinese trees of *A. maximowiczianum* were assigned by the taxonomist Alfred Rehder to the variety *megalocarpum*, showing greater size to every part and greater pubescence, but Chinese botanists consider it synonymous with the typical species.

From the hands of a very few plant explorers have passed the seed of these legacy maples. Over several generations their horticultural reputation has grown and only now are they in the trade to any degree. The elegance and beauty of these rare and wonderful trees is almost mystical. They become more striking, noble, and desirable as they age. We should all be so lucky in life.

We first observed a trifoliate maple (*A. griseum*) grafted onto sugar maple at Dr. Sidney Waxman's trial grounds at the University of Connecticut and were surprised at the rapid growth rate of the plant. It seemed to have grown longer and thicker stems in one season than any trifoliate maple grafted onto its own kind. Based on his results we decided to try a few grafts of our own.

Grafts were made from mid March to early April, sealed with Parafilm, brought to a cool greenhouse (50F), and were inserted into a bed of moist peat, bottom heated to 75F.

Four different grafts were used—saddle, side, side whip, and tongue, and cleft. Understock used was *A. saccharum*, with the majority of these having been potted up the previous fall. A few pots of older understock left over from the year before were also used. These were brought in from a cold frame three weeks prior to grafting. Results are tabulated, a fraction indicating "takes" over total attempts with an accompanying percentage figure, and overall percentage of success by grafting type and by species. *Acer griseum* and *A. triflorum* were about equal in their overall success rate, but *A. mandshuricum*, which was grafted under the same set of conditions, failed in every graft. We can only attribute this to a total incompatibility or to the extremely narrow cambium layer in the Mandshurian maple as compared to the other two species tried which made lining up a good union difficult.

It remains to be seen if these will be good, stable, long-term graft unions or if there will be an incompatibility problem down the road. One option this grafting opens up would be to create stock block hedges of the trifoliate maples which can then be a source of cutting material. We hope to plant out some of our grafts on the Smith College campus and will monitor these grafts over the next few decades.

New and Unusual Plants Worthy of Use and Propagation

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***Fraxinus sieboldiana* (Oleaceae).** A true ash, this plant closely resembles its cousin,*Chionanthus virginicus* with profuse white flowers in late spring. It is a small tree or large shrub. Fall color is golden yellow tinged with purple. Propagation is by seed which has a cold-stratification requirement.

***Hibiscus* 'Lohengrin' (Malvaceae).** A seedless hybrid developed by Hal Bruce at Winterthur Museum between *H. paramutabilis and H. syriacus*. These are large shrubs and are completely hardy in Zones 6B. Propagated by cuttings.

***Hydrangea paniculata* 'Tardiva' (Hydrangeaceae).** An outstanding selection of*H. paniculata* with strong vigorous upright flower spikes. Blooms in late summer to early autumn. Easily propagated from cuttings.

***Camellia sinensis* (Theaceae).** The tea plant of the orient. An excellent fall blooming camellia with masses of tiny white flowers—very fragrant. This plant is not particularly hardy beyond Zone 7, but could be pushed north if planted in the shade. Easily propagated from hardwood cuttings taken in late fall.

***Buddleja globosa* (Loganiaceae).** A South American species which has yellow flowers that occur in rounded clusters, hence its name globosa. *Buddleja globosa* is reliably hardy in Zones 7 but can be pushed into Zone 6. Plant is easily propagated from cuttings and presumably from seed.

***Magnolia ashei*(Magnoliaceae).** Native to North Florida this deciduous magnolia is surprising in that it is perfectly hardy in Zone 6. This magnolia has huge 12-in.-diameter white flowers with a center of purple splotches and light lemon-yellow fall color. Propagation is by seed or budding on to *M. tripetala.*

***Magnolia sieboldii* (Magnoliaceae).** This Chinese magnolia is much later blooming than most—it is not unusual for this plant to bloom in June and July. The flowers are small, 4 to 5 in. across, and have bright red stamens. Propagate by budding. Zone 6.

***Magnolia* 'Butterflies' (Magnoliaceae).** Butterflies is a *M. acuminata* hybrid and has the very distinctive cupshaped yellow flowers. Propagate by budding. Zone 6.

***Heliopsis helianthoides* var. *scabra* 'Sommersonne' (syn.'Summer Sun') (Compositae).** This plant rewards the owner with masses of bright yellow non-stop daisy-like flowers all summer. It is hardy to Zone 4. Propagation is by cuttings, although it is not as easy as most composites. Proper timing and stock plant management is essential for propagation.

***Spiraea fritschiana* (Rosaceae).** A Chinese species with blue-green foliage and excellent flowering both in shade and in full sun. *Spiraea fritschiana* is easily propagated from cuttings. A relatively new introduction into the United States which is hardy to at least Zone 6.

***Clematis stans* (Ranunculaceae)**. A species closely related to *C. heracleifolia* which has masses of white flowers in late summer to early fall. This species is hardy to Zone 4. Propagation is by cuttings or seed, but caution should be exercised as it will hybridize freely with its cousin*C. heracleifolia* and other closely related species.

***Aster novae-angliae* 'Purple Dome' (Asteraceae)**. Dr. Dick Lighty found this plant and introduced it through the Mt. Cuba program. It is dwarf and displays masses of purple flowers in late summer and fall. It is hardy to Zone 2. Propagation is by cuttings while still in vegetative growth—flowering shoots make poor cuttings.

***Clematis* ×*jouiniana* 'Mrs. Robert Brydon' (Ranunculaceae)**. This plant is a hybrid of *C. heracleifolia* and *C.* 'Jackmannii'. It is intermediate between being shrubby and climbing. 'Mrs. Robert Brydon' has sky blue flowers and blooms earlier than the other shrub-type clematis. It is hardy to Zone 4. Propagation is by cuttings. Seed will yield very variable offspring and could be an interesting source of new clematis.

***Viburnum dentatum* 'Moon-Glo' (Caprifoliaceae)**. A selection by H.W. Barnes while at Moon Nurseries in Yardley, Pennsylvania. It is more floriferous than the typical seedling and has a deep purple fall color that is consistent. Flowering is later than the species and is heavier. Cutting propagation is very easy.

***Clematis* ×joshuaensis 'Blue Star' (syn. *C.* ×*bonstedtii* 'Blue Star') (Ranunculaceae)**. A natural hybrid between *C. stans* and *C. heracleifolia*, it is exactly intermediate between the two species. Its flowers are white on the outside of the petals and deep purple blue on the inside. Leaf shape is a precise combination of the two forms and it combines the open habit of*C. heracleifolia* with the compact form of*C. stans*. It is hardy to Zone 6 but its heritage probably offers a cold resistance to much lower temperatures. Propagate by cuttings.

***Syringa josikaea* (Oleaceae)**. Hungarian lilac is a late-blooming lilac with striking pink flowers. This lilac is hardy to Zone 5 and can be pushed into Zone 4. *Syringa josikaea* has clean disease-resistant foliage and makes a medium size shrub. Easy from cuttings. Definitely should be used more.

***Sophora davidii* (Leguminosae)**. A shrubby type of *Sophora* growing to 15 ft. Small pinnately compound leaves add to the reduced stature of the plant. Flowering is heavy with racemes of small white to pale blue pea-like flowers. Fruit set is equally interesting with copious amounts of corkscrew pods that hang on all summer and look like silver Christmas tensile. The plant is remarkably pest free and very drought tolerant. Zone 6. Propagated by softwood cuttings and seed.

***Iris virginica* 'Contraband Girl' (Iridaceae)**. This is a tall robust*Iris* getting to 3 ft or more. Large purple and white flowers are born in the spring. It is hardy to at least Zone 6 and is a southeastern U.S. native. Propagation is by division.

***Dendranthema* 'Hillside Sheffield' (Compositae)**. Properly this plant is *D.* ×*grandiflorum*. The botanists have gotten a hold of the *Chrysanthemum* genus and many familiar plants are now in new genera. But this is still a chrysanthemum and rewards us all with superb fall-flowering ray flowers of pale pink with bright yellow centers. An excellent mound-forming plant which is hardy to Zone 6. Propagation is easy from cuttings.

***Aster tataricus* 'Jindai' (Asteraceae)**. A U.S. National Arboretum release, this is an excellent fall blooming perennial with soft blue-purple flowers. Cultivar is very hardy to Zone 3. 'Jindai' was found by the U.S.D.A. in Japan. The species, *A. tataricus*, is native to Siberia. Propagation is by the separation of shoots from the main crown.

***Dendranthema ×grandiflorum* 'Venus' (Compositae)**. Differs from its cousin 'Hillside Sheffield' in that it is heavier flowering with masses upon masses of white ray flowers turning to pale shades of pink and purple in cool weather. A very robust plant where three small plants set out in spring will yield mounds of 4 ft × 4 ft by fall. Hardy to Zone 6. Very easy to propagate from cuttings.

***Heuchera micrantha* 'Chocolate Ruffles' (Saxifragaceae)**. A selection of our native*H. micrantha*, this plant is ideal for spicing up the landscape. Its combination of green and purple foliage is quite distinct and user friendly. It should be hardy to Zone 4 if sited properly. Propagated by cuttings taken from young rapidly growing side shoots.

***Morus alba* 'Green Wave' (Moraceae)**. Formerly known as *M. alba* 'Holicong', this is a strong weeping selection that is fruitless. It was found growing in a fence row in Holicong, Pennsylvania. In addition to the unique weeping character, no two leaves are the same. It is hardy to Zone 5. Roots easily from softwood cuttings but resists all attempts at staking and will die back to a low bud that will resume growth laterally. High graft to yield the typical weeping mulberry. Totally different than*M. alba* 'Chaparral'.

***Carex pendula* (Cyperaceae)**. Largest of all the *Carex*. Strong dark green heavy textured leaves give a definite vertical accent to the landscape. It is evergreen in spite of the coldest weather. Hardy to Zone 6. This species will tolerate wet sites as well as drought. Species name, *pendula,* comes from the long weeping flowers and the seed pods which hang down like elongated tears. Propagate by seed or division.

***Cercidiphyllum japonicum* 'Tidal Wave' (Cercidiphyllaceae)**. A chance seedling found by H.W. Barnes. 'Tidal Wave' is distinct in having very robust growth that is strongly weeping. It is hardy to Zone 5. Propagation is by grafting. Some cuttings can be rooted if taken early.

***Euscaphis japonica* (Staphyleaceae)**. Dr. J.C. Raulston is promoting this plant and for good reason. The fall show of dark green leaves, striking red bracts, and black fruit offer something for everyone. This is a very robust plant and is worth pursuing. Hardiness is a question. Plants at Philadelphia came through a severe winter with little or no problems. Plants at Longwood Gardens died the same year. Site selection could be the culprit. Propagation is difficult as seed is stubborn, to say the least, with warm, cold, warm, and cold stratification working somewhat. Cuttings are hard to root and do not overwinter well. North Carolina State University is working on this.

***Berberis koreana* (Berberiaceae)**. Korean Barberry is used heavily in the Midwest. It is relatively newcomer to the East Coast of the U.S. It is normally very clean and pest free with a strong upright character. Most effective use is for its blood-red fall color. Hardy to Zone 5. Propagated by cuttings or seed.

***Alnus glutinosa* 'Imperialis' (Betulaceae)**. A very cutleaf form of the European alder, 'Imperialis' offers something different in texture, especially for a plant that is very tolerant of wet spots where plants like *Acer palmatum* cutleaf forms might not thrive. Cultivar is hardy to Zone 3. 'Imperialis' can be propagated by cutting, grafting, or budding.

***Sambucus nigra* 'Aureomarginata' (Caprifoliaceae)**. Splendid white and green variegation set this plant off. Especially useful in shady situations where it both thrives and lightens things up. Cultivar is very hardy to Zone 3. It is also useful in wet areas but does not do well in full sun. Propagated from cuttings in summer.

***Ilex* ×koehneana 'Jade' (Aquifoliaceae)**. A U.S. National Arboretum selection. This is a male plant with heavy-textured, lime-green leaves. It is very hardy and vigorous, I believe it could go well beyond Zone 6. Cultivar is propagated by cuttings.

***Maclura pomifera* 'Sudden Splash' (Moraceae)**. This is a new variegated selection of osage orange which appears to be fruitless. Cultivar roots easily from cuttings and will graft or bud onto seedling osage orange. Hardiness is uncertain, although the mother plant is a chance seedling discovered in Zone 6—found by H.W. Barnes.

***Metasequoia glyptostroboides* 'Silver Lace' (Taxodiaceae)**. A chance seedling with white variegated tips in early spring. Coloration disappears as the summer heat commences. Propagation is easy from cuttings. 'Silver Lace' will suffer somewhat in hot dry situations and is hardy to Zone 6. Coloration is best in cool weather. Found by H.W. Barnes.

***Poliothyrsus sinensis* (Flacourtiaceae)**. A monotypic genus and species native to China. This is large tree species with white to yellow flowers on long pedicels and interesting fall and spring red leaf colors. Plant is unusually pest free and hardy to Zone 6. Responds to cool night temperatures for foliage coloration and not photoperiod. Propagation is from seed or cuttings.

***Quercus aliena* (Fagaceae)**. Chinese white oak is a large tree with very-clean, heavy-textured dark-green leaves that change to yellow to brown fall color. This oak is hardy to Zone 5. Propagation is by seed. Appears to be pest free in Pennsylvania.

***Tagetes filifolia* (Compositae).** Threadleaf marigold, or Irish lace as it is known, is an unusual annual with finely cut leaves resembling spruce needles. It has a low-growing mound shaped. Threadleaf marigold blooms late with tiny white flowers that are the size of pencil points. It propagates from seed or cuttings.

***Oxalis tetraphylla* (Oxalidaceae)**. A bulbous oxalis with bright—pink flowers and large green leaves with a heart-shaped purple splotch. Not hardy but is worth growing as an annual. Propagation is by bulb division. Does well in the shade.

***Impatiens balfourii* (Balsaminaceae)**. A vigorous upright shade-loving species. Can grow from 2 ft to 3 ft. It has jewelweed-type flowers of white and purple. Species is not hardy and propagates easily from seed or cuttings.

Seed Propagation: Stacking the Deck in Your Favor

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Plant propagators sometimes face the need or desire to propagate, by seed, plants about which little or nothing is known. In the arboretum and botanic garden world this is a common occurrence. Coupled with the need to propagate a plant is usually a dearth of seeds. Rarely will you encounter a situation where you have adequate numbers of seeds to run a controlled experiment with multiple treatments. What, then, are your options that will assure, at least, some degree of success? How do you stack the deck in your favor?

Many propagators have developed informal protocols, or processes, by which they gather information before attempting to germinate seed. Without realizing it, I informally developed my own way of obtaining information for the many plants that do not appear in reference manuals. Recently, Rob Nicholson and I published an expanded version of a seed germination protocol (Munson and Nicholson, 1994). In it we described a protocol for obtaining information and also provided an extensive listing of ecological factors that may give clues to pregermination requirements. This paper will describe the steps and some common sources of information. For a more detailed analysis of ecological factors please see the aforementioned paper.

When you first discover that your plant is not mentioned in any of the standard sources of propagation information where do you turn? Before giving up on the literature be sure to consult a specialty text dealing with specific groups of plants or specific genera. While few propagators have easy access to university libraries with extensive collections of plant propagation literature most will have access to the most commonly used references. Our own Dirr and Heuser (1987) and the classic Hartmann, et. al. (1990) are the first choice of many propagators. While extensive, they will not always have the specific information you seek. In addition, many will use Schopmeyer's (1974) seed manual or the later revision by Young and Young (1992). Further, there are several specialty references such as Emery (1988) for California seed plants, Phillips (1985) for wildflowers, and our own Richard Bir (1992) for woody native plants. Of course, it is often beneficial to consult the past Proceedings of I.P.P.S. If your search through all your references yields nothing of direct value you need to take the next step.

The next step normally involves finding propagation information for a plant in the same genus. If their nativities are similar in climate and growing season I usually feel confident in trying the same method. In a large genus such as *Acer* I also consult a reference such as Rehder (1940) to determine the section within which a particular species falls. If I am lucky a member of that section will have a known propagation strategy. Although not a guarantee, many members of a section will germinate under the same conditions. Occasionally, the only information available is for another genus in the same family. Although less likely to yield usable information there still may be some indications that certain treatments will work. The general rule-of-thumb that I follow is that the more closely related two species are the more likely they are to have the same pregermination requirements.

When the preceding two steps still provide no clues, I resort to the third step that

provides less specific, but often useful, information. If you can learn the climate in the plant's nativity it will often provide possibilities for pregermination treatments. Such information as annual rainfall, seasonal temperature extremes, and distribution of precipitation, may suggest certain seed treatments. For example, an annual climate with minor temperature fluctuations suggests that cold-moist stratification is not necessary. If, on the other hand, the local climate is highly seasonal with definite cold and warm periods then cold-moist stratification may be a likely option. At least, seeds are unlikely to be harmed by such a treatment.

Another factor that warrants consideration is when seeds ripen and are dispersed. Seeds that ripen and are dispersed early in the growing season, such as silver maple, *A. saccharinum*, often require no pregermination treatments. Seeds of plants that ripen in the autumn, e.g. sugar maple, *A. saccharum*, usually require a cold-moist period to overcome dormancy. Again, knowing the relatedness of species can give some clues on how to proceed.

Finally, some indications are often gleaned from an understanding of certain ecological factors. The manner of seed dispersal and the position of the plant within its native habitat may be significant in terms of germination requirements. The following general rules are evident from a detailed study of many woody plant genera. Wind-dispersed seeds, such as *Populus* and *Oxydendrum*, usually have either no pregermination requirements or very simple ones. Bird- and mammal-dispersed seeds, such as *Ilex* and *Asimina*, respectively, normally have much more complex or difficult germination requirements. In addition canopy species often have simpler germination requirements than do understory plants. Finally, very small seeds, such as *Rhododendron* and *Betula*, often germinate with no pretreatment. Normally, small seeds are not covered with germination medium and frequently germinate in the presence of light. Large seeds, on the other hand, are often covered with soil and seldom germinate in the presence of light. Although these rules are not fixed, they are often good guidelines when you have little else on which to proceed.

If you are blessed with a large quantity of seeds the wise choice would be to try multiple treatments. This will assure at least one of your methods will result in germination. Minimum quantities of seeds per treatment, where they are large enough to count, should be about 25. It is also possible to combine some treatments on the same seed such as acid scarification and moist chilling.

One last recommendation, based on experience, is to practice patience. Do not throw away any of your seed flats or pots the first year. Put them in a cold frame or overwintering house and allow them to go through another season. Surprisingly, many seeds will germinate if given enough time, although you may not know exactly which treatment really worked and why.

In summary, make the best use of available information by connecting species with known germination requirements with those about which nothing is known. Consider the climate and ecological clues and try multiple treatments whenever possible. Lastly, be patient and rewards will often follow.

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Mist Propagation of Perennials Using Side or Lateral Shoots

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The perennials discussed in this paper are those that typically do not develop a stem or branch with leaves and internodes. Instead, they grow from a crown at the soil surface with leaves grouping themselves around a thickened fleshy base in what are variously called: offsets, suckers, side shoots, lateral shoots, or heeled cuttings. They will be called shoots in this paper. When the stock plants are growing in the ground the preferred method of making cuttings is to cut the shoots by inserting the snippers into the ground at the base of the plant. Some of the plants have shoots that are tender and will be bruised or crushed if they are pulled off by hand.

The general rule is that these perennials root better in the spring or fall when it is cooler than in the summer. Hormondin #3 is normally used. A light mist is preferable, beginning with a short burst at 10-min intervals and after 5 days increasing the interval to 20 min. Just enough mist is needed to prevent visible wilting of the leaves.

The *Achillea* taxa are easy to root. We prefer to force field clumps or 1-gal containers in the late winter and then to pull off the shoots when they are 2 to 4 in. long. Side shoots can also be taken in the fall and stuck in a heated house.

Allium senescens var. *glaucum* roots under light mist in well drained soil.

Armeria maritima will root anytime, even in the heat of summer, if there is a brown sheath at the base of the shoot.

Heuchera, *Tiarella*, and *Heucherella* will root from cuttings taken from outside stock up until frost in the fall. Plants can be forced in the winter also. The larger top leaves are trimmed prior to sticking leaving either bare stems or some of the smaller lower leaves.

Echinacea and *Rudbeckia* need to be propagated prior to flower bud formation. This is a good method to use to catch up on production when one has forgotten to seed enough of them.

Scabiosa roots easily except that the better cultivars bloom so profusely that they

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Scabiosa roots easily except that the better cultivars bloom so profusely that they

forget to make shoots. We did a small-scale test using Florel (Ethephon). A heavy spray was applied to container plants in full flower at the rate of 3 oz to 1 qt. For 1 month there was flower inhibition and the lateral shoot development was three times that of the control. We will test further to see if this affected the rooting rate.

Stachys byzantina 'Silver Carpet' is much preferred over the species because of the lack of flower stalks. It is difficult to produce because it rots quickly in the heat of summer under mist. It needs to be moved out from the mist after 3 days to a shady area with light hand misting or produced in the cool months.

Penstemon 'Husker's Red' roots readily from shoots cut from below ground level. Stem cuttings root slowly and then it takes 2 months for side shoots to develop to make a full plant.

Campanula 'Joe Elliott' (syn. *C.* 'Joan Eliot') can be done in the fall or after blooming and the side shoots have begun to develop.

Sanguisorba obtusa cuttings did well when taken in early June.

Potentilla ×*tonguei* and *P. neumanniana* 'Nana' (syn. *P. verna nana*) are cool-month growers. They can be taken up until frost in the fall but we prefer to force them in the winter. The shoots are easily pulled off by hand and they need the brown sheath at the base of the cutting to root.

Potentilla 'Gibson's Scarlet' is difficult as it easily rots. They do best if forced in the late winter and the shoots are taken when small and tender and the mist is very light.

Question Box

Moderated by Ralph Shugert and Steve McCulloch

Question: For Joerg Leiss. Could you explain once again how to produce *Corylus avellana* 'Contorta' using root pieces to graft onto?

Tim Brotzmann: *Corylus avellana* is not a good understock because it throws root suckers. Use another species such as *C. colurna.*

Question: Will variegated forms of *Aralia elata* and *A. spinosa* if put on their own roots (as by layering) produce variegated suckers or the normal green form?

Tim Brotzmann: I asked Joerg that question but he did not know the answer. My feeling is that it would throw the green form.

Question: Does *Thuja occidentalis* 'Smaragd' ever set seed or ever bloom?

Ken Twombly: We have grown it for about 15 years and have never seen it set seed.

Question: Has anyone had experience using growth retardants on perennials?

Harlan Hamernik: Yes, there are a number that will work, however, the procedures have not been worked out for the broad range of herbaceous perennials. A grower needs to experiment. One of the most effective is Florel that is used in the florist industry. We are doing work at our nursery but mainly to make better plants for propagation.

Question: Are there other economical ways to sterilize cuttings other than bleach before they are stuck?

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Question: Are there other economical ways to sterilize cuttings other than bleach before they are stuck?

Voice: There was a paper in the past proceedings on the use of hydrogen peroxide.

Cameron Smith: We have used 3% hydrogen peroxide with a few ppm of ferrous sulfate which increases the effectiveness tremendously. This combination gives the cleaning effectiveness of the industrial strength hydrogen peroxide (30%).

Peter Nickerson: We spray our entire propagation house with Green Shield before propagating our lilacs. We also wash our cuttings in Green Shield.

Ralph Shugert: We can buy Green Shield cheaper than Clorox.

Bill Barnes: Green Shield is the same as Lysol. Some plants are sensitive so be careful if you soak them in it.

Question: Has anyone had success rooting 'Blue Star' Juniper—timing, hormone, size, date?

Rob Means: A trick we try with some of the *Juniperus squamata* types is to put them in a dry house and cover with newspaper for the first 10 days or so. We stick them in January and mist them lightly once a day. Let the medium slowly dry until almost bone dry and then water them and they take off. If we put them under mist they die.

Bill Hendricks: If you take standard cuttings you are doomed to failure. We found that you should take 1-in. cuttings that are very soft.

Question: How can you root cuttings of *Daphne cneorum*?

John Wilde: In the 1930s I found by accident that you can simply layer them. I noted that if you put a lot of peat moss around the plants and pinned the stems into the peat mulch the smaller side shoots rooted and you could get a lot of small rooted plants by the end of the season. This is what L.H. Bailey had recommended years earlier I subsequently found out.

Bob Gouveia: We have rooted them. We use softwood cuttings and root them in perlite and sand (1:1, v/v) with very little mist. They rot very easily. As soon as rooted we take them out of the mist. We could never grow them in containers but we could in the field.

Question: What is the best way to germinate seeds of *Helleborus orientalis*?

Bill Hendricks: Let the seed germinate under the mother plants and transplant after they germinate.

Robert Herman: Sow them immediately after ripening, carry them through the summer, bring them into a cool greenhouse (40F), and they will start to germinate by December. You could also leave them outside through the winter and they will germinate in the spring.

Question: For Bob Geneve. Is there evidence for viruses causing fasciation in plants? Can it spread with propagation or by insect vectors?

Robert Geneve: I know of no cases. I know of bacterial causes that can be spread.

Question: Where did Heather McCargo purchase her compost? Price?

Brian McGowan: Massachusetts Naturals in Westminster, Massachusetts, for about $500 a trailer load.

Question: Has anyone had experience germinating bulbuls of *Begonia grandis*?

Bill Barnes: Put the bulbuls in a plastic bag with moist perlite, place in a refrigerator until spring, and plant out.

Steve McCulloch: We root them from stem cuttings.

Question: For Bob Gouveia. Fertilizer on *Stewartia*, what rate and form of nitrogen?

Bob Gouveia: We use Peters 20N-20P-20K at 200 ppm, at 10-day intervals in the rooting medium. Once they are potted, we continue the same fertilizer every 10 days.

Question: For Ron St. Jean. With what other genera does the double dip work on?

Ron St. Jean: We have used it for many different taxa of both *Thuja* and *Juniperus*.

Question: For Ron St. Jean. Would like to hear discussion of understocks in use for grafting *Chamaecyparis* species, *Thuja* species, and *Juniperus* species.

Ron St. Jean: We only root hetzi juniper and plumosa juniper for understocks.

Question: For Calvin Chong? Regarding windshield cleaner fluid, do you use this straight, or blend with IBA?

Brian Maynard: Just a solvent or carrier for the auxin.

Question: We've had bad luck overwintering successfully liners of *Styrax japonica* 'Pink Chimes'. Can anyone make a recommendation for us to try?

Ron St. Jean: We overwintered seedlings in a pit house.

Tim Brotzmann: I think there are root hardiness concerns that can carry over in the field for a number of years. We have overwintered 'Pink Chimes' in the rooting flats in a deep pit house.

Question: Is the use of rooting hormone necessary in any examples of root-piece propagation? Are there plants which readily generate shoots, but do not produce vigorous roots?

Dick Bir: We have tried various concentrations of hormones on root cutting and found that it was useless.

John Wilde: From work that I did in the 1940s, they may have a negative effect.

Question: Anyone have information on yellow nut sedge control in transplant beds or field production?

Brian Gilson: We have used Pennant in a granular formulation.

Darell Apps: I use the liquid formulation of Pennant on daylilies and have had almost perfect control. I do have to come back some times because it is short lived.

Ralph Shugert: Classic is the only chemical I have had success with on this weed.

Question: For Mike Hoffman. How come you didn't use double poly for your drip problem in rose propagation?

Mike Hoffman: We don't have a drip problem in the spring and summer.

Question: Does the depth that roots develop in a direct-stick program translate to a depth of planting problem through production into the landscape?

Steve McCulloch: No. We do a lot of direct stick and it is not a problem.

New Plant Forum

Compiled and Moderated by Jack Alexander

PRESENTERS:

Dale Deppe, Spring Meadow Nurseries, Inc., Grand Haven, Michigan
Hydrangea paniculata 'Pink Diamond'
Hydrangea paniculata 'White Moth'

Ruth Dix, U.S. National Arboretum, Washington. D.C.
Acer rubrum 'Sun Valley'
Acer rubrum 'Somerset'
Acer rubrum 'Brandywine'
Viburnum rhytidophyllum 'Cree'
Ilex 'Scepter'
Ilex crenata 'Geisha'

Barry Glick, Sunshine Farm and Gardens, Renick, West Virginia
Spiranthes cernua var. *odorata* 'Chadds Ford'
Oenothera 'Cold Creek'
Penstemon 'Early Dawn'
Helleborus hybrid seedlings
Ajuga reptans 'Carol'

Richard Jaynes, Broken Arrow Nursery, Hamden, Connecticut
Clethra alnifolia 'Ruby Spice'
Kalmia latifolia 'Little Linda'

Steve McCulloch, Briggs Nursery, Inc., Olympia, Washington
Pieris 'Spring Snow'
Rhododendron 'Haaga'

Christopher Rogers, Weston Nurseries. Inc., Hopkinton, Massachusetts
Fragaria 'Wildfire'
Euonymus planipes (syn. *E. sachalinensis*)

Gregory Tormey, University of Connecticut, Storrs, Connecticut
Clethra barbinervis

Ken Twombly, Twombly Nursery, 163 Barn Hill Rd., Monroe, Connecticut
Acer palmatum 'Red Sentinel'
Picea pungens 'Lemonade'

Sidney Waxman, University of Connecticut, Storrs, Connecticut (retired)
Pinus strobus 'Connecticut Slate'
Sciadopitys verticillata 'Jim Cross'

Ajuga reptans 'Carol'

This plant was found in the Wyncote Pennsylvania garden of Roger Copeland. 'Carol', a sport of 'Burgundy Glow', has proven to be 100% stable. It is probably one of the most colorful variegated foliage plants on the market. The maroon, cream, and

green variegation is exceptionally vivid and distinct. As with all *Ajuga* taxa, 'Carol' is extremely easy to propagate by division.

Acer palmatum 'Red Sentinel'

Originally found as a witches broom on *A. palmatum* 'Bloodgood' about 15 years ago. More compact, growing 8 ft high and 5 ft wide in 15 years. It holds its dark red foliage all summer, and it intensifies in autumn. It holds its foliage into December, then sheds it all at once. An excellent plant for summer and fall color, a nice size for small yards and patios.

Acer rubrum

The following three new cultivars of *Acer rubrum* were released in December, 1994 by the National Arboretum. All three resulted from controlled crosses made in 1982 by A.M. Townsend. The new cultivars produce only male flowers; no fruit are produced. Each one also has a significant level of tolerance to the potato leafhopper. They will make excellent lawn, street, highway, or park trees. Their combination of widespread adaptability, leafhopper tolerance, symmetrical shape, and outstanding autumn leaf color will fill important needs in the nursery and landscape industries. In addition, all three are easy to propagate by softwood cuttings using conventional means, with rooting generally occurring in less than 4 weeks.

- ***Acer rubrum* 'Sun Valley'**. *Acer rubrum* 'Sun Valley' is the result of a cross between 'Red Sunset' and 'Autumn Flame'. It has a symmetrical, ovate crown with leaves that turn a brilliant red color in autumn—mid-October in the Washington, D.C. area. The original selection has reached 21 ft in height with a crown spread of 10 ft after 12 growing seasons. It is adapted to U.S.D.A. Zones 4 to 7.
- ***Acer rubrum* 'Somerset'.** *Acer rubrum* 'Somerset' resulted from a cross of 'October Glory' with 'Autumn Flame'. It shows autumn color 1 to 2 weeks later than 'Sun Valley', late October in the Washington, D.C. area. 'Somerset' has outstanding red autumn color, combined with an unusually broad range of adaptability. The crown shape is moderately ovate, and its height at 12 years has reached 23 ft with a spread of 11 ft. It is adapted to U.S.D.A. Zones 4 to 8.
- ***Acer rubrum* 'Brandywine'.** *Acer rubrum* 'Brandywine' also resulted from a cross of 'October Glory' with 'Autumn Flame'. In autumn, the vibrant red leaf color gradually turns to a brilliant purple red as the days grow shorter. This results in a long period (frequently 14 days or more) of effective peak red autumn display. The crown form is moderately columnar and at 12 years, it has reached a height of 25 ft with a spread of 12 ft. It too is adapted to U.S.D.A. Zones 4 to 7.

Clethra barbinervis

Clethra barbinervis, Japanese clethra, is a large shrub or small tree that grows to a height of 15 to 18 ft. One of its finest attributes is its gray, brown and even sometimes white bark which is similar to *Stewartia pseudocamellia*.

Japanese clethra is hardy in Zones 5 to 8 and has white flowers in July and August. We have one plant here that stays completely covered with blooms for up to 2 months. It is easily propagated by cuttings and the seeds germinate with no pretreatment. Feel free to write for seeds or cuttings.

Clethra alnifolia 'Ruby Spice'

Flowers of 'Ruby Spice' are significantly deeper and richer pink than any other selection to date. It was found in 1992 by Andy Brand of Broken Arrow Nursery as a branch sport on 'Pink Spires'. Cuttings were taken and the plants bloomed true for the rich pink color. Flowers are very fragrant and attractive to butterflies. Foliage is darker green than 'Pink Spires'. 'Ruby Spice' is a vigorous grower and expected to be 6 to 8 ft in 10 years and hardy in Zones 4 to 8. Like the species, it is tolerant of shade, adaptable to wet sites, easy to root, and relatively free of insect and disease problems.

Euonymus planipes

This under utilized shrub grows to 15 ft tall and can be trained into a wide, upright low-branched tree. It is very showy in the fall with its bright scarlet fruits. The bright green new foliage turns yellow in autumn. No major pests bother it. Fresh seed takes 1 to 2 years to germinate.

Fragaria 'Wildfire'

This plant originated from seed collected from the patented plant *Fragaria* 'Pink Panda' PP7598. Dark pink to red flowers are produced primarily in May and June, and continuing less heavily throughout the summer. Edible red strawberries are produced in low numbers. The plant produces numerous runners that root anywhere they touch the earth. Performs best in full sun.

Helleborus hybrids

The first results of Barry's decade-long quest for the best hellebores are finally here. Those of you who know me are aware of my insane passion for this genus, and how I have combed every continent for the highest quality parental stock for my hellebore breeding program. The pictures I am showing you are a very small representation of the rainbow of colors and forms that are possible with careful selecting and cross pollination. At this point, the plants that are available are unflowered seedlings from high quality parents. There are several people working feverishly at the perfect regimen for tissue culture, but it seems that we are still a couple of years away.

Hydrangea paniculata 'Pink Diamond'

Grown unpruned this cultivar forms an enormous shrub. The tall panicles of interspersed fertile and sterile cream flowers open in late summer. The panicles are well shaped with slightly rounded tips and are carried in profusion. Starting from the panicle base, the florets gradually develop a pink coloration which advances towards the tip, deepening as it progresses until the whole is a deep shade of rose.

Hydrangea paniculata 'White Moth'

A vigorous and prolific plant. Flowering starts in July and continues well into the autumn, the flowers maintaining their creamy white color throughout.

Ilex 'Scepter'

Ilex 'Scepter' originated from a controlled cross of *I. integra* with *I.* ×*altaclerensis* 'Hodginsii' made in 1960 by W.F. Kosar. It was selected and released by Gene K. Eisenbeiss in March, 1995. It is a rapid-growing tree with a pyramidal habit, compact without shearing. At 16 years it reached a height of 19-1/2 ft with a width of close to 14 ft. The leaves are an excellent glossy dark green, leathery, thinner and more flexible than either parent species. The fruit is bright red, borne in clusters

of 2 to 10 fruits and is persistent throughout the winter. 'Scepter' is sexually compatible with male plants of the parent species and other *Ilex* species such as *cornuta, ×meserveae, pernyi, rugosa,* and *latifolia.* Hardiness is rated at U.S.D.A. Zone 7. It propagates readily from semi-hardwood and hardwood cuttings.

Ilex crenata 'Geisha'

Ilex crenata 'Geisha' is an F3 *I. crenata* hybrid made by W.F. Kosar in 1966 and released by Gene K. Eisenbeiss in March, 1995. 'Geisha' is a small, evergreen shrub with a spreading habit. At 10 years it can be expected to reach approximately 2-1/2 ft in both height and width. Although 'Geisha' is not a dwarf plant, the leaves are unusually small and glossy, and it has the smallest leaves of any *I. crenata.* The fruit color is yellow, which is very distinct from the black fruit typical of this species. 'Geisha' branches quite readily following shearing. Hardiness is rated at U.S.D.A. Zone 7. It propagates readily from semi-hardwood and hardwood cuttings.

Kalmia latifolia 'Little Linda'

Miniature or small-leaved mountain laurel (form *myrtifolia*). 'Little Linda' resulted from a sequence of five generations of controlled crosses begun in 1963, with the final crosses made in 1982. Significant features of 'Little Linda' are the red-budded flowers that open near white and age to a medium pink. In addition the plant is dense and low growing with leaves that are 1/2 to 2/3 normal size and glossy and dark green. The plant is expected to be 30 by 30 in. in 10 years and hardy in Zones 5 to 8. This is the most recent release of a series of miniature mountain laurel that includes 'Elf', near white flower; 'Tiddlywinks' and 'Tinkerbell', rich pink flowers; and 'Minuet', burgundy flowers. Like most ericaceous plants, 'Little Linda' requires an acid well drained soil. The miniature mountain laurels by virtue of their smaller habit are adapted to landscape situations where normal mountain laurel would be too large. 'Little Linda' is difficult to root from cuttings, so as with other mountain laurel selections, plants are best multiplied by micropropagation. There is a breeders fee of $0.15 per plant payable to Richard Jaynes, Broken Arrow Nursery, 13 Broken Arrow Rd., Hamden, CT 06518

Sources—all are producing plants in tissue culture:
Briggs Nursery, 4407 Henderson Blvd., Olympia, WA 98501
Planeview Nursery, 770 Wapping Road, Portsmouth, RI 02871
Prides Corner Farms, Waterman Rd.., Lebanon, CT 06249
Stoneboro Nurseries, R. D. 2, Stoneboro, PA 16153

Oenothera 'Cold Crick'

'Cold Crick' was almost dismissed as another nice but weedy evening primrose. Definitely not the case here. When Polly Rowly of Coki Crick Farms brought this plant to me several years ago, I graciously accepted her gift and tucked it out of the way expecting the worst. Boy, was I surprised. This plant has no bad habits. It is day-blooming, compact, non-invasive, bright yellow, long-lived and very floriferous. It flowers continuously during the summer and is a good cleaner-upper. Cuttings root in 2 weeks under mist with no bottom heat and a dip in a 10% solution of Ed Woods rooting hormone.

Penstemon 'Early Dawn'

'Early Dawn' was a chance seedling discovered in the Garden of Norm Beale of

Raleigh North Carolina. Untypical of the large-flowered *Penstemon* hybrids, this plant is very long lived and hardy so far to 2F with no snow cover. It has icy white flowers kissed on the tips with the lightest pink blush. Propagation is by cuttings or division.

Picea pungens 'Lemonade'

Picea pungens 'Lemonade'. Bright lemon-yellow new growth in spring lasts for 3 to 4 weeks, then turns to a pleasing blue-green in summer.

Pieris 'Spring Snow'

Pieris 'Spring Snow' is reported to be a hybrid of *P. floribunda* × *P. japonica*. It was selected by Del Brown of Marysville, Washington. In 1979 'Spring Snow' was registered and introduced to the trade by Briggs Nursery Inc. Although this selection is nearly 16 years old, it still remains a superb ornamental. 'Spring Snow' is appropriately named. In the early spring, 'Spring Snow' is smothered with a blizzard of snow white blooms. Flower corollas are very white, borne in upright *P. floribunda* like panicles. This selection does require dead heading. Plants are dense and compact with attractive *P. japonica* like foliage. 'Spring Snow' is hardy to parts of Zone 5 (U.S.D.A.).

Pinus strobus 'Connecticut Slate'

Pinus strobus 'Connecticut Slate' originated not as a seedling, but as a graft taken from a witches'-broom found hanging high above a river near Putnam, Connecticut. This plant was selected for its unique color and for its unusual growth habit. Its foliage is a bright grayish-blue, and contrasts sharply with other white pines. Its form is indeed variable having densely tufted branches which arise at chance locations. By no means is it symmetrical. It was named Connecticut Slate for its place of origin and for the color of its foliage. After 11 years it has grown 4 ft high and 6 ft wide.

Rhododendron 'Haaga'

'Haaga' is a new elepidote hybrid rhododendron from the breeding program at the University of Helsinki, Finland. The breeding program's goal is to produce winter hardy ornamental plants that can tolerate temperatures below -31F. This hybrid resulted from the cross of the extremely hardy species (USDA Zone 4) *R. brachycarpum* ssp. *tigerstedtii* with the red-flowered ironclad rhododendron 'Dr. H.C. Dresselhuys'. 'Haaga' is a profuse blooming and hardy rhododendron. Upright trusses containing 14 florets are deep pink that fade to pink. Plants are well branched and upright growing, with a mature height of 5 to 7 ft. Foliage is attractive, coarse, and dark green. Plants are rated H-1 and have performed well in Zone 5.

Sciadopitys verticillata 'Jim Cross'

Sciadopitys verticillata 'Jim Cross' was selected for its two main features: its needles and its form. The needles are curved, more so than on most other umbrella pines. Its relatively short shoots and its dense branches present a solid surface of glossy needles which effectively shield the stems from view. The slightly downward curve of its needles causes them to reflect light and present a glossy surface. This tree is broadly conical and in 20 years has grown to a height of 10 ft and a width, at its base, of 8 ft.

Jim Cross was admired for his knowledge, his love of plants, his humor, and his modesty. He was a good friend. I named this plant for him.

Spiranthes cernua f. *odorata* 'Chadd's Ford'

Just imagine a fragrant, native, terrestrial orchid that just about anybody, anywhere can grow. Hardy to Zone 5, this is primarily a moisture-loving plant, but it will tolerate drier soil and is not that particular about sun or shade. Propagation is quick and easy as the root tips curl up to the surface of the soil and produce copious amounts of new plants. In the late summer, early fall, large spikes of vanilla scented, long lasting flowers will grace the landscape. It also makes a very attractive and saleable cut flower.

Viburnum rhytidophyllum 'Cree'

Viburnum rhytidophyllum 'Cree' was initially selected by Donald R. Egolf in 1989 from a seedling population grown from seed collected in 1980 by T.R. Dudley in Shennonngjia Forest District, Western Hubei Province, the Peoples Republic of China. 'Cree' was chosen specifically for its compact growth habit and superior dark evergreen foliage throughout the winter. Although the leaves will droop during cold weather, they appear less likely to curl or roll during extremely cold periods. 'Cree' has excellent flowering and fruiting. In mid May it is covered with cymes of fuzzy, creamy-white flowers. The bright red fruit ripens in late August through September, gradually maturing to black before being eaten by birds. In form 'Cree' is a somewhat spreading, dense-branched shrub that has reached a height of 8-1/2 ft × 8 ft width in 14 years. It is reliably evergreen and hardy in USDA Zones 6 to 8.

POSTER SESSIONS

Daylilies Worthy of Commercial Production

Darrel Apps
Woodside Nursery, 327 Beebe Run Road, Bridgeton, New Jersey 08302

There are nearly 38,000 daylily cultivars, however, only a few are worthy of widespread commercial production. Over 270 people are actively hybridizing daylilies so older cultivars are being rapidly superseded. The cultivars listed below were selected for the mid-Atlantic and northeastern states and are based on beauty and then performance factors[1], such as:

1) Winter hardy in containers
2) An increase of 3 to 1 or greater each year
3) Three weeks or more of bloom time (20+ buds)
4) Clean, green foliage until fall
5) Free from insects and diseases
6) Divide easily
7) Preferably set few seeds

CULTIVARS[2]

Arctic Snow: 23 in., M[3], 5-1/2 in., ivory with black pollen sacks, dormant tetraploid

Barbara Mitchell: 20 in., M, Re, 5-1/2 in., pink self, semi-evergreen, diploid

Beauty to Behold: 24 in., M, 5-1/2 in., yellow self, diploid

Becky Lynn: 20 in., EM, 6-3/4 in., rose, semi-evergreen, diploid

Beige Beacon: 20 in., M, Re 5-1/2 in., cream self, dormant, diploid

Betty Clair: 20 in., EM, 3 in., pink self, dormant, diploid

Bittersweet Honey: 28 in., M, 2-3/4 in., orange blend, dormant, diploid

Bitsy: 18 in., EE, 1-1/2 in., lemon-yellow self, semi-evergreen, diploid

Black Eye: 30 in., M, 5 in., purple with darker eye, dormant, tetraploid

Brocaded Gown: 26 in. EM Re 6 in., Lemon-cream self, semi-evergreen, diploid

Camden Gold Dollar: 19 in., EM, Re, 3 in., gold, semi-evergreen, diploid

Charles Johnston: 24 in., EM, Re, 6 in., cherry-red self, semi-evergreen, tetraploid

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[1] Selections are based on author's observations from growing them in South Jersey and not on actual data. Most of these cultivars are most suitable in Zones 5, 6, and 7.

[2] The cultivars are followed by plant height, season of flower (E, M, etc), if it reblooms (Re), flower size, flower color, foliage type (dormant, semi-evergreen, evergreen), and chromosome number (diploid or tetraploid).

[3] Abbreviations: E, early; EE, extra early; EM, early mid season; L, late; M, mid season; ML, mid season late; Re, rebloom; self, petals and sepals same color.

Classic Rose: 26 in., L, 6 in., rose-pink, dormant, diploid

College Try: 28 in., EM, 3-1/4 in., dormant, diploid

Condilla: 20 in., EM, 4-1/2 in., deep gold self double, dormant, diploid

Congeniality: 36 in., M, 6 in., near white self, dormant, diploid

Double Bourbon: 28 in., EM, Re, 4-1/2 in., orange-brown double, dormant, diploid

Fairy's Petticoat: 18 in., EM, 3-1/4 in., salmon-pink with rose eye, dormant, diploid

Final Touch: 32 in., L, 5 in., lavender-pink, dormant, diploid

Happy Returns: 18 in., EE, 3 1/4 in., yellow self, dormant, diploid

Innocent Bystander: 36 in., M, 5 in., near white self, semi-evergreen, diploid

Janice Brown: 21 in., EM, 4-1/4 in., pink with rose eye, dormant, diploid

Jen Melon: 26 in., ML, Re, 5 in., melon yellow, dormant, diploid

Jeremy: 20 in., M, Re, 3-1/2 in., beige-pink with violet eye, dormant, diploid

Jolyene Nichole: 14 in., M, 6 in., rose blend, dormant, diploid

Katie Elizabeth Miller: 16 in. E Re 4 in., pale pink deeper eye, dormant, diploid

Lady Fingers: 32 in., M, 6 in., yellow self spider, dormant, diploid

Lady of Fortune: 26 in., ML, 3-1/2 in., ivory-cream, dormant, tetraploid

Lavender Patina: 28 in., EM, 4-1/2 in., blue-lavender, semi-evergreen, diploid

Lavender Tonic: 17 in., M, 5-1/4 in., lavender, dormant, diploid

Little Squiz: 26 in., M, 2-1/2 in., dark red with darker eye, dormant, diploid

Lullaby Baby: 19 in., EM, 3-1/2 in., light pink, semi-evergreen, diploid

Naomi Ruth: 30 in., M, 3-1/2 in., apricot self, dormant, diploid

Neal Berrey: 18 in., M, 5 in., rosy pink blend, semi-evergreen, diploid

New Testament: 18 in., EE, Re, 6 in., pink self, evergreen, diploid

Numinous Moments: 26 in., M, 4-1 /2 in., deep lavender-rose with deeper eye, dormant, diploid

Palace Guard: 28 in., M, Re, 6 in., orange-red self, semi-evergreen, tetraploid

Pardon Me: 18 in., M, Re, 2-1/4 in., cranberry red self, dormant, diploid

Pastures of Pleasure: 36 in., EM, 4-1/3 in., orchid self, dormant, diploid

Perky Prize: 30 in., M, 3-1/2 in., rose with red eye, dormant, diploid

Pink Corduroy: 28 in., M, Re, 5-1/2 in., pink self, semi-evergreen, diploid

Plum Royal: 25 in., M, 5-1/2 in., blue-lavender, dormant, diploid

Preppy Pink: 32 in., M, Re, 3-1/2 in., rose-pink, dormant, diploid

Pudgie: 16 in., M, 3-1/2 in., light yellow self double, semi-evergreen, diploid

Punk: 26 in., ML, Re, 2-1/4 in., purple self, dormant, diploid

Queen Anne's Lace: 23 in., M, 4-1/2 in., near white self, dormant, diploid

Red Cadet: 22 in., M, 3-1/4 in., dark red self, dormant, diploid

Red Rum: 15 in., M, 4 in., rusty red, semi-evergreen, diploid

Rococo: 20 in., M, 4 in., light yellow spider, self, dormant, diploid

Royal Frosting: 36 in., EM, 5-1/2 in., near white self, dormant, diploid

Royal Occasion: 26 in., M, Re, 4-1/3 in., dark violet with darker eye, semi-evergreen, diploid

Scarlet Orbit: 22 in., E, Re, 6 in., red self, evergreen, tetraploid

Siloam Amazing Grace: 24 in., EM, 5-1/2 in., yellow self, dormant, diploid

Siloam Double Classic: 16 in. EM 5 in., pink self double, dormant, diploid

Siloam Gum Drop: 18 in., EM, 3-1/4 in., light pink with strong red eye, dormant, diploid

Siloam John Yonski: 16 in., M, 3-1/4 in., light pink with pink eye, dormant, diploid

Siloam Merle Kent: 18 in., M, 3-1/2 in., orchid with purple eye, dormant, diploid

Siloam Plum Tree: 24 in., EM, 4 in., dark black purple self, dormant, diploid

Siloam Royal Prince: 19 in., M, 4 in., purple self, dormant, diploid

Siloam Ury Winniford: 23 in., EM, 3-1/4 in., dark cream with purple eye, dormant, diploid

Siloam Wendy Glawson: 16 in., M, 2-1/8 in., light pink with burgundy eye, dormant, diploid

Sounds of Silence: 26, in., M, 4-1/3 in., cream self, evergreen, diploid

Spindazzle: 26 in., M, 6 in., copper-tipped red-brown spider, semi-evergreen, diploid

Strutter's Ball: 28 in., M, 6 in., black-purple, dormant, tetraploid

Texas Sunlight: 28 in., 3-1/4 in., gold self, dormant, diploid

Unique Style: 21 in., M, Re, 3-1/4 in., yellow edged amber, dormant, diploid

Velvet Shadows: 15 in., ML, 2-3/4 in., violet purple, dormant, diploid

Vera Biaglow: 28 in., ML, 6 in., rose-pink edged grey, dormant, tetraploid

Wish List: 35 in., EM, 3-1/2 in., pink with rose eye, dormant, diploid

Woodside Amethyst: 30 in., EM, 4 in., lavender-purple blend, semi-evergreen, diploid

Woodside Fire Dance: 26 in., EM, 3-1/2 in., red self, dormant, diploid

Woodside Jewel: 32 in., M, 4 in., yellow and gold, dormant, diploid

Woodside Rhapsody: 31 in., M, 4 in., purple self, dormant, diploid

Woodside Ruby: 34 in., M, 4-1/2 in., ruby red self, semi-evergreen, diploid

Yellow Explosion: 27 in., ML, 5-1/2 in., yellow self, dormant, diploid

Effect of Microwave Treatments on the Germination of Seeds

H. William Barnes
Lorax Farms, 2319 Evergreen Ave., Warrington, Pennsylvania 18976

MATERIALS AND METHODS

Twenty-five seeds each of *Leucanthemum* ×*superbum* 'Alaska' (syn. *Chrysanthemum maximum* 'Alaska'), *Lathyrus latifolius*, and *Eschscholzia californica* (California poppy) were soaked in cold water for 24 h. Seeds were then removed and placed upon moist paper towels. The seeds were subjected to 900 watts microwave radiation for a specified period of time, sown in a tray of sterile soil, and germinated in a greenhouse at 70F. Germination results were taken daily with the final counts made on Day 10 of the test period.

The resulting seedlings were place in identical garden situations (except *Lathryus* was not set out due to lack of space) to evaluate longer-term effects.

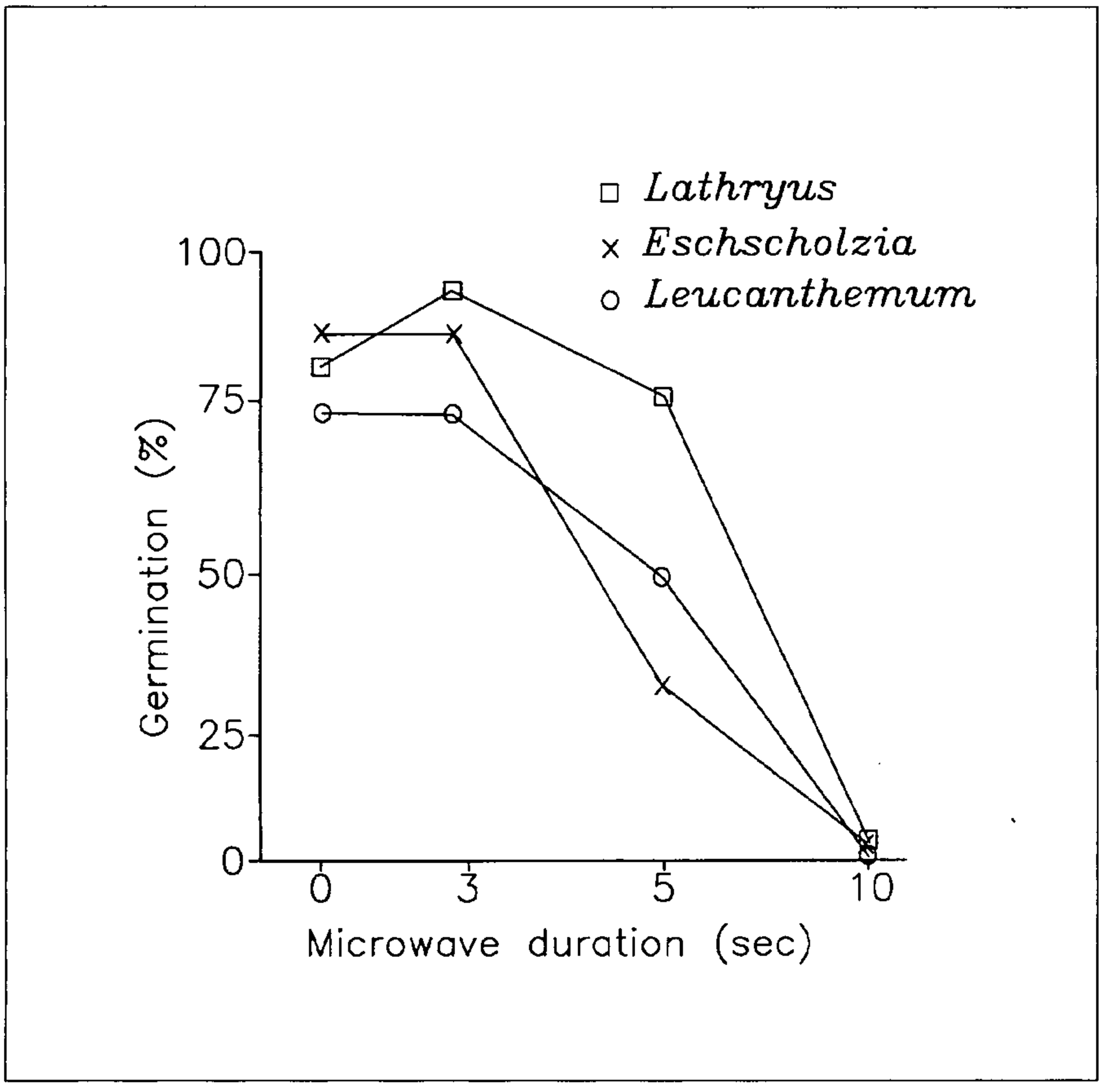

Figure 1. Effect of microwave duration on seed germination of three species.

Table 1. Germination of *Lathryus, Eschscholzia*, and *Leucanthemum* after varying exposure times to microwave radiation.

	Number germinated per day									
Treatment (sec)	1	2	3	4	5	6	7	8	9	Total
Lathryus latifolius										
0	0	0	0	0	0	12	2	4	2	20
3	0	0	0	0	0	14	2	5	3	24
5	0	0	0	0	0	14	1	1	1	17
10	0	0	0	0	0	1	0	0	0	1
Eschscholzia californica										
0	0	0	0	0	0	19	2	0	0	21
3	0	0	0	0	0	19	2	0	0	21
5	0	0	0	0	0	5	1	1	0	8
10	0	0	0	0	0	0	0	0	0	0
Leucanthemum ×*superbum* 'Alaska'										
0	0	0	0	0	0	0	0	15	2	17
3	0	0	8	4	4	1	0	0	0	17
5	0	0	1	4	6	3	0	0	0	12
10	0	0	0	0	0	0	0	0	0	0

Table 2. Growth of seedlings after microwave treatment of seed.

Treatment	Number planted out and response
Leucanthemum ×*superbum* 'Alaska'	
0	17
3	17+
5	12*
Eschscholzia	
0	21
3	21**
5	8

* Two dwarfs were selected from this treatment and not planted with the others, for a total of 14 plants.

\+ Of these, two plants bloomed with normal flowers, none of the other plants either controls or those treated for 5 sec bloomed.

** Of these two plants bloomed white, none of the control plants had white flowers. Normal flower color is orange to yellow.

DISCUSSION

In normal nursery practice many seeds are exposed to water, hot water, and even boiling water soaks or pretreatments. It is obvious that water has an important part in seed germination but it is not clear what role if any the heat may have in conjunction with the water. Microwaves are a means of applying precise doses of heat to seeds in a very manageable and reproducible manner. It has been suggested by Deno (1993) and others that heat is causing a physical change in the seed coat which then in turn allows for the entrance of water to facilitate germination. Perhaps the role of heat in seed germination is more than a merely physical treatment. It is possible that applied heat is having an effect upon enzyme action, the elimination of specific germination inhibitors, or some other activity such as the turning on of a specific genes that promote germination.

The results presented here are merely preliminary and are too early to demonstrate a specific trend. Also, it should be noted that different plant taxa respond differently to the same microwave treatment. Note the fact that *Lathryus* will tolerate a higher dosage of microwaves than will *Eschscholzia* and *Leucanthemum* and that *Leucanthemum* will tolerate higher levels of radiation than *Eschscholzia* (Fig. 1).

LITERATURE CITED

Deno, N. 1993. Seed germination, theory and practice. State College, Pennsylvania

An Aid to Plant Propagation and More

Carlo Belgiorno
Belgiolno Nursery, 1165 Connetquot Avenue, Central Islip, New York 11722

V-trays with their aerated inverted V's can be used for the germination of seedlings and the rooting of cuttings in horticulture, forestry, and by the gardening public with great satisfaction.

The aerated inverted V's produce a very vigorous and fibrous root system. There is a good exchange of air in the root zone which gives the plant an edge over root-rot problems.

The fibrous root system develops into an inverted V shape which can be butterfied outward. The lower-inverted shape root systems intercept water movement which promotes a quicker positive take.

Plants grown in V-trays and V-pots have better transplantability. This feature can be used as a marketing tool by the manufacturer, the grower, and the retailer.

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Propagation of Allegheny Pachysandra by Divisions and Root Cuttings

Timothy C. Brotzman
Brotzman's Nursery, Inc., 6899 Chapel Road, Madison Ohio 44057

In August or September we dig mother plants of *Pachysandra procumbens* (Allegheny pachysandra) cutting them into single stems which must include some of the below-ground, white (etiolated) portions. The presence of roots is an obvious advantage but not a necessity in developing a good liner. Heavy root pieces are graded out and trimmed to be planted as well.

Single stem divisions, about 75 in number, are planted in a deep plastic "grape box" (15 in. × 22 in. × 7 in.). We find this deep box works well to support divisions that may be 8 to 12 in. tall. Root pieces are densely spread in a more conventional flat (15 in. × 24 in. × 3-1/2 in.). A loose, aged medium of rice hulls, peat, and pine bark (10 : 3 : 7, by volume) is used. Both boxes and flats are placed under shade (in the woods works well) and watered as needed for 1 year. These boxes and flats have been overwintered in an unheated polyhouse, outside under plastic or loose leaves, and in a deep 3- to 4-ft covered pit. No overwintering losses have been detected using any of these methods.

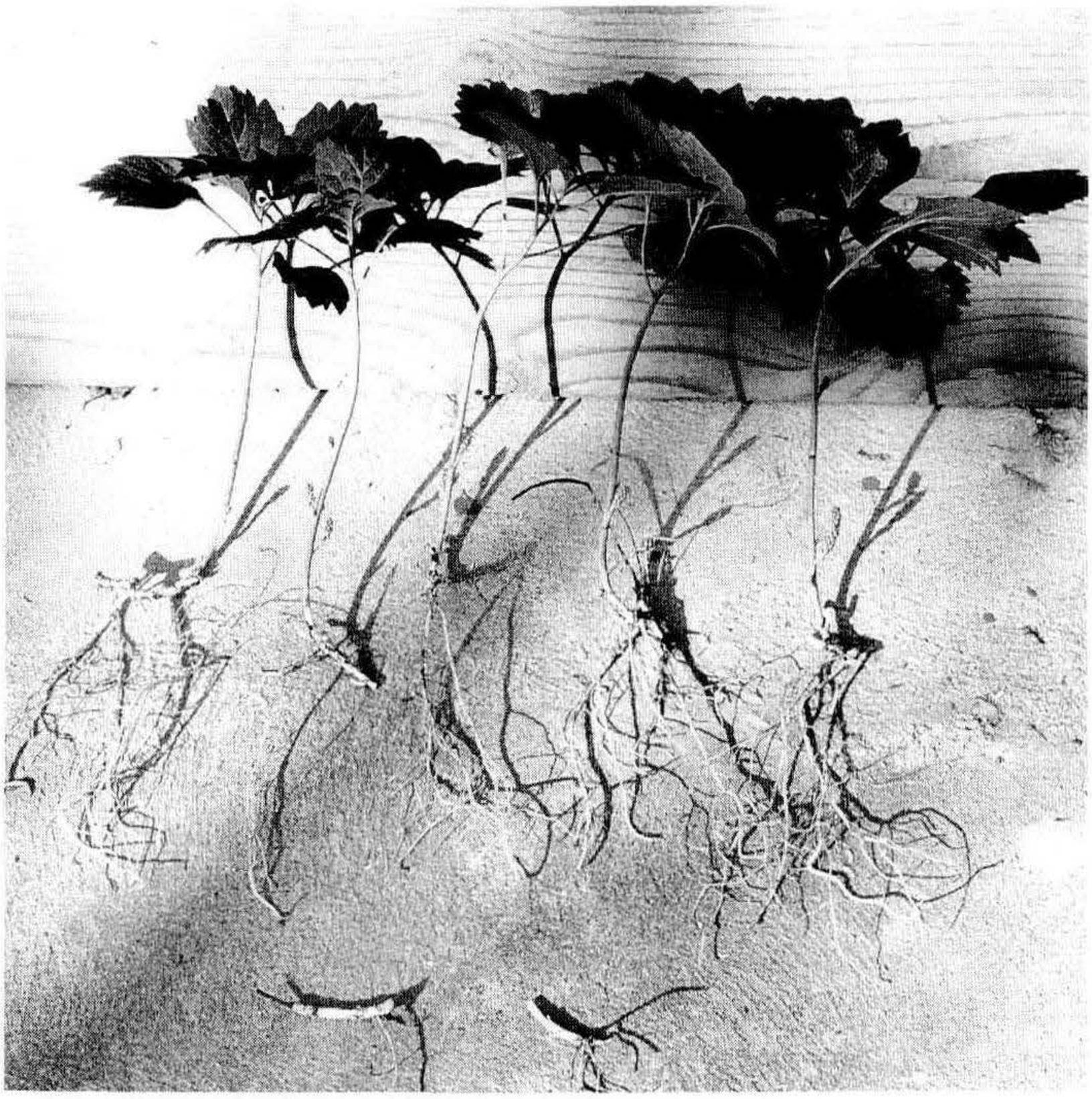

Figure 1. Single stem divisions are made.

At the end of 1 year, well-rooted liners are removed from both flats and boxes and potted into 1-gal containers. These are then grown an additional year and usually develop by that time into saleable, husky three- to six-stem plants.

Allegheny pachysandra is a slow-growing and very fine native ground cover. Though our own production method is not a quick one, the success rate with this program has been close to 100%. Without the need for a greenhouse or mist equipment, expenses are very low once a stock block is established.

Environmentally Friendly Nursery Production Practices

Calvin Chong and Bob Hamersma
Ontario Ministry of Agriculture, Food and Rural Affairs,Horticultural Research Institute of Ontario, Vineland Station, Ontario, Canada L0R 2E0

INTRODUCTION

The ornamental nursery/landscape industry has been one of the fastest growing agricultural sector in Ontario. Nursery research at Vineland has provided leadership and direction in research and development to make this industry competitive and viable. Research has focused on: propagation, container production, new and innovative technologies, and environmentally friendly practices.

PROPAGATION

Our studies have confirmed the benefits of rooting selected difficult species using liquid IBA rooting solutions. A range of plastic plugs were shown to increase rooting, facilitate small plant handling, and facilitate production.

More recent studies have demonstrated that readily available and inexpensive plumbing, car radiator, and windshield antifreezes were suitable alternative solvents for dissolving IBA and that these mixtures were satisfactory for the rooting of cuttings from a wide range of woody taxa. These studies will make it easier and less costly for propagators to formulate and use rooting hormones.

CONTAINER PRODUCTION AND WASTE RECYCLING

Our research has demonstrated the benefits of container growing using potting mixes derived from a wide range or combinations of composted or uncomposted waste by-products, such as spent mushroom substrate, paper mill sludge, waxed corrugated cardboard, composted municipal wastes, tree barks, wood chips, wood wastes, pulverized broken glass, food wastes, animal wastes, and various manures.

Experiments using trickle fertigation and slow-release fertilizers have demonstrated the benefits of reducing water, fertilizers, and run-off pollution. Recently, in cooperation with Dr. Glen Lumis, University of Guelph, we initiated research on a "closed-loop, zero-run-off" system of container nursery culture, the first of this type of research in Canada. We also studied nonchemical weed control in nursery containers using: (1) various types of weed discs on the surface of the media, and (2) weed bags (plastic sleeves) wrapped around the container like a florist's sleeve.

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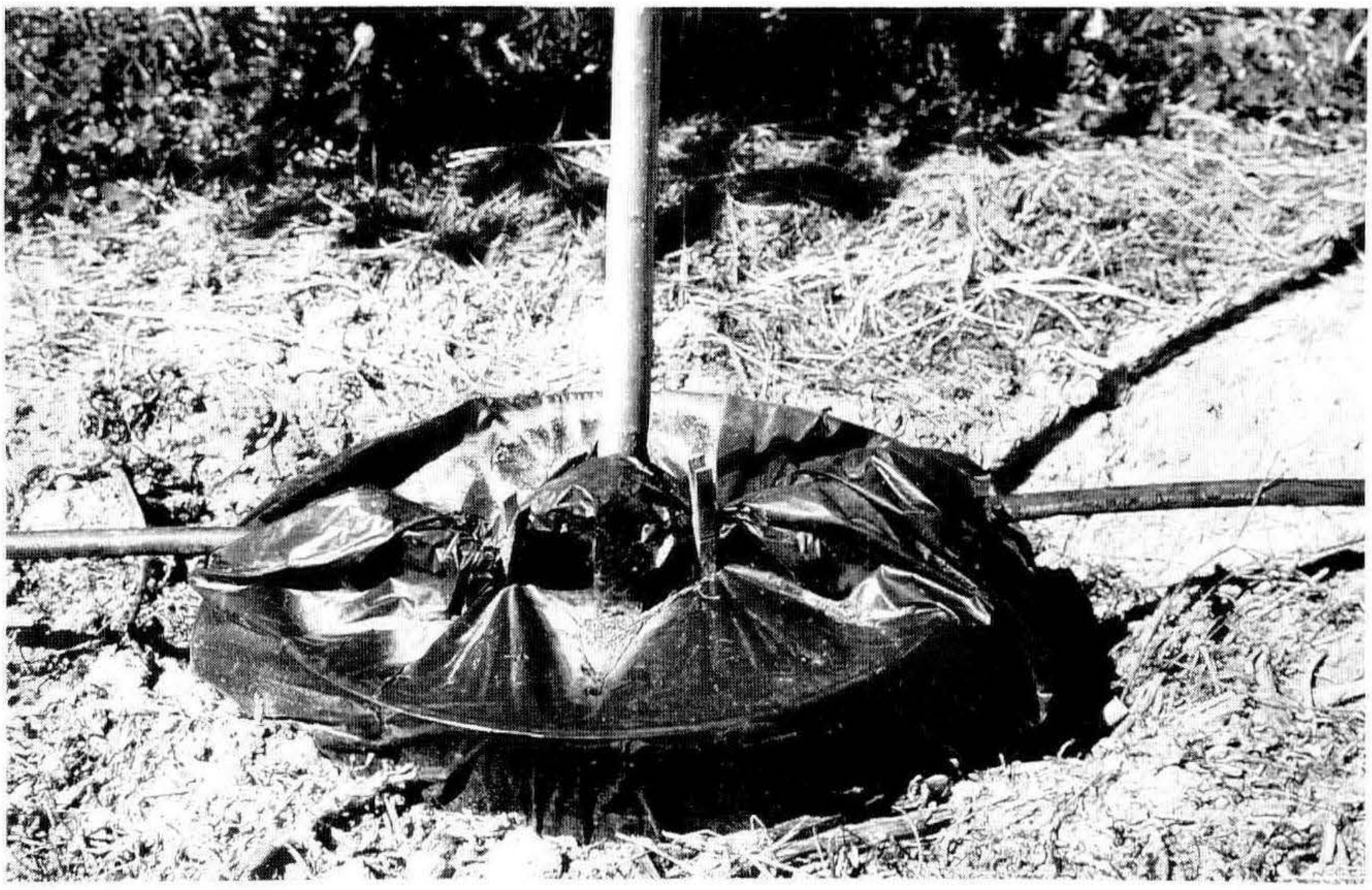

Figure 1. A trickle-irrigated pot-in-pot tree. The garbage bag suppresses weeds and reduces evaporation from the medium.

SHADE TREE PRODUCTION

We have tested and evaluated various in-ground or above-ground container growing methods of tree culture. In the late 1980s, we introduced and tested in Ontario in cooperation with Dr. Glen Lumis, University of Guelph, the new innovative in-ground pot-in-pot tree-culture technique which we first observed in Oklahoma. Our results demonstrated that trickle-irrigated shade trees in 25-gal containers supplied with special combinations of slow-release fertilizers, can be produced more rapidly than by traditional field culture. Preliminary observations indicated that black garbage bags placed over the pot is very effective in controlling weeds (Fig. 1). Less irrigation is required during the season since evaporation from the medium is much reduced. We are now growing the trees using a range of recycled wastes in the container media.

LAND REHABILITATION WITH PAPER MILL WASTES

Each day Ontario generates over 2000 tonnes of raw paper-mill sludges—about 10% is produced in the Niagara Region. Projects in recycling and utilization of paper mill sludges in agriculture and horticulture have included: land reclamation and rehabilitation, soil amendment for field crop production, greenhouse, and nursery potting mixes, and composts for gardeners and landscapers. A long-term "mega-project" is now underway to reutilize paper mill sludge to grow a 3000-acre forest and landscape on near-barren, heavy clay soil previously dug from the Welland Canal on an 11-km strip near Niagara Falls, Ontario.

PUBLICATIONS

During the past decade, we have released over 150 technical and scientific publications on all aspects of the nursery research program. Since 1990, we have also published an annual report summarizing the findings of our research at Vineland.

Black Vine Weevil

Richard S. Cowles
Connecticut Agricultural Experiment Station, Valley Lab, P.O. Box 248, Windsor, Connecticut 06095

Black vine weevil (Fig. 1) is the Trojan horse insect pest of nurseries. The flightless, nocturnally active adults enter propagation areas from outdoors and often remain undiscovered. The soil-dwelling larvae are not easily found until they grow large enough to have caused economic loss, or are inadvertently shipped to customers. A non-exclusive list of favored hosts includes members of the Ericaceae, Pineacea, Primulaceae, Rosaceae, Saxifragaceae, Taxaceae, and Vitaceae.

Black vine weevil develops through egg, six larval instars, pupa, and adult female life stages (they are parthenogenic). Larvae generally overwinter, however, adults may live more than 1 year and also can overwinter. In warm propagation areas, larval development is accelerated, so adults can emerge in February or March, whereas adults developing from overwintered larvae in field populations emerge in June and July. Adults require approximately 4 weeks of feeding before they can lay eggs. Because there are different populations developing at various temperatures, there is a risk of egg laying from March through September. To detect adult populations before they have a chance to lay eggs, workers should vigilantly check for characteristic feeding notches on the edges of leaves. If signs of adults are found, then application of adulticides are warranted. Only long-residual pyrethroids (cyfluthrin or bifenthrin) are suitable, along with acephate, bendiocarb, and cryolite.

Larval feeding on roots causes the most important damage. If adults were not adequately controlled, then larval infestation is likely. Initially, the legless, hunch-

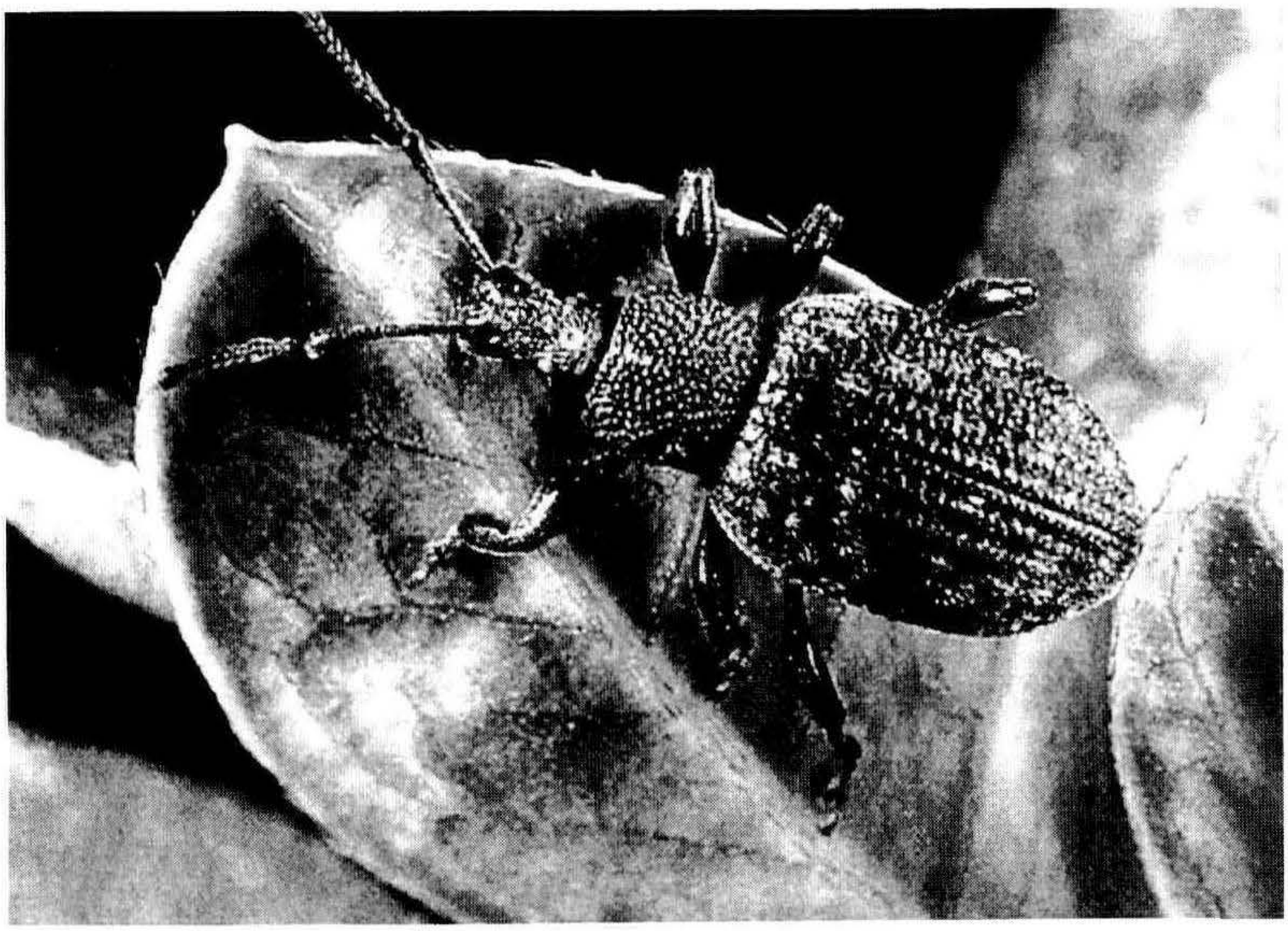

Figure 1. Adult black vine weevil.

backed, white grubs feed on fine roots. On certain plants, especially rhododendrons, the late instar (large) larvae move to the soil surface and girdle woody plants. Under the moist, warm soil conditions common to rooting benches, insect pathogenic nematodes are a good control option. Two effective species of nematodes are available, *Steinernema carpocapsae* and *Heterorhabditis bacteriophora*. Infective juvenile nematodes are approximately 0.5 mm long, and sold in quantities of millions or billions. They can be applied as a coarse spray or drench of the nematode suspension.

Preventative measures include demanding BVW-free propagation material, elimination of favored hosts adjacent to rooting areas, and installing exclusion barriers. Many nurseries become infested when potted liners containing larvae are shipped to them. Therefore, check shipments as they arrive for any signs of BVW activity, including leaf notches. Be especially wary of *Acer palmatum* (Japanese maple), *Rhododendron*, *Erica*, *Calluna*, and spruce shipped in liner pots from the Pacific Northwest, and of any perennials shipped from mail-order houses. Growers should demand that plants either be shipped as bare-root stock, or that effective treatment be done prior to shipment.

Eliminate hosts adjacent to rooting areas to remove the threat caused by local sources of beetles. Adults often seek out warm locations, including houses, for overwintering sites. Move old stock (such as mother plants in large tubs) away from propagation areas, since they can act as asymptomatic hosts from which adults emerge.

Exclusion barriers can prevent adults from climbing into an area. Bury the bottom edge of 6-in., aluminum-flashing strip 2 in. into the soil, then coat the upper 2 in. with grease. The coating needs to be reapplied every 3 to 4 weeks. This approach can also be used to establish on-site quarantine locations for questionably weevil-free plant material, or to divide nurseries into BVW management areas.

Future control methods that look promising are bait-formulated insecticides to control adults and suSCon Green, a 10% chlorpyrifos product that can give 2-years' control of larvae when incorporated into the soil. Both of these options are currently being investigated by the author and other workers in the U.S.

The Impact of Flowers on Adventitious Root Formation in Chrysanthemum Cuttings

Carrie DeVier and Robert L. Geneve
Department of Horticulture University of Kentucky, Lexingtion, Kentucky 40546

It has been generally accepted that the removal of flower buds from cuttings is beneficial to the rooting of cuttings (Hartmann et al., 1990). The antagonistic interaction between flowering and rooting has been observed in a number of species including carnation, dahlia, fuchsia, geranium, and chrysanthemum (Selim, 1956; Woycicki, 1938). This study compared the rooting ability of mum cuttings from vegetative and flowering plants of similar chronological age and in similar growing conditions. In addition, an attempt was made to separate the flowering stimulus from the competition for resources as the mechanism for rooting inhibition.

Root formation in Dendranthema (chrysanthemum) cuttings was reduced as flowers developed on stock plants. The negative impact of flowering on root formation could be partly overcome by IBA (1 mM) in cuttings taken when buds began to show color. However, after flowers began to open rooting was dramatically reduced and IBA had little effect on improving rooting.

The negative impact of flowering on root formation was found in all 10 cultivars evaluated in this study. Not all cultivars were affected equally by the presence of flowers on the cuttings. There was also no apparent relationship between intensity of rooting during the vegetative stage and the ability of cuttings to root with flowers.

This observed effect could result from the presence of a rooting inhibitor produced during flowering. Roberts (1953) showed that flowering chrysanthemum plants produced an "anti-auxin" responsible for the inhibition of rooting. O'Rourke (1942), implied that the flowering response rather than the flowers themselves was responsible for the reduction in rooting of blueberry cuttings containing one or more flower buds. Removing buds from either vegetative or reproductive cuttings of mum prior to sticking reduced the number of roots per cutting. IBA could compensate for the loss of buds in vegetative cuttings but not in flowering cuttings. Preventing flower formation during stock plant development by continually removing buds as they became visible had a negative impact on subsequent rooting of those cuttings. The data suggests that both vegetative and flower buds have a stimulating effect on root formation. However, the data strongly suggests that the flowering stimulus associated with the short-day photoperiods during stock plant development was responsible for inhibiting root formation in flowering cuttings.

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Lagerstedt Hot Callusing Pipe

Don Cross
Cross Nurseries, Lakeville, Minnesota 55044

Hot callusing is a method used in grafting to expose the graft union to a higher temperature for a period of time to speed cell division in the graft union.

Aesculus glabra 'Homestead' grafts were made on 16 January 1992.

The callusing pipe was placed in a cold greenhouse on a sand bed. A central-heat pipe produces a constant temperature of 70F. Grafts were placed into the pipe slots (Fig. 1) with the graft union in the pipe slot. The rootstock roots are placed on sand and covered with a slightly moist sphagnum moss to prevent drying of the rootstocks.

The scions of the finished grafts are placed on sand and covered with burlap—this is to keep scion buds from swelling. Fourteen to 21 days were allowed for heat treatment. During this time, callusing begins but no bud swelling occurs.

By 14 February, 94% of the grafts were callused. At this time they are removed and placed in boxes and covered with slightly moist sawdust. One month later the grafts were planted into containers. Six weeks after potting we had a 91% success rate.

An evaluation of *Aesculus glabra* grafting over three seasons has shown that success overall is dependent more on root system quality and the timing of season than on the hot callusing pipe. We have found by experience that the period between early January and mid February is the better time to graft (Table 1).

Table 1. Hot callusing of *Aesculus* in 1993.

Grafts made	Off heat pipe	Success (%)
Jan. 11	Feb. 6	81
Feb. 10	Mar. 4	51
Mar. 6	Mar. 30	6

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The scions of the finished grafts are placed on sand and covered with burlap—this is to keep scion buds from swelling. Fourteen to 21 days were allowed for heat treatment. During this time, callusing begins but no bud swelling occurs.

By 14 February, 94% of the grafts were callused. At this time they are removed and placed in boxes and covered with slightly moist sawdust. One month later the grafts were planted into containers. Six weeks after potting we had a 91% success rate.

An evaluation of *Aesculus glabra* grafting over three seasons has shown that success overall is dependent more on root system quality and the timing of season than on the hot callusing pipe. We have found by experience that the period between early January and mid February is the better time to graft (Table 1).

Table 1. Hot callusing of *Aesculus* in 1993.

Grafts made	Off heat pipe	Success (%)
Jan. 11	Feb. 6	81
Feb. 10	Mar. 4	51
Mar. 6	Mar. 30	6

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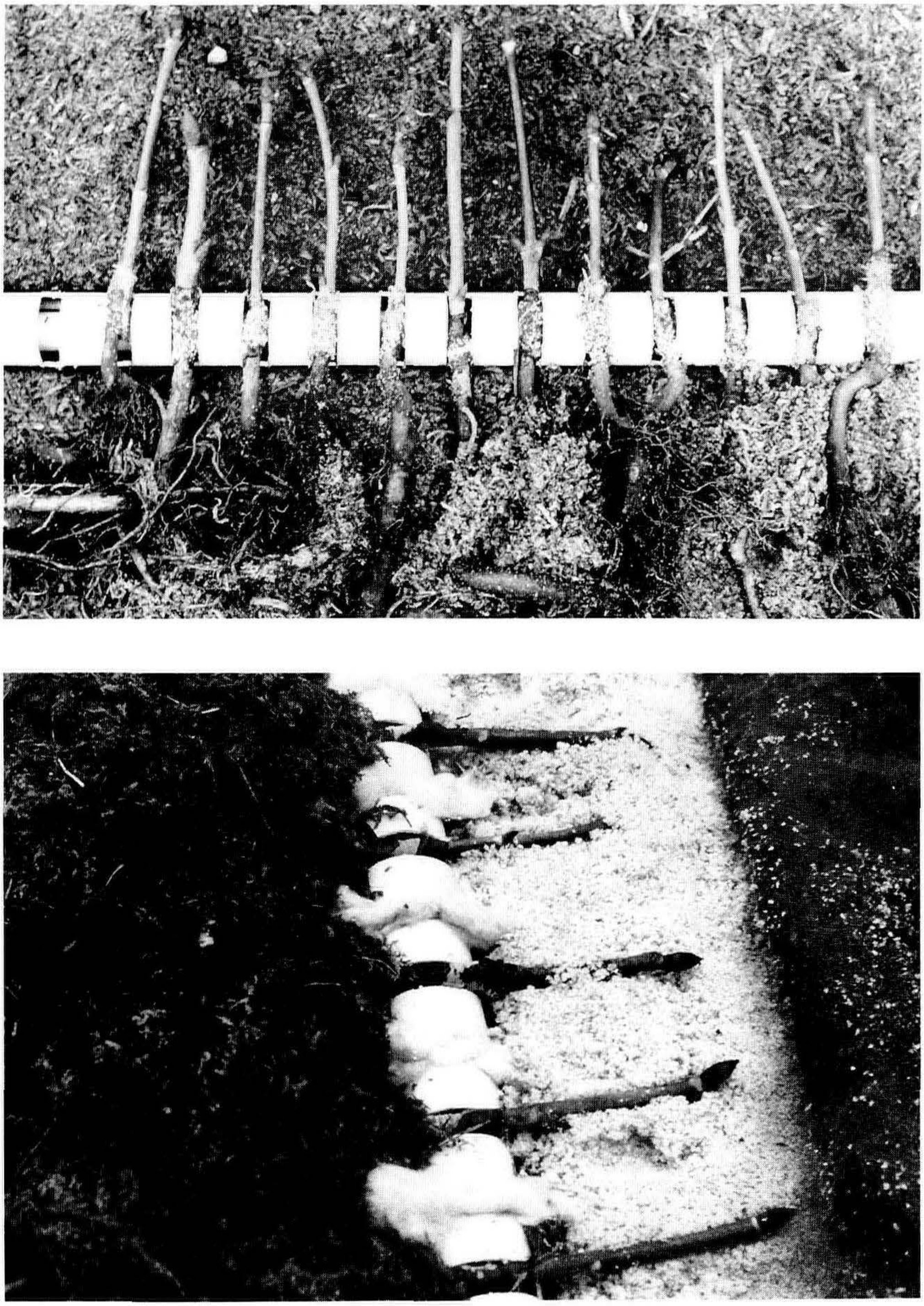

Figure 1. Grafts unions placed into the pipe slots (A) before covering the rootstock roots, (B) after covering the rootstock roots.

Flowering of *Rhododendron* and *Kalmia* in Response to Application Date of Bonzi or Sumagic

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INTRODUCTION

Growers would like field-grown *Rhododendron* and *Kalmia* to have a compact growth habit and flower in the 3rd year from propagation. Thirty years ago, Stuart (1960) showed that growth-retarding chemicals, in combination with a cold and day-length forcing treatment, would induce flowering in *Rhododendron* a year after propagation. The triazol chemicals, uniconazol and paclobutrazol (Davis et al., 1988), may induce flowering more effectively thán those used previously. The reduction in stem elongation due to triazols can last for several years. A drench of paclobutrazol at more than 1000 ppm essentially inhibited any growth of*Rhododendron* in the following year (Wilkinson and Richards, 1991). I applied lower concentrations of paclobutrazol (Bonzi^{TM}) and uniconazol (Sumagic^{TM}) in three seasons to determine how concentration enhances flowering of *Rhododendron* and *Kalmia*.

MATERIALS AND METHODS

Plant Material and Growth Conditions. The large-leaf *Rhododendron catawbiense* 'Boursault' and *Kalmia latifolia* 'Carousel' were used in this study. All plants were propagated and potted in 8-liter pots at Prides Corner Farm (a commercial nursery), Lebanon, Connecticut. The 'Boursault' plants were grown in a mix of hardwood bark, softwood bark, peat, and sand (32 : 32 : 32 : 5, by volume). The 'Carousel' plants were grown in a mix of peat, hardwood bark, and sand (50 : 33 : 17, by volume). In March of the year of treatment, all pots were top-dressed with an Osmocote 9-month timed-release formulation of 17N : 6P : 10K w/w plus minor elements at a rate of 36 g for the 'Boursault' and 24 g for the 'Carousel'. During the growing season, plants were spaced one-pot diameter apart in full sun, and watered at regular intervals. To protect the plants over the winter they were arranged as closely as possible in unheated high tunnels that were covered with white-polyethylene film in late October and uncovered in late March. Insecticides and fungicides were applied according to normal production practices.

Application of Growth Regulators. All plants were treated in mid June of the 2nd year after propagation and grown on at Lockwood Farm, Hamden, Connecticut—the experimental farm of the Connecticut Agricultural Experiment Station. Treatments were a single spray application of one of a range of concentrations of two growth regulators. The chemicals were paclobutrazol in the Bonzi formulation (Uniroyal Chemical Co., Naugatuck, Connecticut) and uniconazol in the Sumagic formulation (Valent Chemical Co., Walnut Creek, California). A volume of 100 ml was applied per plant in 1992 and 1994, and 50 ml per plant was applied in 1995. In the results, the concentrations applied in 1992 and 1994 are doubled, as if plants received 50 ml (1.5 fluid ounces) of the spray in each year.

A batch of solution was applied in its entirety to a group of plants. The solution was applied to leaves and stems as a timed, directed spray, with repeated applications to equalize the volume applied to each plant, and to reduce runoff to a minimum. Six or more plants of each cultivar were not sprayed to serve as controls.

Measurements. In April, three stems on each plant were marked with white paint just below the terminal bud. In October, the length of new growth was measured on three branches of each plant. Typically, the growth was measured for the longest leader on each of three different branches resulting from pruning in the first year of propagation. If there were only two branches, a side shoot was measured. In October, stems terminating in a flower bud or truss were counted. The large terminal buds of 'Boursault' were presumed to be reproductive buds.

Analysis. An analysis of variance was done separately for each cultivar. The chemicals were treated as independent fixed effects. Regression determined the significance of concentration of the chemicals. The three stem lengths for each plant were treated as repeated measures.

RESULTS

Stem elongation of 'Boursault' was relatively insensitive to the growth regulators. It was only partially retarded at the highest concentration of Bonzi applied in 1992. Bonzi had less effect than Sumagic at the concentrations used here. It had no effect on stem elongation in 1994 and 1995. Sumagic only reduced stem length at concentrations greater than 5 ppm in 1995.

Except in 1995, the 'Boursault' rarely flowered unless sprayed. When sprayed in 1992 or 1994, each concentration of Sumagic was effective for inducing flower buds. Every plant flowered when sprayed in 1992 with 8 ppm Sumagic. Flowering tended to increase with concentration of Bonzi in 1992, but Bonzi did not increase flowering in 1994. Neither Bonzi nor Sumagic increased flowering of 'Boursault' in 1995.

Stems of 'Carousel' grew 7 and 10 cm, when sprayed in 1992 with 60 ppm Bonzi or 24 ppm Sumagic, respectively, compared to 18 cm for the controls. In 1994, both Bonzi and Sumagic reduced stem growth from 19 to about 4 cm. At the concentrations used in 1995, Sumagic reduced stem growth more than Bonzi.

In 1992 and 1994, the 'Carousel' rarely flowered unless sprayed, but when sprayed in June, most of the plants flowered. In 1992, Sumagic and Bonzi induced a similar number of flowers per plant. In 1995, the untreated 'Carousel' had about 7 stems terminating in flowering racemes. Bonzi increased the number of flowers only at 10, 100, and 200 ppm, and Sumagic increased the number of buds only at concentrations of 10 ppm and above.

DISCUSSION

Wilkinson and Richards (1991) reported that paclobutrazol greatly enhanced flowering in *Rhododendron*. They suggested a spray application at 500 ppm would be appropriate for inducing flowers. Ranney et al. (1994) found that a spray of 200 ppm Bonzi did not enhance flowering of*R*. 'Roseum Elegans', although soil drenches were effective. I found that sprays of Bonzi at concentrations as low as 10 ppm were effective. These contrasting results may be due to differences in the environment in which the plants were grown and in their age. Day length and temperature affect flowering of*Rhododendron* and these vary among the locations in which the growth

regulators have been tested. Ranney et al. (1994) treated plants in the first year after propagation, a younger stage than the plants used in the present study, which were in their second year. In Connecticut, triazol growth regulators sprayed at low concentrations on 'Boursault' in the first year of propagation did not affect stem elongation or flowering (Larson 1993, personal communication).

Sumagic was more effective than Bonzi at inhibiting stem growth, as observed for several other species (Davies et al., 1988). Sumagic was more effective than Bonzi for inducing flowering of 'Boursault'. However for 'Carousel', the flowering response to Bonzi and Sumagic did not differ.

These triazol growth retardants may more effectively induce flowering than the chemicals used in the past because of the persistence of their effects. As shown by Wilkinson and Richards (1991), triazols can affect growth and flowering for 2 years after application. In the present study, spray applications in June induced flower buds, although the development of visible flower buds did not occur until 3 months after application. Thus, the persistence of the effect of Bonzi and Sumagic may be an important aspect in their ability to induce flowering.

The persistence of the effect of triazol growth retardants on stem elongation could be a problem for landscape plants. Transplants may not fill out the space allocated to them for several years, or as long as stem elongation is inhibited. A continuation of the present study will determine the effect of the triazol growth regulators on stem elongation of transplanted 'Boursault' and 'Carousel' plants in the 3 years after application of the chemicals.

Acknowledgements. I thank M. Emmons, R. Kiyomoto, P. Larson, M. Sellew, R. Schmidt and G. Walton for helpful discussions, and M. Short for expert technical assistance. Prides Corner donated plant material for these experiments, and cooperated in field trials with the growth regulators. This research was supported in part by grants from the Connecticut Nurserymen's Association and Uniroyal Chemical Co.

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The Propagation of Rose Stem Cuttings in Three Propagation Media

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INTRODUCTION

There are innumerable factors which have an effect on the success of a propagation trial, including the method of propagation, propagation environment, medium composition, water availability, and pH.

This paper compares the rooting percentage and root quality of rose stem cuttings in three different propagation media to determine a successful and reliable medium for the standard propagation of several different rose cultivars by cuttings.

MATERIALS AND METHODS

Propagation Media Used. Three different propagation media were compared in this experiment.

1) Medium A—bark mix. This was a purchased mix composed of bark, sand, and peat (9 : 2 : 9, by volume), pH=6.0. This mix was contained in Jiffy peat pots.
2) Medium B—Oasis rootcubes. This ready-made growing medium was purchased from Oasis Grower Products and was contained in plastic cube trays, pH=5.5 to 6.5.
3) Medium C—sand and peat (4 : l, v/v). This was a homogeneous mixture of coarse sand and sifted peat which was contained in plastic plug trays. Medium C is the standard mix used for cutting propagation at the Royal Botanical Gardens.

Rose Cultivars Propagated. Nine each of 13 different rose cultivars were propagated in each of the media (A, B, or C) to determine the most successful rooting medium. The rose cuttings were obtained from the Royal Botanical Gardens rose collection in Hendrie Park (accession numbers are available)—Table 2 contains a list of rose cultivars used.

Preparation of the Cuttings. Cuttings were collected on the mornings of July 16 and 17, 1995. The air temperature was 20C and it was an overcast day. Terminal stem cuttings, 10 to 14 in. long, were removed from the parent plant using clean secateurs, dipped in lukewarm water, and placed in plastic bags. All cuttings were stored in a cold storage room (approximately 10C) until the afternoon of July 17 when the cuttings were prepared for sticking. A basal cut was made just below a node leaving a 4.5- to 6-in. stem. Basal leaves were removed exposing two to three nodes for rooting and thorns were also removed from the base. A shallow, 1/2-in.-long wound was made just above the bottom node to increase the surface area available for rooting. The remaining three to four upper leaves were reduced by one third in size to reduce water loss from the leaves.

Auxin Treatment. All cuttings were dipped in Stim-root 5000 liquid rooting hormone (0.5% indole-3-butyric acid) for 4 sec. Cuttings were stuck immediately into the three trial media.

Propagation Environment. The propagation environment used was a shaded fiberglass propagation greenhouse with a two-clock, solenoid-valve misting system set to maintain 100% relative humidity. The first clock operates on a 24-h cycle and turns the second clock on and off. This clock was set to come on from 8AM to 8PM. The second clock runs on a 30-min cycle with 30-sec intervals. This clock was usually set to release mist for one 30-sec interval every 30 min except on extraordinarily hot or humid days during which mist was released for 30 sec every 15 min. B10 brass misting nozzles were suspended 18 in. above the propagation benches and were spread 36 in. apart. Mist benches and electric-heating cables were covered with fibre cloth and maintained a bottom heat of 22 to 24C. The City of Hamilton water used for misting was alkaline.

Cuttings were monitored daily to ensure that proper environment was maintained and to note rooting progress, remove dead leaves, etc. Results were recorded on August 29, 1995.

RESULTS

Two criteria, rooting percentage and root quality, were used to determine the effectiveness of each medium.

$$\text{Rooting (\%)} = \frac{\text{number of cuttings rooted}}{\text{total number of cuttings in each medium}} \times 100$$

Root quality was determined qualitatively using a scale of 0 to 3 with the following criteria: "0", no roots or rotted roots; "1", some roots, may die; "2", several roots, should live; "3", many healthy roots, no root rot; "2" and "3" = superior quality rooting.

Other factors taken into consideration were root size (length and diameter), degree of root rot, and evenness of rooting around the stem. The root quality rating is an average of the root-quality numbers assigned to each cutting in a particular medium.

Table 1. Rooting percentage and root quality of rose-stem cuttings propagated in three different media.

Medium	Composition	Rooting (%)	Root quality
A	Bark mix	81.2	2.48
B	Oasis rootcubes	71.8	1.92
C	Sand and peat	71.8	2.35

DISCUSSION

Table 1 shows that the Oasis rootcubes and the sand and peat mix were equally successful in rooting percentage with 71.8% of cuttings developing roots. However, there was a substantial degree of variance in root quality obtained. The bark mix surpassed both the Oasis rootcubes and sand and peat mix in both rooting percentage and root quality.

Root development trends in the Oasis rootcubes tended to be a small number of strong, thick roots. The roots were often bound and folded around the bottom of the cube signifying that the plastic container the cubes were in did not allow maximum root growth. This could be partially overcome by earlier transplanting of cuttings to pots. Roots also tended to be one-sided, having uneven spread around the stem. Root quality was significantly decreased due to root rot caused by excessive water in the cubes. This is attributable to the high water-holding capacity of the cubes. William Shakespeare® rose had many roots develop above the medium level in the oasis cubes which is a sign of excess water, but did not show this symptom in either the bark or sand and peat mix.

The most notable observation about the rooted cuttings in the sand and peat mix was the long, even spread of root growth the plug trays allowed. Many cuttings had roots up to 3 in. long. Some degree of root rot was observed.

Roots of the cuttings propagated in the bark mix were plentiful and virtually unaffected by the container size, as the roots were able to penetrate through the peat pots. Very little root rot occurred suggesting that drainage was sufficient.

Table 2. Rooting percentage by cultivar and medium in the propagation of rose stem cuttings.

Cultivar	Rooting (%)		
	Bark mix	Oasis rootcubes	Plug trays
'Ausbred', Bredon® rose	100	100	100
'Ausmas', Graham Thomas® rose	100	77.8	100
'Golden Wings'	77.8	44.4	44.4
'Schneewittchen'	88.9	100	77.8
'Ausroyal', William Shakespeare® rose	88.9	88.9	88.9
'Morden Ruby'	0	0	0
'Bucbi', Carefree Beauty® rose	100	66.7	66.7
'Country Dancer'	77.8	77.8	77.8
Charles Austin® rose	77.8	77.8	66.7
Stadt Rosenheim® rose	55.6	11.1	22.2
'Nearly Wild'	100	100	100
Lyric	88.9	100	100
The Fairy	100	88.9	100

Figure 1 provides a graphical presentation of the results in Table 1. It depicts the percentage of cuttings having superior root quality (root quality ratings 2 and 3) to show the percentage of cuttings that will produce a quality saleable plant with standard care after transplanting, as compared to those that may require special handling, additional nutrients, longer time to maturity, etc. The data implies that propagation in the bark mix will produce 12.8% more superior quality plants than the Oasis cubes and 13.7% more than the sand and peat mix.

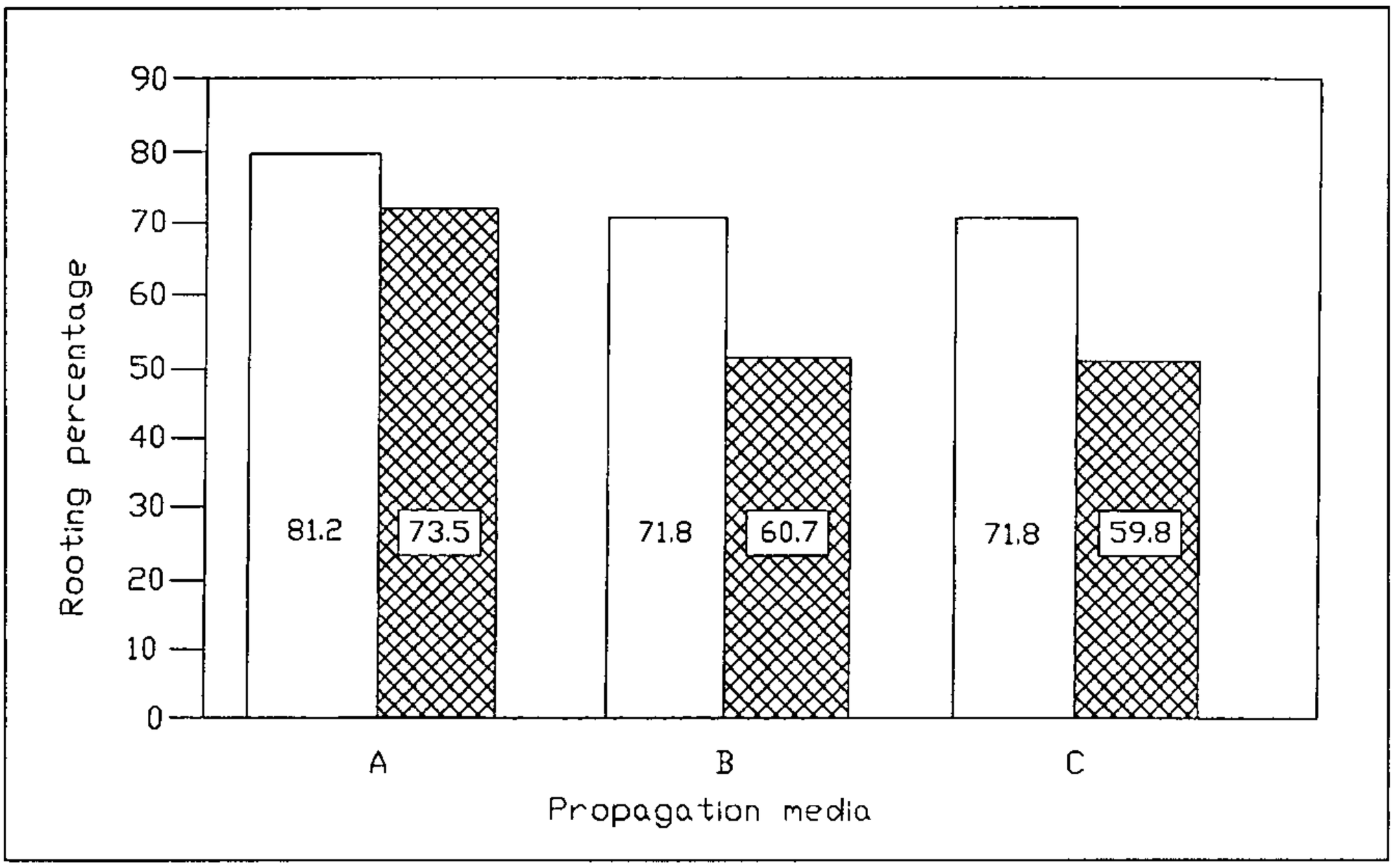

Figure 1. Comparison of total rooting percentage and superior quality rooting percentage for rose stem cuttings in three propagation media. Non hatched = total rooting (%), hatched = superior quality rooting (%).

Table 2 shows that with only two exceptions the rose cultivars were relatively easy to root from cuttings. Propagation medium had no effect on the rooting success of 'Morden Ruby' which failed to root at all, but caused significant variation in the rooting percentage of Stadt Rosenheim® rose. For Stadt Rosenheim® rose, 33.4% more rooted cuttings were obtained in the bark mix than in the plug trays and 44.5% more than in the Oasis cubes. This cultivar is likely more vulnerable to deviation from optimum conditions. This is an important factor to consider when choosing an effective propagation medium for several cultivars. It is interesting to note also that Graham Thomas® rose obtained 100% rooting in all media except the Oasis rootcubes, in which rooting decreased by 22.2%

Another notable observation was the importance of wounding and removing the basal thorns. Roots initiated far more frequently from the knife and thorn wounds than from the nodes. For example, the difficult-to-root Stadt Rosenheim® rose had roots initiating only from the wounds and showed no evidence of root growth from the nodes.

CONCLUSION

On the basis of the results obtained, it stands out that the bark mix was the most successful and reliable medium for the cutting propagation of several different *Rosa* cultivars. It can be seen from these trials that propagation medium is a moderate factor in root development. A great deal of the variation in root quality was due to other controllable factors, such as container size and water requirements, so it may be desirable to investigate these media further under conditions where water availability, for example, is the variable.

Improvement of rose propagation by cuttings will be aided by this experiment and subsequent investigation into propagation factors taken on by other interested parties.

Rooting Procedures for *Alstroemeria* Divisions and Micropropagated Cuttings

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INTRODUCTION

The breeding of *Alstroemeria* has been ongoing at the University of Connecticut since 1985. Four cultivars of the *Constitution Series* were patented and introduced in 1994: 'Freedom[P]', 'Liberty[P]', 'Patriot[P]', and 'Redcoat[P]'. These *Alstroemeria* can be propagated asexually by the division of rhizomes or through micropropagation. As a result of a Goodyear grant from the state of Connecticut, we are conducting research to develop a commercial production protocol for the *Constitution Series*. As part of this research, rooting procedures for both conventional divisions and micropropagated cuttings are being evaluated.

RHIZOME DIVISION

Plants of *Alstroemeria* 'Freedom[P]', 'Liberty[P]', 'Patriot[P]', and 'Redcoat[P]' were divided and randomly planted into 4-in. pots in four rooting media. The media used were Fafard 1-P®, Fafard 2®, Fafard 3® and UConn Mix. Fafard 1-P® is peat moss and perlite (7 : 3, v/v), Fafard 2® is peat moss, perlite, and vermiculite (7 : 2 : 1, by volume), Fafard 3® is peat moss, perlite, vermiculite, and bark (3 : 1.5 : 1.5 : 4, by volume), and the UConn Mix is part soil, part peat moss, and part perlite (1 : 1 : 1, by volume). Plants were divided in August, October, and December of 1994 and placed under greenhouse conditions with 16-h days from 400w HID lights and 55F night temperatures. There were 8 replications per treatment except for 'Liberty[P]' which had 3 replications. Evaluations were made 4 weeks after division.

Table 1. Percent rooting of *Alstroemeria* divisions.

Cultivar	Rooting medium			
	Fafard 1-P®	Fafard 2®	Fafard3®	UConn Mix
Freedom[P]	99 a[a]	96 a	96 a	95 a
Liberty[P]	94 a	75 b	75 b	94 a
Patriot[P]	71 b	74 b	44 c	87 a
Redcoat[P]	95 a	91 a	73 b	98 a

[a] Means followed by the same letter are not significantly different (P<.05).

Significant differences in the percent rooting of divisions were noticed between cultivars and between rooting media (Table 1). 'Freedom[P]' had excellent rooting in all of the four media; 'Liberty[P]' had the best rooting in the Fafard 1-P and the UConn

[P] = Plant Patent

Mix; 'Patriot^{P}' rooted best in the UConn Mix; and 'Redcoat^{P}' rooted well in the Fafard 1-P, Fafard 2, and the UConn Mix. 'Patriot^{P}' was the most difficult cultivar to root from rhizome division. There were no significant differences in the time of year on rooting.

Although the UConn Mix provided good rooting percentages for all four cultivars, the soilless Fafard 1-P mix or a similar mix of peat moss and perlite is presently being used. The peat and perlite mix provides excellent rooting, is easier to handle, and more economical and lighter for handling and shipping.

ROOTING OF MICROCUTTINGS

The objective of these experiments was to determine if micropropagated *Alstroemeria* needed Stage III root initiation treatment in vitro before acclimation and rooting. From a commercial point of view, it would be ideal to root microcuttings directly from the multiplication stage II. This would eliminate the need for a stage III treatment, which requires additional labor, time and space.

Alstroemeria cultivars from the *Constitution Series* were maintained on a modified Alstroemeria Medium (Bridgen et al., 1991) with 1mg/litre^{-1} benzylaminopurine (BAP). Three in vitro media were used for this experiment: Alstroemeria Medium with BAP, Alstroemeria Medium with no BAP, and Alstroemeria Medium with 5% activated charcoal and no BAP. After 4 weeks on the three in vitro media, the cuttings were stuck in two rooting media in clear polyethylene propagation trays with the lids secured. The rooting media used were vermiculite and sphagnum peat moss mix (1 : 1, v/v) and Pargro™ peatwool. The plants were maintained at 68F with 16-h photoperiod for 4 weeks and then evaluated. There were 10 plants per treatment and six replications.

Significant differences were noted for all treatments (Table 2). The best overall rooting results were obtained by using the Stage III Alstroemeria Medium without BAP pretreatment followed with rooting in Pargro™. The Stage III medium with BAP provided the poorest results in both rooting media. The Pargro peatwool medium provided overall higher rooting percentages than the vermiculite/sphagnum medium.

The results indicate that under these conditions it is necessary to include stage III pre-rooting with auxin before stage IV rooting and acclimation.

Table 2. Percent rooting of *Alstroemeria* microcuttings.[a]

In vitro *Alstroemeria* medium	Rooting medium	
	Vermiculite/sphagnum	Pargro™
(+) BAP[b], (-) activated charcoal	33f	50e
(-) BAP, (-) activated charcoal	57d	80a
(-) BAP, (+) activated charcoal[c]	63c	67b

[a] Means followed by the same letter are not significantly different ($P<.05$).
[b] 1mg liter^{-1} BAP.
[c] 5% Activated charcoal .

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The Role of Micropropagation in the Incidence of Tissue Proliferation in *Rhododendron* 'Montego'

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Tissue proliferation (TP) is a condition primarily seen in certain micropropagated rhododendrons. Cultivar Montego was studied because plants grown in containers and in vitro cultures show distinctive morphological and physiological phenotypes which identify plants or cultures which are prone to TP.

Our goal in this study was to test the hypothesis that adventitious events during micropropagation are involved in the induction of TP-like culture characteristics and to test if the cytokinin 2iP plays a role in this induction.

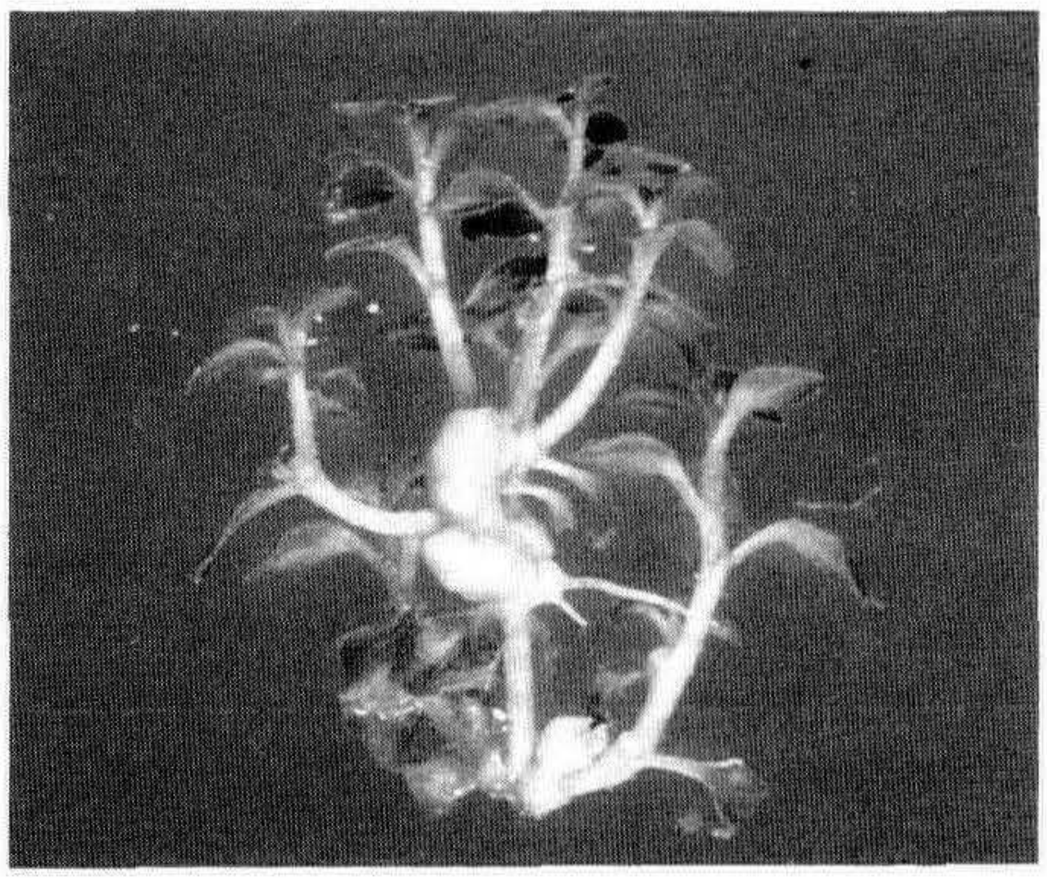

Figure 1. Swellings produced on shoots of a TP+ in vitro culture of *Rhododendron* 'Montego' on basal Woody Plant Medium.

Comparisons were made between 'Montego' with TP (TP+) and 'Montego' control plants that had no TP (TP-) in their propagation history. This was done to avoid the possibility plants or tissues derived from plants with TP may retain the potential to express TP even if TP was not apparent. TP- stock plants were obtained by rooting cuttings from the original 'Montego' plant grown from seed. Cuttings were supplied by Dr. David Leach of the Holden Arboretum. TP+ 'Montego' plants or tissues originated from plants with TP.

Three experiments were conducted. Experiment 1 compared in vitro culture initiation and maintenance char-

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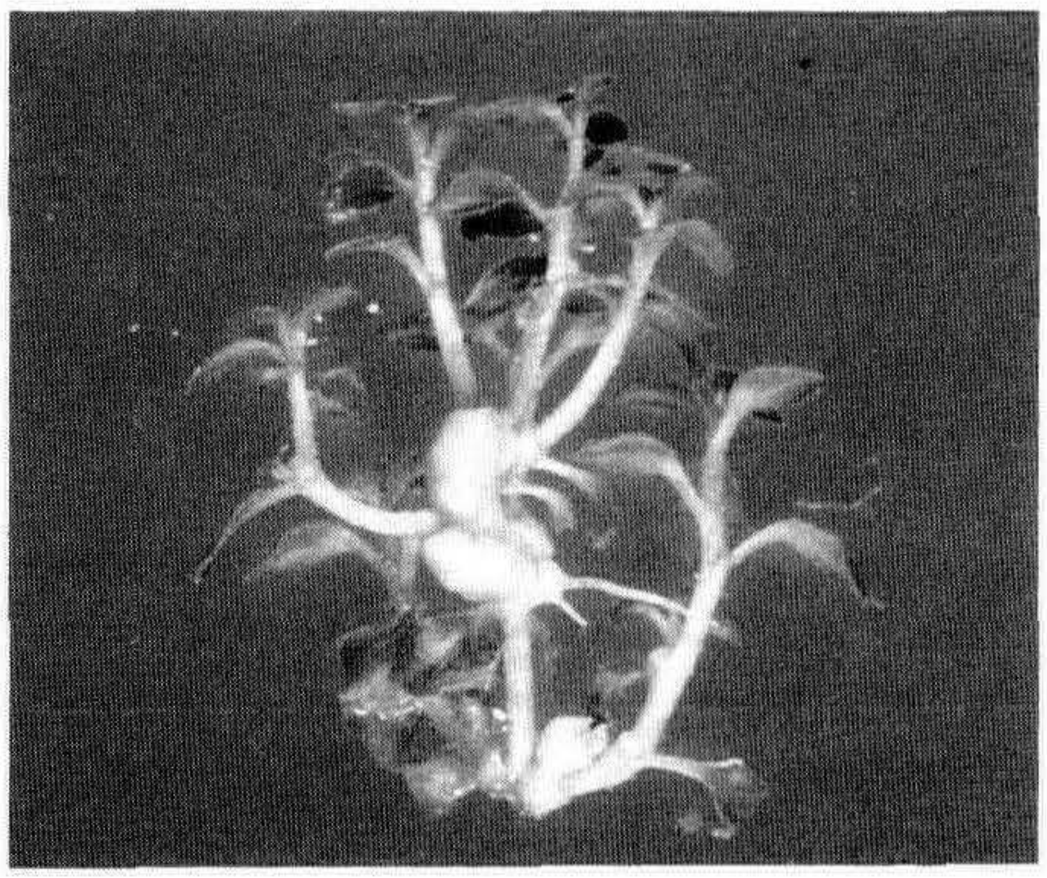

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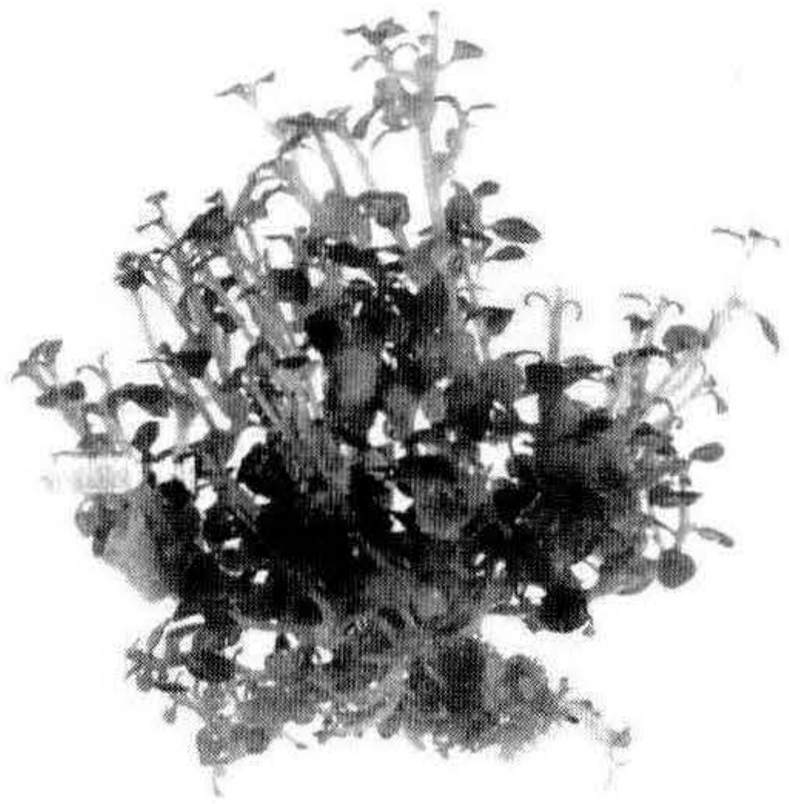

Figure 2. Typical TP+ in vitro culture of *Rhododendron* 'Montego' growing on basal Woody Plant Medium.

Figure 3. Typical TP- in vitro culture of *Rhododendron* 'Montego' growing on Woody Plant Medium containing 10 mM 2iP.

acteristics of TP- and TP+ explants; Experiment 2 tested the effectiveness of 2iP in inducing TP-like characteristics in TP- cultures; and Experiment 3 studied the role of adventitious events in TP- tissues in generating TP+ culture and plant characteristics.

Cultures were initiated by transfer of explants from TP+ and TP- stock plants onto Woody Plant Medium (WPM) supplemented with 10 mM 2iP. Shoot tips of TP+ and TP- 'Montego' behaved differently after the culture initiation period. TP+ cultures miniaturized and multiplied 4 months after initiation (AI); TP- cultures required 10 months to reach the same stage. Dramatic changes occur in TP+ at 6 months when excess shoot branching with little shoot elongation and very rapid multiplication began. This is accompanied by development of TP-like swellings at nodes (Fig. 1). By 10 months TP+ cultures become so compressed due to reduction in shoot extension they were overwhelmed by adventitious growth. In order to encourage shoot extension, we then transferred shoot clusters off initiation medium onto basal WPM which contains no hormone. Growth on basal WPM was required to maintain TP+ shoot cultures (Fig. 2). Repeated subculturing shows these cultures can rapidly multiply in the absence of 2iP. This culture behavior is typical of TP+.

TP- cultures maintained on WPM with 10 mM 2iP begin slow, steady multiplication 14 months AI. Only nonadventitious shoot tips and stem segments were transferred. The rate of multiplication has not increased 28 months AI, and 2iP is required for multiplication. Shoots elongate well, but multiply slowly (Fig. 3). This culture behavior is typical of TP- cultures.

In Experiment 2 significantly more adventitious meristem was produced at the base of TP- shoots grown on WPM containing 50 mM 2iP than on WPM containing 10 mM 2iP. The increase in adventitious meristem was correlated with an increase in TP+ culture behavior.

The role of adventitious events in generating TP-like characteristics was further investigated in Experiment 3 where shoot organogenesis from TP- leaves was used to generate adventitious growth which was classified by phenotype as putative TP+ or putative TP-. Six of 41 leaves (15%) of the leaves produced cultures with TP+

culture behavior (putative TP+). The presence of intermediate cultural phenotypes suggests that partial conversion of TP- to TP+ may occur during adventitious events. Plants grown from putative TP+ and putative TP- cultures produced significantly different leaf and shoot morphology. This morphology was statistically identical to control plants derived from TP+ and TP- stock plants and cultures initiated from their shoots.

Many growers are concerned that micropropagation cannot produce plants free of TP. Our work shows that phenotypically normal rhododendron can be produced via micropropagation. We have not observed TP+ tissues arising from axillary multiplication from nonadventitious shoot tips. Stable, "normal" cultures can be maintained by: (1) vigilant removal of basal callus and adventitious meristem masses, (2) use of low cytokinin levels to maintain slow-to-moderate multiplication rates, and (3) production of shoots through axillary multiplication from nonadventitious shoot tips.

Utilizing Band Pots For Herbaceous Plant Production

Michael Kolaczewski
Flora and Fauna Horticultural and Biological Consultants, 324 Silver Street, Elgin, Illinois 60123

Purpose. Band-pot technology is not new to plant propagators. Indeed, this type of container, originally known as milk carton blanks or pots, has been in use for many years with several variations of different types of materials. This presentation shows the utilization of this container to grow herbaceous plants and the subsequent uses for this band-pot-grown product.

Why Use Band pots. I looked at using band pots after considering several factors.

1) Presently, most of the mail order nurseries sell their perennials, bare root. Customers receive their plant material via mail or UPS. They then either pot it up or plant it into their gardens. People in most cases pay full retail prices for a bare-root plant.
2) In general, most perennial crops are 8 to 12 weeks in production duration after transplanting seedlings or rooted cuttings. It is possible to grow plants in band pots and bring them to marketability several times during 1 year or season.
3) The reutilization of containers can effect lower production costs. This of course means that you could gain a better profit margin, if all aspects of production remained fixed or the same.
4) You could in effect plant a "smaller" container on a project, yet still get "1 gallon" results after reasonable period of time.

What I am trying to do with my company is grow a reasonably priced plant for a retail client, yet keep my costs as low as possible. Considering that mail order companies sell bare-root materials for full retail prices, or in some cases better than, I tried to incorporate this concept into a price and product formulation for local clientele. Since my present production location is limited in size, I had to get the most material grown in a limited space—about 1 acre. Field growing plants and then bare root storage was out of the question. So I decided to begin growing seedlings or divisions, depending on size, and cuttings in a smaller, yet marketable container. The bottomless band pot seemed to fit the bill. They come in a range of sizes, allow

culture behavior (putative TP+). The presence of intermediate cultural phenotypes suggests that partial conversion of TP- to TP+ may occur during adventitious events. Plants grown from putative TP+ and putative TP- cultures produced significantly different leaf and shoot morphology. This morphology was statistically identical to control plants derived from TP+ and TP- stock plants and cultures initiated from their shoots.

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for more or less normal root growth, and can be held in flats for easier movement. Their size allows for more plant per square foot than conventional 1-gal containers.

Band Pots. I have used the Anderson Die and Manufacturing band-pot products for several years in conjunction with seedlings and cuttings of woody plants. I decided upon several different sizes of band pots for perennial growing. I use the 3-5/8 in. × 3-5/8 in. × 6 in., 3-9/16 in. × 3-9/16 in. × 4-1/4 in., and the new 2-3/4 in. × 2-3/4 in. × 2-1/2 in. pots in my system. I coupled this with the present mode of seeding propagation, the Growing Systems Groove Tube tray, and several plug trays. The end result, of course, is to achieve a uniform product from start to finish. The one weak link here, is that the seeds are manually sown into the trays. Obviously I am looking at either semi- or fully automated seed-sowing and production.

Advantages and Disadvantages. I looked at the advantages and disadvantages of this system and have condensed the main points as follows. This will help you to decide if such a system will work for you. It is important to remember that at present, over 90% of what I grow is used "in house", and we recycle over 95% of the band pots, after sale or installation, back into propagation and production.

Disadvantages.

- Individual pots versus flats.
- Filling separate bands can take longer than whole flat trays.
- Individual pots can require more handling.
- Bandpots may not work with an automated filling or potting system.
- Size disparity of band may not appeal to customer.
- Product "comes to market" sooner in a smaller container, may require special handling, or shifting up if not sold in a reasonable time period.

Advantages.

- Less space used by band pots, greater product density per square foot.
- Quicker rooting of plugs into bands versus larger container.
- Less likelihood of root disease, and "wet bottoms".
- The dollar value of this container could be the same as a larger pot, if this concept is marketed properly.
- This system allows for custom propagation. A client could utilize a smaller size container on larger projects, i.e., corporate jobs, highway projects, or large subdivision work.
- Band pot could be bid at a more competitive price than the standard 1-gal pot.
- When educated, a consumer, either wholesale or retail, could be returning bands after installing plants, and therefore reduce future production costs.

The next step will be to further evaluate different species for growing adaptability, shipping logistics of this container, a dormant plant versus a growing plant, and a more precise price comparison of various container production costs.

With the nursery and landscaping field seemingly becoming more competitive, any edge that you can develop over the competition could be significant. I hope this presentation has given you food for thought, and perhaps you may be able to utilize some of these techniques in your own operation.

"To Seek and to Share"... Founding a New I.P.P.S. Region

Peter Orum
Midwest Groundcovers, P.O. Box 748, St. Charles, Illinois 60174

The I.P.P.S. continues to seek active members in all areas of the world. One of the newest regions to be established is IPPS-Denmark, the Scandinavian Region.

Sponsored by the Eastern Region, the first step was to organize and find interested people in the new region. There were already some active I.P.P.S. members. An organizing conference was held in 1992.

With the financial and moral support of the International and the Eastern Region membership, brochures were produced in both English and Danish and potential members were contacted throughout Scandinavia.

The first conference was held in Odense, Denmark in September 1992. Attending were Eastern Region organizer Peter Orum and International Secretary John Wott. Later that same month, IPPS-Denmark President Erik Lund-Andersen attended the International Conference in Sacramento, California and obtained acceptance of the new Region.

The second conference was held in Jutland, Denmark, in September 1993. September, 1994 saw the third conference in Odense, Denmark. International President John L. Machen, Sr. attended and presented a paper. Other speakers included Eastern Region Vice President David Beattie and Eastern Region Past President Peter Orum.

The fourth annual conference was held in September 1995 in Zealand, Denmark. International President Ian Gordon visited and spoke.

Highlights of the conference included a visit to a working greenhouse at a Danish Horticultural School. On landscape day, conference attendees saw examples of wildflower sod from Sweden as well as a demonstration of how horses are once again being used for certain forestry work.

Another highlight of the conference was a visit to a leading Danish container nursery that supplies plants to garden centers.

Today IPPS-Denmark is thriving and working hard to recruit new members in Sweden, Norway, and Finland. The Region produces a quarterly newsletter through which members stay in touch and share information. Thanks to the diligent support and spirit of the sponsoring Eastern Region, I.P.P.S. is continuing its educational mission in Scandinavia and gaining in turn from this region's long history of horticultural innovation.

Rooting Response of Microcuttings of Hybrid Dogwood

Deborah D. McCown and Andrew J. Daun
Knight Hollow Nursery, Inc., 3333 Atom Rd., Middleton, Wisconsin 53562

Flowering dogwoods are among America's most elegant and popular small trees. While dogwoods can be grown from seed, most are propagated from cuttings. Elite selections for superior flowering and interspecific hybrids of *Cornus florida* and *C. kousa* for disease resistance require clonal propagation. Successful cutting propagation of dogwoods has required use of rooting hormones. A survey of I.P.P.S. Proceedings recommended that softwood-tip cuttings should be treated with IBA at 0.3% to 2% in talc or 2500 ppm IBA + 2500 ppm NAA as a liquid dip for high percentage rooting.

Knight Hollow Nursery has been micropropagating several cultivars of interspecific crosses of *C. florida* and *C. kousa* for 4 years. Woody Plant Medium solidified with 1.4 g litre^{-1} phytogel and 4 g litre^{-1} agar and supplemented with 6 mM calcium gluconate and 1 μM zeatin is a satisfactory culture medium. Growth is rapid and subculture cycles are normally 4 to 6 weeks. Our experience with woody plant microcuttings in general is that they are easily rooted ex vitro with no additional treatment. Some plant types (notably apples) may require auxin treatments for satisfactory rooting but our experience indicated that even dilute auxin treatments on the base of microcuttings resulted in classical burn symptoms. Ex vitro rooting of dogwood microcuttings, however, was slow and percentages erratic. We decided to once again investigate the potential of using rooting hormones on microcuttings to see if we could enhance root growth on dogwoods.

Sixty tip cuttings of micropropagated *C.* 'Rutdan' Celestial™ dogwood PP#7204 were harvested from 5-week-old cultures. Cuttings were approximately 4 to 5 cm long and were randomly divided into 6 groups. All treatments were done with Dip 'N Grow, a commercial liquid preparation containing 1% IBA (10,000 ppm) and 0.5% NAA (5000 ppm). The 5-sec dip treatments were 0%, 20%, 40%, 60%, 80%, and 100% Dip 'N Grow, diluted with distilled water. Data were collected after 4-weeks rooting time. The experiment was repeated using 11 cuttings per treatment.

The combined data from the two experiments (Fig. 1) indicate close to a doubling in percent of cuttings rooted, number of roots produced, and root length at the 40%, 60%, and 80% concentrations compared with the no hormone treatment. Common lilac microcuttings root at nearly 100% with no treatment while classical softwood cuttings are treated with auxin concentrations of 1500 to 5000 ppm IBA to achieve high rooting percentages. That dogwood microcuttings require auxin treatments of 12,000 ppm (80%), the same requirement of traditional softwood cuttings, is remarkable.

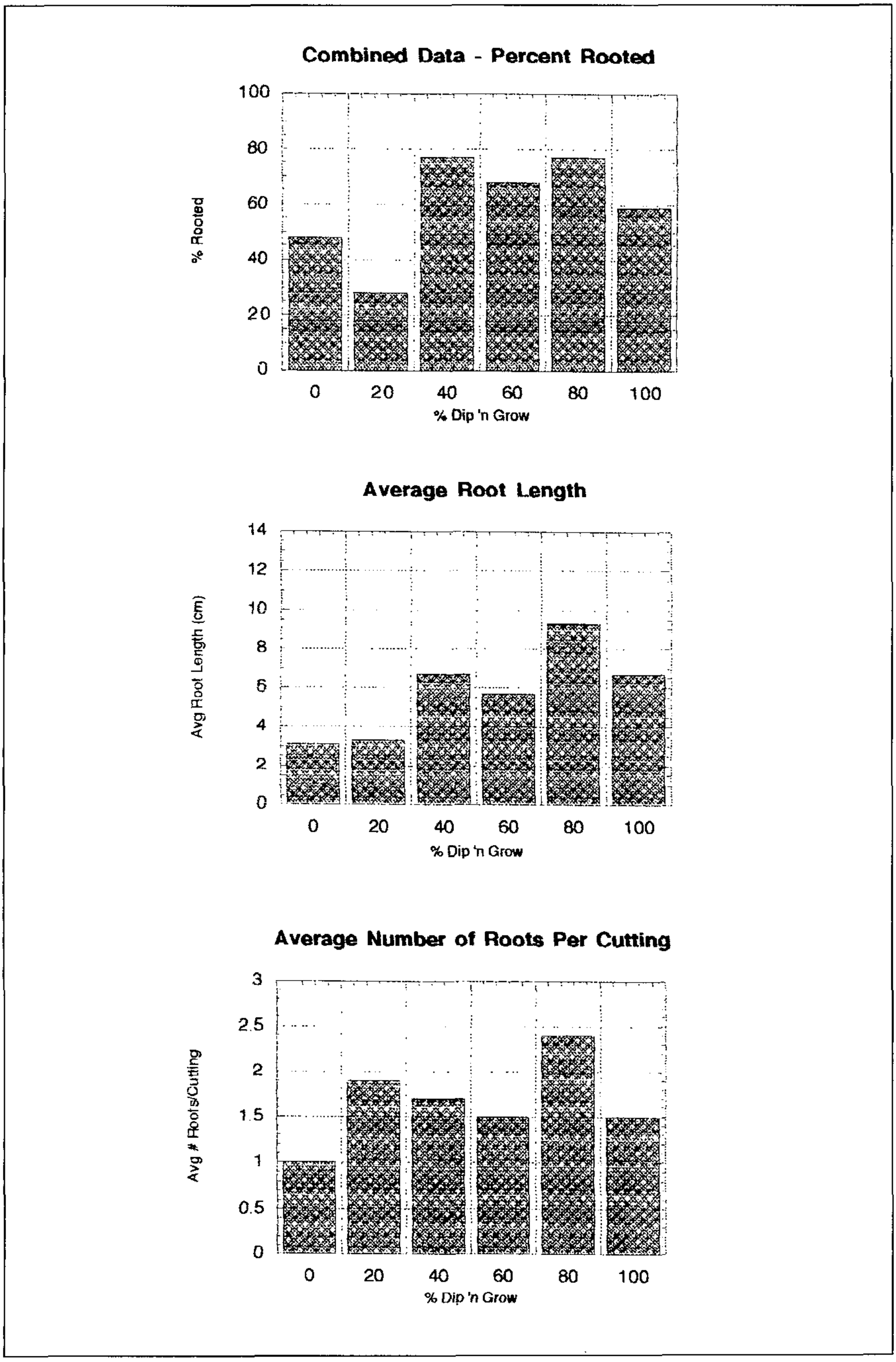

Figure 1. Rooting response of microcuttings of hybrid dogwood. Results are combined data from two experiments with 10 cuttings minimum per sample per experiment. Dip 'N Grow of 100% equals 10,000 ppm IBA and 5000 ppm NAA

Low-Tech Fern Propagation

Richard H. Munson
The Holden Arboretum, 9500 Sperry Road, Kirtland, Ohio 44094

Fern propagation has been discussed a number of times in past Proceedings, most recently in 1993 (O'Dell). In order for fern spores to germinate, and eventually produce fern plants, certain requirements must be met: a ready supply of viable spores; sterile, or at least pasteurized, growing medium; a clean, translucent watertight container; a certain amount of light; and a continuous supply of moisture. Although the basics of fern propagation remain unchanged, a method that uses small, recycled containers may be useful to small nurseries and to teachers for classroom demonstrations.

Grocery stores and restaurants frequently use hinged plastic containers for take-out salads, nuts, alfalfa sprouts, and other perishable foods. Normally these have a clear lid for product viewing and either a clear or opaque bottom. These leftover containers, once thoroughly cleaned, make excellent growing chambers for fern spore germination. Normally, the lid has an interlocking rib that connects the lid to the bottom, forming a fairly tight seal. I get these containers from my home and from students or friends who have been alerted to the need for such containers.

The growing medium I use is a sterile peat-lite, fine-textured mix. The mix is thoroughly moistened with excess moisture squeezed out by clean hands, and then placed in the bottom part of the container. Since the fern plants will not spend a great deal of time in the container once they are large enough to transplant, the depth of medium need not be more than 1 inch. It is more important to leave head space in the container so that the young plants have enough room to develop.

Fern spores are distributed over the surface of the moistened medium and are "watered in" with a spray mist bottle. This brings the spores into close contact with the medium and assures the greatest opportunity for germination. Once the spores germinate, they produce a multicellular structure, often heart-shaped, called the prothallus. This structure contains the antheridium and the archegonium. For fertilization and subsequent formation of a plant, sperm must swim from the antheridium across the prothallus in a film of water to the archegonium. Although the humidity level will remain very high inside the closed container there is no assurance that the prothalli will remain wet enough for this process to take place. Periodically (approximately every 2 weeks) I remove the lid and mist the surface of the medium. This reestablishes the water "bridge" which facilitates fertilization. I continue this process until I am ready to transplant the young fern plants.

Because I use clear plastic, tightly closed containers I cannot put them in a place where they will receive direct sunlight. The best place I have found is under greenhouse benches near the rear edge. Although somewhat dark in this location, the process works quite well and reduces the chance that sunlight will strike the container, causing excessive heat buildup.

I raise the ferns in a greenhouse that is heated year-round. For hardy ferns it usually takes about 1 year from the sowing of the spores until transplanting. This can be shortened, perhaps, by transplanting at a very small size and placing the new plants under mist to reduce transplant shock.

In summary, the keys to this simple propagation process are cleanliness, the right container, the proper environment for spore germination, a supply of viable fern spores, and patience.

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O'Dell, K. 1993. Fern propagation from spores. Comb. Proc. Intl. Plant Prop. Soc. 43:462-463.

Propagation of Summer Blooming Azaleas

Christopher S. Rogers
Weston Nurseries, Inc. Hopkinton Massachusetts 01748

INTRODUCTION

In the 1940s Ed Mezitt saw the need for extending the flowering season in the New England landscape. He began working with native azaleas and was successful in developing a wide range of flower colors and plant habits. These plants begin blooming after mid-June in Hopkinton, Massachusetts, and add color at a time when most woody plants have finished blooming. Several are sufficiently winter hardy to thrive in all but the northmost areas of New England.

MATERIALS AND METHODS

Plant Material. The cuttings are collected from container-grown plants from this year's growth. The plants are allowed to put on 5 to 6 in. of growth before taking the cuttings. The top 4 in. is collected. The cuttings are taken first thing in the morning, moistened in a plastic bag and placed in a cooler at 48F. Enough cuttings are collected for 1 day's work. The bottom 2 in. of foliage is stripped off each cutting and a fresh cut is made at the base of the cutting. Cuttings are dipped in a solution of Dip N Gro (1 : 20, v/v) for 10 sec. The cuttings are kept moist at all times prior to sticking.

Medium. The medium consists of aged pine bark, peat moss, and coarse perlite (2 : 1 : 1, by volume) to which 1 lb Aqua-gro granular and 2 lb dolomitic limestone are added per 21 ft^3 of medium. After all components are in the mixing machine, enough water is added to thoroughly moisten the mixture.

Propagation House. Two 21 ft × 96 ft hoop houses are used for all the azalea, shrub, and tree cuttings. A 63% shade cloth is utilized on top of the greenhouses. All propagation plug trays are placed on the ground. Three inches of pea stone covers the floor with a weed control mat placed over the pea stone. Prior to sticking cuttings, the whole house is treated with Green Shield.

Fog is utilized for rooting the cuttings. Time clocks are used to control the output; the cycle varies depending upon the weather conditions. On hot, sunny summer days, the fog is on 1 min every 5 min. No bottom heat is utilized, but the air temperature is allowed to reach 95F.

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The bottom-air-intake end vents of the greenhouse are blocked with air allowed into the houses only from the upper convection tube opening. A poly curtain is set up 6 ft into each house. This allows for even distribution of air flowing into the houses and also protects the main electricity areas.

Several hundred cuttings are prepared and stuck all at once. Cuttings are direct stuck into the plug trays on the floor. The cuttings are inserted 1 to 1-1/4 in. in depth into the medium and thoroughly watered in. The medium is checked on a regular basis for any drying that might occur. Depending on cultivar, rooting occurs in 6 to 10 weeks. On average 90+% rooting can be obtained.

Post Rooting. Once rooting has occurred, the cuttings can be hardened off and moved into another house for overwintering or left in the propagation house for overwintering. The house is set at 35F night temperature and the vent temperature is set on 42F.

The average speed for taking field cuttings, preparing the medium, filling plug trays by hand, preparing the cuttings, and sticking the cuttings is 130 cuttings per worker hour per person per day.

Control of Root Outgrowth by Copper Hydroxide in Capillary Mat Plug Production

Myra Stafford, Robert L. Geneve, and Jack W. Buxton
Department of Horticulture, University of Kentucky, Lexington, Kentucky 40546

Capillary mat subirrigation offers several advantages over standard overhead watering. It provides a relatively constant supply of water reducing fluctuations in the water content of the medium caused by evaporation between overhead watering cycles. Also, it is a viable option to meet new or pending regulations for managing water and water effluent for greenhouse production. The drawback for plants grown on capillary mats is root outgrowth from the container into the capillary mat (Koranski and Kessler, 1991). Root outgrowth reduces the life of the mat, can make removal of plants from the mat difficult, and reduce the quality of the seedling for transplanting.

The objective of this study was to determine the efficacy of treating the outside, bottom of plug containers with Spin Out™ (a commercially available formulation of copper hydroxide in latex paint) to control root outgrowth into capillary mats during plug production of marigold seedlings.

Seeds of marigold (*Tagetes* Little Devil hybrids) were sown into plug flats and moved to capillary mats. Three square-plug flats—512, 406, and 288, and two octagonal-plug flats—384 and 288 (differing in volume and shape but with a constant height of 2.5 cm) were compared for seedling development. The outer, bottom surface of half the 16-celled flats were dipped in Spin Out™ (Griffin Corp, Valdosta, Georgia) containing 100 g $Cu(OH)_2$ $liter^{-1}$ (7%, w/w). Seedlings were evaluated for leaf area, shoot and root dry weights, and root length. Root length in 13-day-old seedlings was determined from 8-bit digital images obtained using a Coho video camera and analyzed using a Quadra 700 Macintosh computer.

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The overall root outgrowth was reduced by 80% to 92% by the copper treatment regardless of cell shape or volume (Fig. 1). Seedlings grown in octagonal plugs showed less root outgrowth and produced 21% more roots compared to square plugs. Larson et al. (1987) observed larger tomato transplants produced in square compared to round containers. Seedlings transplanted to cell packs showed no effect of copper treatment on shoot and root growth. Seedlings grown in small square-shaped plugs showed reduced overall growth compared to large plug sizes. Improved growth following transplanting has been one of the benefits shown by plants grown in copper-treated containers (Struve and Rhodus, 1990).

Results from this study show the potential usefulness of using Spin Out™ on the outside bottom of plug containers to control root outgrowth onto capillary mats. The current study was limited to marigold seedlings and additional research will be required to show the general usefulness of this procedure with other species.

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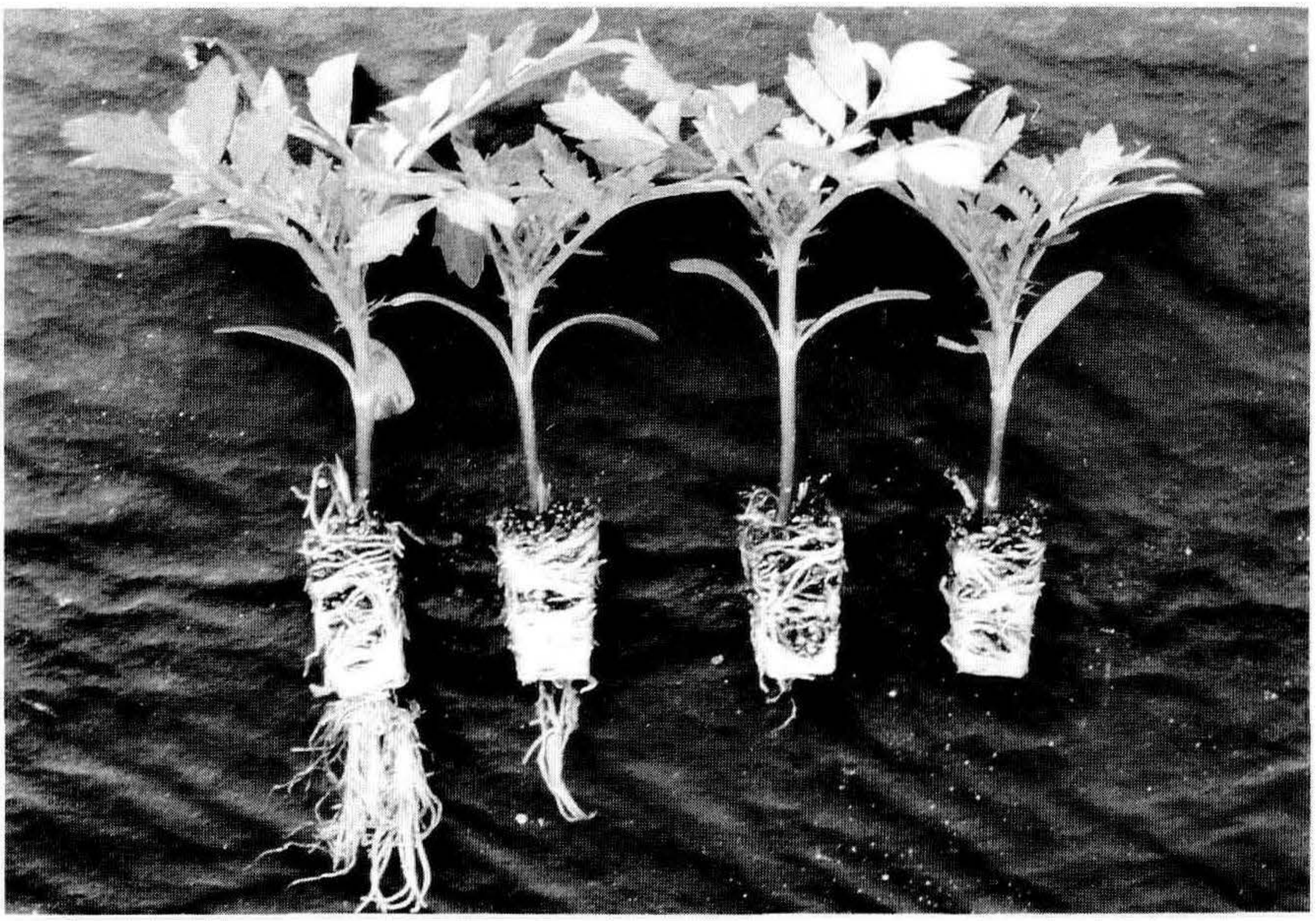

Figure 1. Marigold seedling growth after 16 days showing root outgrowth from the drainage hole in untreated plug (left) and copper-treated (right).

New Concepts in Improving Ornamental Plant Adaptability with Stress-Tolerant Rootstocks

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INTRODUCTION

Fifteen years of ornamental plant adaptability trials at The NCSU Arboretum with widely diverse species from around the world has shown the single most important environmental/climatic limitation to be root survival under wet, hot summer conditions. As temperatures rise, respiration rates increase, which create a requirement for more oxygen to permit root survival. Sudden flooding of poorly drained soils during maximum temperature periods can create temporary, but quickly fatal, anaerobic conditions for roots at the time of peak oxygen demand. This situation is unique to the southeastern U.S. Conversely, soils in southwest and western states are dry (and subsequently well aerated) during periods of high temperatures, while central and northeast areas are cooler when rains occur.

In addition, modern container production with carefully formulated media of coarse texture and rapid drainage allows simple, successful production of plants with fragile root systems which often cannot be subsequently grown easily in landscape soils of the production region. Prominent examples include many Ericaceous plants and such native and exotic taxa as *Franklinia alatamaha*, *Gordonia lasianthus*, *Ilex* ×*meserveae* ("blue hollies"), and *Taxus* ×*intermedia*.

Grafting is used to produce plants which combine aerial portions of superior ornamental or productive capacity with adapted and tolerant root systems suitable for the area of production. The majority of such grafting is used in fruit crop production, where an economic product permits the extra costs of such specialty propagation. Very little research has been conducted on potential rootstocks specifically for ornamental plants in the southeastern U.S. due to: (1) lack of commercial grafting operations in the region, (2) lack of such specific skills among most academic researchers, and (3) the time and expense to conduct such long-term trials on "minor" crops.

Commercial grafting firms in the Pacific Northwest and the Northeast are not aware of the potential problem and often use rootstocks which work well in those areas, but are failures when planted in the southeastern U.S. A prime example is the use of *Abies balsamea* or *A. fraseri* seedling rootstock for all fir grafting—due to their low cost and availability as a major Christmas tree species. These are the two weakest rootstock systems for firs, and such grafted plants never survive the first month of wet summer conditions in the southeastern US. In early years after its introduction, *Cornus* 'Eddie's White Wonder' was grafted in the Pacific northwest on *C. nuttallii* which cannot be grown in the southeast, leading early researchers to believe the scion cultivar could not be grown in the east. Many other such examples exist.

CONCEPTUAL GRAFT COMBINATION SUGGESTIONS

The following listing contains **theoretical, proposed** rootstock : scion graft combinations for research and production trials. The listing has been formulated from observations of plant behavior at the NCSU Arboretum, other gardens around the world, and from native habitats of many of the species. The plants listed first (before the hyphen) are taxa which have been observed to have more tolerance to hot, wet southeastern U.S. soils than average species of the genera and therefore have potential for rootstock use. The plants listed following the hyphen are those which have ornamental value, but have been observed to have survival problems in poorly drained soils and therefore would be the scion or cultivar that becomes the shoot system of the grafted plant.

In a few cases, bigeneric combinations (where species from different genera are grafted together) have been proposed where tolerant species do not exist within the problem genera. Bigeneric grafts are generally less successful than interspecific grafts, but enough successful combinations have been achieved in the past to warrant trial. An asterisk (*) is used after the proposed combination where promising trial grafting work has been conducted at NCSU or observed elsewhere.

POTENTIAL LOW-OXYGEN- AND HIGH-SOIL-TEMPERATURE-TOLERANT ROOTSTOCK: GRAFT COMBINATIONS

Abies firma—for other *Abies* taxa*.

Acer japonicum or ***A. palmatum***—for *A.. circinatum* and *A. macrophyllum.*

Acer rubrum—for *A. pentaphylla**.

Acer saccharum—for *A. griseum**.

Arbutus unedo—for *A. arizonica, A.menziesii*, and *A. texana.*

Baccharis halimifolia—for *B. pilularis*.

Betula nigra—for other *Betula* taxa*.

Calycanthus floridus—for *C. occidentalis.*

Ceanothus ×pallidus or ***C. americanus***—for west coast *Ceanothus* taxa.

Cercis canadensis or ***C. chinensis***—for *C. griffithii, C. occidentalis.*

Chamaecyparis pisifera or ***C. thyoides***—for *C. lawsoniana* and *C. nootkatensis* cultivars.

***×Chitalpa tashkentensis* (*Catalpa* × *Chilopsis* hybrid)**—for *Chilopsis linearis*.

Cornus florida—for *C. nuttallii* and *C.* 'Eddie's White Wonder'*.

Crataegus aestivalis—for other *Crataegus* taxa.

Cupressus bakeri or ***C. arizonica* [syn. *C. glabra*]**—for *C. sempervirens* 'Swane's Golden'.

Elaeagnus ×ebbingei or ***E. pungens***—for *E. angustifolia.*

Fagus grandifolia—for *F. sylvatica* cultivars; trial on *Nothofagus sp.* ??

Garrya lindheimeri **[syn. *G. ovata* var. *lindheimeri***—for *G. elliptica* 'James Roof'.

Photinia* ×*fraseri—for *Heteromeles arbutifolia* .

***Ilex* 'Nellie Stevens'**—for *I. aquifolium* and *I.* ×*meserveae* ("blue hollies")*.

Itea chinensis—for *I. ilicifolia.*

Kalmia latifolia—for *K. cuneata* and *K. microphylla.*

Magnolia virginiana—for *M. sieboldii* and *M. wilsonii.*

Myrica cerifera—for *M. californica.*

Picea abies, P. omorika, or ***P. orientalis***—for *P. breweriana.*

Pieris japonica—for *P. floribunda.*

Two-Needle Pines: *Pinus glabra* , *P. pinea, P. sylvestris,* or ***P. virginiana***—for *Pinus edulis, P. muricata.*

Three-Needle Pines: *Pinus palustris, P. serotina, P. rigida,* or ***P. taeda***—for *Pinus coulteri, P. jeffreyi, P. ponderosa, P. sabiniana* .

Five-Needle Pines: *Pinus cembra, P. parviflora,* or ***P. strobus***—for *Pinus albicaulis, P. aristata, P.flexilis, P. torrey*

Pseudolarix amabilis—for *Larix* taxa (unlikely bigeneric graft—but the only possibility for *Larix* in the South).

Quercus virginiana—for the numerous west coast and Mediterranean evergreen *Quercus* species.

Rhaphiolepis umbellata—for *Raphiolepis indica* taxa.

Rhododendron chapmani—for small-leaved evergreen *Rhododendron* taxa; a possible trial for *Kalmiopsis leachiana.*

Rhododendron atlanticum—for deciduous *Rhododendron* taxa; specifically *R. occidentale.*

Sorbus alnifolia—for other *Sorbus* taxa.

Spiraea sp.—for *Holodiscus discolor* (unlikely bigeneric graft, rootstock suckering is a potential problem).

Stewartia monadelpha, S. pseudocamellia Koreana Group, or ***S. pseudocamellia***—for *S. malacodendron* and S. *ovata.*

Styrax americanus or ***S. japonicus***—for *S. hemsleyanus, S. obassia, S. officinalis, S. officinalis* var. *redivivus* [syn. *S. californicus*], *S. platanifolia, S. texana,* and *S. youngae.*

Syringa oblata* var. *dilatata—for *S. vulgaris* cultivars.

Taxus chinensis—for *Taxus* ×*media* cultivars.

Thuja orientalis **[syn. *Platycladus orientalis*]**—for *Microbiota decussata* (unlikely bigeneric graft—but the only possibility for the South).

Tsuga canadensis or ***T. sieboldii***—for *T. caroliniana, T. heterophylla,* and *T. mertensiana.*

CONCLUSION

Successful combinations from the above potential grafting/rootstock trials would make possible the favorable landscape cultivation of new ornamental plants currently impractical or impossible to grow in the southeastern U.S. There is an industry conception that grafted plants are a commodity of the past with increasingly unavailable skills needed and greater costs than for cutting production of clonal taxa. This statement is generally true for mass-market crops, but for a number of plants grafting may be the only feasibility for successful use of the taxa in the region. Knowledge of graft combination feasibility would create opportunities for development of regional specialty propagation nurseries to fill the potential consumer market for such connoisseur plants.

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Fate of Herbicides in Container Nursery Runoff

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Multiple preemergence herbicides applications are used in nurseries to control troublesome weeds throughout the growing season. Much of the applied chemicals are subject to runoff losses from the irrigation water, and recycled irrigation water may contain herbicide residues that could be harmful in the production of landscape plants. In 1991, we started research to determine the fate of herbicides in nursery runoff water. Two nurseries that recycle irrigation water were surveyed over a 2-year time period by analyzing containment pond water and sediment samples monthly. Pendimethalin, oxyfluorfen, and oryzalin herbicides were detected in water and sediment at times in both nurseries; however, herbicides did not accumulate over time and there was no strong correlation between amount detected and amount or timing of herbicide application. On-site, nursery runoff studies were used to evaluate quantities lost from a single herbicide application and the length of residual activity in containment pond water. Approximately 5% of the amount of oryzalin and oxyfluorfen applied moved in the runoff water from the first irrigation after treatment. Herbicide residues decreased over time in the containment pond and no residues were detected 3 weeks after herbicide application. Micro plot studies indicated plastic bed covers enhanced runoff losses compared to gravel. Other field runoff studies with Snapshot TG (isoxaben and trifluralin) revealed that as much as 12.5% of the applied isoxaben was lost in the first 5 days after application. Isoxaben dissipated below detection limit in the pond water 60 days after application. Sprayable isoxaben was more subject to runoff losses than granular formulations and light played an important role in the dissipation of isoxaben. Greenhouse studies revealed that herbicide residue levels detected in the irrigation water were 100 times lower than the level that would cause measurable landscape plant damage. Grassed water ways and vegetated filter strips will lower the levels of pesticides reaching the surface water bodies.

INTRODUCTION

Current management practices in the production of containerized plant materials require the frequent use of pesticides to control weeds, insects, and pathogens, but information on the movement and environmental fate of these chemicals is limited. Granular pesticide formulations are popular because of applicator safety and handling ease, but up to 80% of the pesticide may be deposited onto the production surface around the containers (Gilliam, et al. 1992). Overhead irrigation, typically 30% efficient, generates runoff water which may transport the pesticide off site or into ponds used for irrigation. Recycling of runoff water presents the potential for the introduction of injurious levels of herbicides onto the growing beds.

In 1991, questions were asked by a research team as to the magnitude and fate of herbicides in nursery runoff water. A survey project began to determine the nature of herbicide residue at two nurseries in South Carolina that frequently use preemergence herbicides and recycle their irrigation water. On-site runoff studies were conducted to ascertain the quantities of herbicides lost in runoff water and residual activity in ponds. Microplot studies evaluated the influence of bed cover composition and herbicide formulation on quantities of herbicide moving into water bodies. Greenhouse experiments were used to quantify the residue levels and irrigation frequency for herbicide injury to occur on liners of landscape species.

Our research indicated that herbicides were reaching the irrigation water sources but they did not accumulate. However, the herbicides did persist at low concentrations for 3 to 7 weeks after application but these concentrations were well below potentially damaging levels to landscape plant production. Since detectable concentrations of herbicides in surface water could be problematic to government agencies and nontarget plants and animals, efforts focused on reducing and/or eliminating herbicide movement in surface water through the use of grassed/vegetated waterways. The objective of this paper is to provide the readers with an over view of what we have learned about the fate of herbicides in runoff water and what may be done to minimize the off-site movement of herbicides.

METHODS AND MATERIALS

Two commercial nurseries in the coastal and piedmont areas of South Carolina were surveyed monthly for herbicide residue in containment pond water and sediment from February 1991 through January 1993. Samples were taken in areas where runoff entered the ponds and the greatest probability of residues existed. Water was sampled from the top 15- to 31-cm (6 to 12 inch) depth and sediment samples were taken from the top 10 cm (4 in.) of the mud. Herbicide residues in samples were determined using high-pressure-liquid chromatography with detection limits of 1 ppb. Oryzalin, pendimethalin, and oxyfluorfen are the components of the two preemergence herbicides (Rout and OH-2) applied at both nurseries. Nursery records documented amounts and dates of herbicide application and correlated applications to residue levels detected .

Nursery runoff studies were conducted on one growing area encompassing over 3 acres and isolated from the rest of a commercial nursery. The beds sloped uniformly and unidirectionally so that runoff water could easily be channeled and directed into a gravel drainage ditch. All of the runoff water from this bed entered a single containment pond through a pipe [61 cm (24 in.)]. Runoff water was sampled before and after herbicide application from the drainage pipe, and water/sediment samples were taken from the containment pond to determine herbicide dissipation. Three studies were conducted on this site from 1992 to 1995 determining the nature of herbicide loss in runoff water and the dissipation in the pond.

In 1994, the drainage ditch was reconfigured to evaluate the effects of vegetation on pesticide concentration in runoff water. Hybrid Bermuda grass *(Cynodon dactylon* × *C. transvaalensis)* was sodded in the drainage area [91 m × 1.8 m (300 ft × 6 ft)] that received runoff from half of the site. A 91-m-long (300 ft) planting of cattails (*Typha latifolia*) was installed to further filter the runoff which drained through the grass waterway. The remaining growing area drained across a gravel and clay road bed (reference ditch). Weirs were installed at the termination of all

waterways to facilitate sampling and to allow for quantification of runoff volumes. Commonly used pesticides, an insecticide—Dursban, a fungicide—Clearys 3336, and a herbicide—Snapshot TG (isoxaben + trifluralin), were applied at recommended rates in two applications, 6 weeks apart, 1 year after establishment of the waterways. Runoff water samples were taken after irrigation events to determine the movement of the pesticides in runoff water and the influence of vegetation on the movement of these pesticides.

RESULTS AND DISCUSSION

Results of the 2-year survey from the piedmont nursery indicated concentrations of pendimethalin, oryzalin, and oxyfluorfen from either OH-2 or Rout applications in sediment and water. Low herbicide levels (highest level detected was 13 ppb in water and 12 ppm in sediment) were documented compared to the quantities of herbicides applied (26 to 110 lb ai per year). Results also indicated that herbicides did not accumulate in containment ponds following repeated applications, and there was no correlation between herbicide levels detected and amount or timing of herbicide application (Camper et al., 1994).

At the coastal nursery, herbicide levels found in pond water and sediment were approximately two-fold greater during the second year, corresponding to an increase in herbicides applied. The highest concentrations of oxyflurofen found in water and sediment were 40 ppb and 4 ppm, respectively. The highest concentration of pendimethalin found in water and sediment was 8 ppb and 14 ppm, respectively. In the irrigation water samples, the highest concentration of oxyfluorfen and pendimethalin detected were 5 ppb and 2 ppb, respectively. The herbicides did not accumulate in water or sediment over a 2-year period (Riley et al., 1994).

The nursery runoff studies showed maximum herbicide residue detection within the first 15 min of water runoff . Oryzalin residues were the greatest of the three herbicides evaluated (4 ppm at 15 min), and showed a rapid decreases thereafter. Herbicides detected in pond samples decreased over time until detection limit was reached 2 weeks after application. The micro plot study indicated that plastic and fabric ground covers allowed the greatest movement of oryzalin and pendimethalin while gravel significantly retained and retarded movement of all three herbicides. These results indicate bedcover composition plays a significant role in the movement of herbicide from the site of application. Release of active ingredient from granular formulations was also evaluated. Dintiroanalines (oryzalin and pendimethalin) release faster than oxyfluorfen. Oryzalin in Rout was the most rapidly released. It was the most water soluble of the investigated hebicides, and 71% of total active ingredient was accounted for after 3 weeks (Keese et al., 1994).

Nursery runoff investigations of Snapshot TG (isoxaben + trifluralin) indicated that 8.2% of the applied isoxaben moved from the application site in the first irrigation event. A total of 9% and 12.5% of the applied isoxaben moved from the application site in runoff water within 5 days after treatment during 1992 and 1993, respectively. Isoxaben concentrations in pond water were highest immediately after the first irrigation runoff event following herbicide application and decreased below detection limit at 60 days. Studies also indicated that light played an important role in the degradation of isoxaben in pond water. Micro plot studies revealed that sprayable formulations of isoxaben allowed more loss in runoff water than the granular formulations (Wilson et al., 1994).

Greenhouse studies investigated the growth and development of selected landscape species watered with various concentrations of oryzalin, isoxaben, and oxyfluorfen in the irrigation water. Liners of the woody species including dwarf gardenia (*Gardenia augusta* 'Radicans'), buccaneer azalea (*Rhododendron* 'Buccaneer'), snow azalea (*R.* 'Snow') and Heller's Japanese holly (*Ilex crenata* 'Helleri') were tolerant to 10 ppm or less of these herbicides in the irrigation water for 6 weeks. Herbaceous species of fountain grass (Bot. Ed., *Pennisetum alopecuroides* or *P. setaceum*) and daylily (*Hemerocallis*) were injured by greater than 1 ppm of these herbicides. Oryzalin was the most injurious of these herbicides. This concentration was several hundred times greater than the levels of herbicides found in the survey and runoff water studies (Bhandary and Whitwell, 1994).

The vegetated waterway experiments indicated that all four pesticides were detected on the day of application though amounts of Dursban and trifluralin were very negligible and approached the limits of detection. Isoxaben was detected through 8 days after application with amounts approaching the limit of detection. Isoxaben losses were reduced 21% by the grass waterway as compared to the reference ditch. The cattail treatment further reduced movement of the pesticide by 12%. Clearys 3336 (thiophanate-methyl) losses were reduced 25% by the grassed waterway, and 60% by traversing the grass and cattail treatments as compared to the reference waterway (Briggs et al., 1995).

Minimizing the movement of pesticides from the site of application to nontarget areas should be the goal of nursery managers. The application of pesticides to smaller areas at one time followed by less irrigation water, or the use of cycle irrigation reduces both the quantities of pesticide available to move and the amount of runoff water which may carry pesticides to irrigation ponds or drainage waterways. Avoid using plastic in the waterways or on beds. Grassed waterways and wetlands will filter some of the pesticides and remediate excess nutrients. Additional research is needed to develop information on the most efficacious vegetation system to improve runoff water .

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Irrigation Tailwater Regulations in the 1990s

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INTRODUCTION

A reliable supply of quality water is the life blood of the nursery industry. Agriculture consumes 42% of all industrial water used nationwide. This figure increases to 85% in California where agriculture represents 10% of the State's industry (Bolusky and Regelbrugge, 1992). As the 1990s continue, there will be a growing struggle between agriculture, industrial, urban, and environmental interests over water. As this struggle intensifies, water regulations will likely increase.

In spite of the recent changes in Congress and the deregulation of Federal laws, most Americans want environmental laws strengthened rather than weakened. In a recent survey, when asked about safe drinking water laws, 76% favored stricter laws, while 15% did not (American Nurseryman, 1995a). The current environmental consciousness of society and concern for safe drinking water makes it necessary for the nursery industry to understand and become proactive in current and future water regulations, as they relate to irrigation tailwater management in the 1990s.

Water regulations that nursery managers need to be aware of can be broken down into two major areas, the quantity of water consumed and the quality of irrigation tailwater leaving the nursery.

QUANTITY OF WATER CONSUMED

As the South continues to be the fastest-growing region in the country, demand for municipal drinking water will increase and begin taxing the current supply of water within the region. Currently most southern states have no restrictions on the amount of water used by nurseries.

Florida currently requires nurseries to obtain consumptive water permits for wells from regional water management districts and limits the time periods that irrigation can occur. Most nursery irrigation is permitted between 5 PM and dawn with allowances for syringing during the day in summer.

In 1993, Alabama passed a Clean Water Act that will require growers that consume more than 100,000 gal of water a day for irrigation to file a usage form with the State (American Nurseryman, 1995b).

In the state of Washington, state officials believe that groundwater is a public resource and want to put meters on all private wells to charge for the use of this public resource.

In contrast to this, the State of Wisconsin which required the state's largest nursery to report monthly groundwater usage, dropped this requirement in 1995.

While the amount of water consumed by the nursery industry is of primary concern, a secondary concern will come from stress on municipal water supplies to meet the demands for drinking and landscape irrigation water by increasing urban populations. Municipal water rationing could result and have a profound impact on landscape plant selections in urban areas.

CURRENT FEDERAL LEGISLATION CONCERNING WATER QUALITY

The *Clean Water Act* is the backbone of federal water regulations. It defines a polluter as anyone that alters the physical or chemical composition of water. Initially, it focused pollution control efforts on *point sources*. These are pollution sources with easily definable discharge sites, such as the end of a pipe, and they were required to obtain permits (NPDES permits) with pollutant limitations to discharge into lakes, streams, and rivers. *Nonpoint pollution sources* were defined as pollution sources with multiple, dispersed discharge sites. Agriculture and Forestry were classified as nonpoint sources of pollution and were exempted from the permit system. Nurseries are included in the agriculture exemption.

The upper limit for nitrate-nitrogen in safe drinking water has been established as 10 mg liter^{-1}. This is the numerical figure being enforced by most states when they are monitoring surface or groundwater. A six-state survey of container nurseries revealed that this limit was being exceeded at certain times (Yeager et. al., 1993).

The Clean Water Act is up for reauthorization this year and some changes that could occur include: (1) a focus on nonpoint pollution sources, (2) a 5-year review, similar to the national Farm Bill, (3) a requirement of all states to identify high priority, threatened, or impaired watersheds with site-specific plans that account for all nutrients and pesticides down to the nursery level, and (4) a new emphasis on pollution prevention through voluntary compliance with Best Management Practices (BMP), rather than through regulation.

Another lesser known, but in some instances more important, federal bill is the Coastal Zone Act Reauthorization Amendments. This bill required states to develop management plans for nonpoint pollution sources (agriculture and nurseries were specifically mentioned) within the first two counties in from coastal estuaries. These management plans were to be filed by July 1995 and had to include sections on erosion and sediment control, nutrient management, irrigation water management, and pesticide management. The plans also had to include enforceable mechanisms to deal with violations and the management measures must be economically viable options.

NURSERY IRRIGATION TAILWATER REGULATIONS

Currently, very few states regulate nursery irrigation tailwater; but every state is complaint-driven when it comes to enforcement of state and federal water pollution laws. Oklahoma has a voluntary compliance agreement between the Oklahoma Department of Agriculture and the state's largest nurseries. This compliance agreement covers surface water only and sets annual average limits on nitrate-nitrogen (10 mg liter^{-1}), total phosphorus (1 mg liter^{-1}), and pesticide residue (zero tolerance).

Texas requires irrigation tailwater discharge permits for the state's largest nurseries, but each discharge permit has different requirements. Greenleaf Nursery Company's Texas Division permit called for daily maximums on nitrate-nitrogen (15 mg liter^{-1}), ammoniacal-nitrogen (15 mg liter^{-1}), total phosphorus (15 mg liter^{-1}), chemical oxygen demand (150 mg liter^{-1}), and pesticide residue (zero tolerance).

While most states are currently concentrating on surface water, Wisconsin is more concerned with groundwater monitoring. The state's largest nursery is required to monitor its deep water irrigation wells and drinking water wells within 1/4 mile of the nursery. They are just monitoring for nitrate-nitrogen to be below 10 mg liter^{-1}, but would prefer levels to be below 2 mg liter^{-1}.

BEST MANAGEMENT PRACTICES

The Southern Nurserymen's Association sponsored the development of a *Best Management Practices* (BMP) manual written and edited by university professors from throughout the South. The Best Management Practices covered in this manual include irrigation water management, media management, fertilizer management, pesticide management, and tailwater management.

This manual can provide the backbone for initiating a dialogue between the nursery industry and state regulators as a starting point for developing a state nursery nonpoint pollution prevention program. Through the wise use of this BMP manual and cooperation among the nursery industry, Alabama state regulators and Auburn University—a pollution management plan has been developed that's being used as a model for other nonpoint source industries within the State. This is also occurring in Louisiana.

By employing BMPs, irrigation tailwater quality problems can be prevented; but it will be at a greater expense to the nursery industry.

FUTURE CONSIDERATIONS

All future enforcement efforts will probably focus on pollution prevention at the source of the pollutant. Surface water pollution will be dealt with through river basin (watershed) management. These efforts will involve multiple state agencies and multiple states in many instances (downstream states rights to clean water).

These river basin management plans will involve total maximum daily load limits. These will establish numerical daily limits on the amount of specific pollutants that can be released off site by individual pollution sources. These daily pollution limits can be traded or sold between industries, similar to current air pollution limits.

The nursery industry is part of the environmentally oriented sector of our economy. In spite of the environmental benefits of our product, nurseries are perceived as wasteful users and polluters of water. The industry must become proactive on both the state and national level to work with regulatory agencies and the public on the development of nursery water management plans to change the current perception and to ensure that our industry is perceived as prudent water managers.

As water becomes more scarce and as national concerns over the quantity and quality of water intensify, a significant increase in the amount of guidance at the state and national level will be required to assure the survival and well-being of the nursery industry.

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Compatibility of Worker Protection Standards and Integrated Pest Management Strategies

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COMPLYING WITH THE WORKER PROTECTION STANDARD LAW

The Worker Protection Standard Law went into full implementation this year. Southern Growers Nursery has made the capital expenditures, spent the extra man hours, and put forth the effort to comply with all regulations. These efforts include: increasing employee training, providing and maintaining personal protective equipment, building decontamination sites, buying and using notification signs, establishing a central posting sight, and maintaining records. After considerable expenditures of both money and effort, we are to the best of our knowledge in compliance with this new law.

UTILIZATION OF INTEGRATED PEST MANAGEMENT (IPM)

The restricted entry intervals (REIs) imposed on our employees are preventing the use of many of the best available fungicides, as well as some highly effective insecticides. We are coping with these hardships by turning to Integrated Pest Management (IPM). For our company, IPM includes the use of products with reduced REIs (whenever possible), regular scouting, insect and disease identification, and spraying only when insect threshold levels are met. There are 114 products recently authorized by the EPA to have the new 4-h REI. The EPA has identified those products as being "low toxicity". We use as many of these reduced-REI chemicals as possible, including *Bacillis thuringiensis* (Dipel), glyphosate (Roundup), paraffin oil (Target and Sunspray), fatty acids (M-pede), NAA, and IBA. We are also experimenting with the use of predatory insects. To add more chemicals to the list of 4-h REIs, the EPA must be petitioned before 31 December 1995.

INSECTICIDAL OIL AND SOAP SPRAYS

Oil and soap have proven to be effective against many insects on a broad range of plants. We have used Saf-t-Side, a Lawel Chemical Company product, against two-spotted spider mites, white flies, lacebugs, aphids, mealybugs, overwintering scale, scale crawlers, spruce spider mites, and European red mites. We have successfully sprayed oil during every month of the year; we do not spray oil when the temperature is below 2C (35F) or above 27C (80F) or and when those temperatures will be met before the spray has dried. Narrow-range oil phytotoxicity is discussed in great detail in the *Alabama Cooperative Extension publication Nur95-1* (Tilt, et al., 1995). We successfully use soap year round. We use M-Pede, by Mycogen Corp., to combat aphids, white files, and fungus gnat adults. We do not spray soap when the temperature is below 7C (45F) or above 32C (90F). Neither insecticidal oil nor soap can be sprayed on plants that are dry, or that appear to be under moisture stress. Other advantages of these insecticides include the establishment of beneficial insects, low mammalian toxicity, and no resistance build up. I have found that after using soap to control aphids, white flies, and thrips during

the growing cycle, phenomenal control can be gained with more traditional chemical insecticides to ship an insect-free crop. IPM not only reduced our company's pesticide budget, but also has alleviated some of the problems created by REIs. We have taken a proactive stance towards government regulations—one instance being hosting all the nursery inspectors for the state of Alabama during their WPS training sessions.

CCC ASSOCIATES

Our parent corporation is CCC Associates, whose American operations include Southern Growers Greenhouse, Cassco (a wholesale nursery supply), Southern Homes and Gardens (a retail garden center), a landscape division, Naturaline (a dried flower producer), wholesale cut flowers, a retail florist, a wholesale floral supplier, and a silk flower division. Approximately 450 employees work at our 265-acre main complex which includes extensive public gardens. Considering the safety of our employees and customers as well as the resident wildlife population, we must be conscientious of pesticide handling, pesticide selection, and overall management of our watershed.

WPS COMPLIANCE

I have contacted the WPS enforcement offices for Alabama, Georgia, Florida, South Carolina, North Carolina, Texas, and Tennessee. These states are all in EPA Region 4. Region 4 is the lead region for WPS compliance. Each state aforementioned is currently in a compliance assistance mode. None of the states have yet assessed any fines for WPS violations. Texas inspected the most nurseries (361) in the southern U.S., but only 128 farms were inspected. The rest of the southern states inspected between 100 and 160 nurseries per state. Each state does intend to switch to an enforcement mode in approximately 2 to 6 months. Texas and Florida have built a database to work from to begin the enforcement process. As fines begin to be assessed, the issue of WPS laws will become heated. Every gain made to ease compliance is a milestone for the nursery industry.

RESPONDING TO THE EPA

The American Association of Nurserymen (AAN) is our unified voice to the EPA in Washington. They have contributed to several successes in WPS negotiations. Some of these include the exception for "limited contact" activities, reduced restricted entry levels, delay of implementation, exception for irrigation activities, exemption for crop advisors, and the 5-year retraining interval. The current EPA docket, which is open for discussion, includes a pending decision regarding the proposal to change the required sign size for posting from 36 cm × 41 cm (14 in. × 16 in.) to a minimum of 8 cm × 10 cm (3 in. × 4 in.) (Environmental Protection Agency, 1995). The smaller sign would not only ease the problems associated with wind blowing over the stands but also reduce the cost of signs and stands. Other advantages of the smaller signs would be the ability to identify small areas and the advantage of a spot sprayer to be able to carry signs with them. A problem with this proposal is that the EPA wants to make this exception valid only if the larger signs cannot be used, leaving the interpretation of the law in the hands of the individual investigators. The deadline for the nursery industry response to this issue is 13 November 1996.

ESTABLISHING NURSERY INDUSTRY GOALS FOR COMPLIANCE LAWS

We must, as an industry, set common goals to help make compliance with these federal laws feasible. Perhaps nurserymen, speaking with a loud, unified voice, can convince the federal government to listen to our concerns. We, as an industry, can become a leader in the agricultural community by following practices such as *Best Management* and *Integrated Pest Management*. This will benefit each nursery in many ways, saving money and time, avoiding future governmental conflicts, and maintaining a reputation with the consumer as being an environmentally-friendly, "green" industry.

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Fall Fertilization of Nursery Crops

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INTRODUCTION

Fall fertilization should play an important role in nursery production programs. Knowledge of the leaf tissue N level in plants prior to dormancy is essential for maximizing spring growth. A desirable level of leaf tissue N can be attained by following the proper procedures for fall fertilization.

WHY FALL FERTILIZATION

Although the attainment of proper nutrient levels in woody plant tissue in the fall is an important aspect of production, it is usually necessary to curtail fertilizer application to most container-grown woody plants by early fall in order to avoid a late flush of growth, which may not have sufficient time for cold acclimation before the onset of freezing temperatures. Shoot elongation ceases for many woody plants by late summer but shoot dry weight accumulation often continues well into the fall months. In Virginia, *Ilex crenata* 'Convexa' has been observed to accumulate over 40% of its seasonal shoot dry weight between mid-September and mid-November (Walden, unpublished data). This continued increase in shoot dry weight, coupled with decreased fertilizer application, can dilute leaf tissue N levels to well below the 2.0% to 2.5% considered optimum for the growth of most woody plants. Since it has been firmly established that the level of N in dormant woody plants strongly influences the time of bud break and magnitude of the first growth flush in the spring (Wright and Gilliam, 1977a, 1977b; Meyer and Splittstoesser, 1969; Meyer and Tukey, 1965), the benefit of restoring nutrient levels in the plant prior to winter storage is apparent.

TIMING AND RATES OF NUTRIENT APPLICATION

Nutrient absorption in woody plants is influenced by both temperature and the concentration of applied nutrients (Wright and Blazich, 1983; Wright et al., 1983). Procedures have been developed for reapplication of fertilizer to the container in the fall when air temperatures are low enough to preclude the initiation of a late growth flush in response to N fertilization (Wright and Blazich, 1983). When maximum daily air temperatures no longer exceed 18C (65F), application of a complete fertilizer for 4 to 6 weeks will allow adequate time for sufficient nutrient accumulation. A concentration of 30 to 50 ppm N should be maintained in the container substrate solution. This is most easily accomplished through liquid fertigation, usually at one-half the rate required for vigorous growth during the growing season. If a slow-release fertilizer is utilized, it should be one which will release the major portion of its nutrients over this time period at temperatures below 18C (65F).

LEAF TISSUE N LEVEL

Leaf tissue analysis is an important aspect of fall fertilization. Some slow-release fertilizers or fertigation at low concentration may provide adequate nutrition during late summer/early fall to maintain sufficient N levels in the plant without stimulating a late growth flush. An initial sampling of the uppermost mature leaves should be taken for nutrient analysis in early fall to determine the need for fall fertilization. A second sampling should be taken 4 weeks after the start of fall fertilization to determine if the desired level of leaf tissue N has been attained.

This raises the question "what level of dormant leaf tissue N resulting from fall fertilization will maximize spring growth of woody plants?" Limited research indicates that woody plants may respond to dormant tissue N levels which are higher than those normally recommended for vigorous growth. Walden and Epelman (1992) found the critical leaf tissue N level in dormant *I. crenata* 'Convexa' which resulted in maximum spring growth was 3.4% N—higher than the critical leaf N level of 1.8% to 2.4% N reported for other *I. crenata* cultivars during the growing season (Gilliam and Wright, 1977c). Walden and Epelman also found that the number of buds breaking in the spring was greater at 3.4% N than at 2.6 % N. Leaf drop, however, increased in response to increasing N in dormant leaf tissue. No leaf drop was evident when tissue N ranged from 1.6% to 2.6 %, while plants with 4.3% N lost more than half their leaves. In light of the leaf drop associated with high levels of dormant leaf tissue N, I would recommend 2.5% to 3.0% N as a desirable range in dormant plants for maximizing spring growth.

SPRING FERTILIZATION

In the same study, for *I. crenata* 'Convexa' with 1.6% N in the leaves of dormant plants, spring growth was increased by early spring fertilization (6 weeks prior to bud break), in comparison to the growth which resulted when fertilizer applications were delayed until just prior to bud break (Walden and Epelman, 1992). The timing of spring fertilization had no effect on spring growth when leaf tissue in the dormant plant was 2.6% N. Thus, the level of dormant leaf tissue N should influence a grower's decision regarding when to initiate spring fertilizer applications. This result implies that the timing of initial fertilizer applications in the spring is less critical when dormant leaf tissue N levels are sufficient due to fertilization the previous fall. For growers who use surface-applied granular fertilizers, spring applications to small blocks of containers can be spread out over time with no loss of spring growth. Such a practice would help to minimize nutrient runoff from container production areas.

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Application of Israeli Low-Volume Irrigation Technology

J. Kevin Parris
Gilbert's Nursery Inc., 4675 Peachtree Road., Chesnee, South Carolina 29323

INTRODUCTION

Two years ago Gilbert's Nursery faced a dilemma. We were rapidly increasing the number of taxa we were producing as well as increasing overall production. We were operating mist systems in our six propagation houses off a well capable of delivering 26 liters (7 gal) of water a minute. Four pressurized tanks were used to increase our water volume, but this was not enough to comfortably supply our 1394 m^2 (15,000 ft^2) of propagation houses with sufficient pressure to operate our misting sprinklers. We were solely using the Olson 0-4000 sprinkler. We liked this type of misting device because it also allowed us the capability of watering in liners after they rooted. However, it delivers 6 liters (1.5 gal) per min. This was putting an incredible strain on our pump which also supplies our propagation room, break room, bathrooms, and offices with water. We also had twelve other propagation structures totaling 1498 m^2 (16,128 ft^2) which we were misting with recycled pond water. In an effort to cut back on potential for disease, we also had a goal of supplying this area with well water.

OBJECTIVES

Therefore, we had three objectives: (1) to make our area currently being misted with well water more effective and reliable, (2) to increase this area to twice its original size, and (3) to accomplish the first two objectives without increasing the amount of water available to us.

OPTIONS

The evolution began with a phone call to Mark Lurey of M.L. Irrigation, in Laurens, South Carolina. Mark made several visits to our nursery to educate us about our options. After a great deal of study on the part of James Gilbert and Bob Smart, we selected the Ein Dor 809 Mister. It can be fitted with a number of nozzle sizes ranging from 0.8 to 2.2 mm. Each nozzle size is color coded for convenience. We are predominantly using the green nozzle which is 1.3 mm. The low water volume generated is ideal for rooting conifers like *Cryptomeria japonica* which are sensitive to excess soil moisture in the pre-callus stage. Its spray pattern, however, provides

Meyer, Jr., M.M. and **H.B. Tukey, Jr**. 1965. Nitrogen, phosphorous, and potassium reserves and the spring growth of *Taxus* and *Forsythia*. Proc. Amer. Soc. Hort. Sci. 87:537-544.

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enough water for plants like *Hydrangea quercifolia,* which are extremely sensitive to foliage desiccation immediately after sticking. The droplet size produced by the 1.3 mm nozzle satisfies both of these cultural limitations. The 809 Mister can be operated in the upright position or suspended in a downward position. This versatility has allowed us to make use of this one style throughout all of our propagation houses.

LAYOUTS

At Gilbert's Nursery we have basically three different greenhouse configurations. In one greenhouse we have raised benches, each equipped with two risers fitted with 809 misters. The risers are spaced 1.2 m (4 ft) apart as this gives adequate coverage with the 1.3 mm nozzle. We have 24 benches in this house divided into six zones of four benches each. This allows us to propagate vastly different crops within the same structure. We control our mist in this house and other propagation areas with the Phytotronics Controller in conjunction with a 24 h timer.

In the second configuration, which we have adopted in the five adjacent houses, we have suspended the mist system from the framework to create intermittent fog. With this layout we can leave our previous sprinklers in place for watering-in after rooting. The emitters are also spaced 1.2 m (4 ft) apart in these houses. With the misters at a higher elevation above the cuttings, we have found that we can use the 1.0 mm orange nozzle and still get adequate coverage with less volume because of the swirling drift of the mist.

A third configuration, in which we have made use of the 809 Mister, is in our 4.3 × 29.3 m (14 × 96 ft) propagation houses. In these 12 structures we have a center aisle with two lines which run the length of the house. These lines are each contained within frames that give us additional cold protection, since these houses are not heated. The spacing is also 1.2 m (4 ft), with the 1.3-mm green nozzle being used.

NON-DRIP DEVICE

What makes all of this work is the Ein Dor 530-10 Non-Drip Device. This allows for tremendous flexibility in the layout of a mist system. Normally, a line must be level or flow will continue from the emitter which is at the lowest elevation. Therefore, water volume in the line is partially depleted between cycles which affects the uniformity of coverage at the onset of the next cycle. The non-drip device enables upside down operation of misters and placement of a line on a slope. The pressure valve within the device opens at 166 kPa (24 psi) and closes at 76 kPa (11 psi), preventing formation of air in the line. This insures uniform operation, regardless of slope, configuration, or position of emitters within the line.

PLASTIC COMPONENTS

Another advantage to this system is the plastic construction, with interchangeable parts and easy assembly due to the press-fit design. There are three custom tools which aid in the assembly of the components. The 1320-6 Key is useful for removal of nozzles from the 809 Mister. The 1306-0 Puncturer places a 3.5-mm hole in the line for the insertion of plungers which connect with tubing. Collars are fitted into tubing with the aid of the 1301-5 Insertor. No glue or sealant is required in assembly. All components fit securely with no leakage.

The only problem we have experienced is separation of collars and non drip devices from plungers the morning after temperatures drop below 4C (40F) for an extended

period of time. We feel this is due to contraction of the components followed by the sudden pressure exerted on the line during the first mist cycle. This only occurs on a small percentage of fittings. Under these cooler conditions, we daily replace only between 5 to 20 out of 1728 possible connections. We have dealt with this by scouting our unheated greenhouses for separated fittings at 10:30 AM November through March. This involves a little labor, but since walking through the houses is a daily routine, it is not out of the way. It is important to note that separation of fittings has not been a problem in houses were we can maintain moderate temperatures.

CONCLUSION

Use of Israeli low-volume irrigation has allowed Gilbert's Nursery to increase its effective propagation space without bringing in an additional water source. We are now servicing all propagation houses 2892 m^2 (31,128 ft^2)—plus offices and bathrooms with one well. We do realize that we have once again stretched this well to its limits. We are currently developing a layout that will tap into our recycled pond water. This water, which is already being chlorinated, will then subsequently pass through a bromine filter before it flows into our propagation houses. This "double" filtration will give us adequate protection against pathogens. The recycled water will give us an unlimited volume from which to operate, and the irrigation equipment we have adopted will serve the growing needs of Gilbert's Nursery for years to come.

Unique Bottom-Heat System for Propagation of Ornamentals

Marla Townsend
Hawksridge Farms, Inc., P.O. Box 3349, Hickory, North Carolina 28603

INTRODUCTION

Hawksridge Farms, Inc. was established in 1982. At present, we are approximately a 24-ha (60 acre) container nursery. We have 35 full-time and 15 seasonal employees. Of these employees, four full-time employees and three seasonal work in propagation.

We grow approximately 650 taxa of trees, ornamental shrubs, needled evergreens, ornamental grasses, bamboo, vines, and perennials. We propagate approximately 75% of what we grow.

The nursery has had a propagation facility since it began. However, 1983 was when the first bottom heat house was built. Several other nurseries were visited, and a lot of ideas were synthesized in development of the bottom heat system we utilize at our nursery. A few changes have been made over the years, but the basic concept has stayed the same.

The main crop used in our bottom heat houses is our needled evergreens. We grow a lot of upright conifers that would be hard to root if we did not use bottom heat. We grow approximately 100 cultivars of needled evergreens.

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PROPAGATION SYSTEM DESIGN

The propagation house we use is a Jaderloon 8.5 m × 29 m (28 ft × 95 ft) quonset greenhouse frame. It is covered with a double layer of 6-mil polyethylene film, and a 47% shade cloth is put on top.

Our third bottom-heat house was built in Fall 1994. A layer of gravel approximately 7.6 cm to 10.2 cm (3 to 4 in.) deep is placed in the house before the beds are constructed. The gravel size is 1.3 cm (0.5 in.) in diameter. The 8.5 m × 29 m (28 × 95 ft) house has two beds along the sides, which are each 0.9 m (3 ft) wide and 27.4 m (90 ft) long. In addition, there are two island beds down the middle of the house, which are each 1.8 m (6 ft) wide and 26.5 m (87 ft) long. There is sufficient space at each end of these two middle island beds to walk around them.

On the sides of the beds are 5.1 cm × 30.5 cm (2 in. × 12 in.) treated boards that are placed lengthwise on the gravel — which makes the beds 30.5 cm (12 in.) deep. A 5.1 cm × 15.2 cm (2 in. × 12 in.) board is placed every 0.9 m (3 ft) on the gravel to help hold the bed together and also to secure the bottom heat pipes and mist lines. The bottom heat pipes [1.3 cm (0.5 in.) CPVC] are placed 15.2 cm (6 in.) apart. A 0.9 m (3 ft) bed would have six pipes, three for supply of the hot water and three for return to the boiler. These pipes are held in place with clamps on each 5.1 cm × 15.2 cm (2 in. × 6 in.) board.

Approximately 15.2 cm (6 in.) above the gravel another board is placed every 0.9 m (3 ft), and 12.5-gauge woven field fence is placed on top of this board. The woven field fence is fastened with "U" nails. Twenty-seven gauge screen wire is placed on

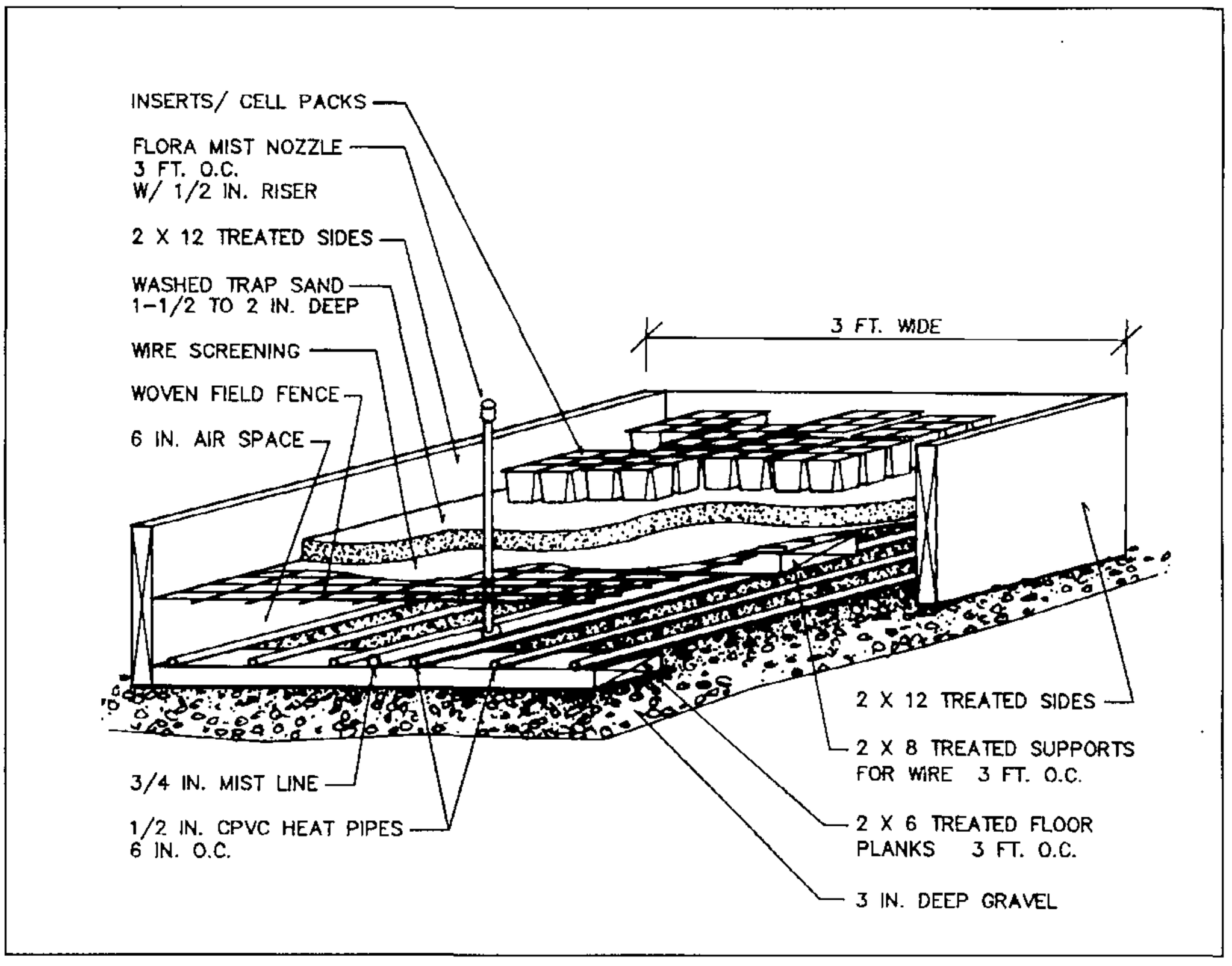

Figure 1. Propagation bed and bottom heat system at Hawksridge Farms.

top of the woven field fence. The screen wire is stapled to the 5.1 cm × 20 cm (2 in. × 8 in.) boards. A 3.8 cm (1.5 in.) layer of washed trap sand is then spread on top of the screen wire. The air space between the gravel and the sand provides for more even heat throughout the bed. A detailed drawing of bed construction is found in Figure 1.

The boiler we use is a Crown 225,000 BTU Input that is fueled by propane. We try to maintain soil temperature around 18C (65F). Air temperature is maintained around 4C (40F) by a 175,000 BTU Modine heater.

Inserts, cell packs, or whatever type of container that is used are then placed on top of the sand. The size container that is used will determine the number of cuttings a house will hold. For example, if we use 60s-cell packs for an entire house, we can stick approximately 63,000 cuttings. Propagation media will then be shoveled into the containers and smoothed. Our mix for winter cuttings consist of 2 bales of peat moss [0.23 m^3 (8 ft^3)] and 12 bags of perlite [109 kg (240 lb)] (2 : 5, v/v) plus 6.4 kg (14 lb) of lime and 1.1 kg (2.5 lb) of Micro Max.

Mist is regulated by a 5-min timer that is controlled by a 24-h clock. The amount of mist varies day to day according to the weather. Once plants are rooted, mist is no longer used and plants are watered overhead by spinner nozzles. Plants stay in the propagation houses until they are to be potted in the field, a period of 6 to 9 months.

COST OF PROPAGATION SYSTEM CONSTRUCTION

Cost of this system excluding labor and greenhouse frame is:

1) Mist	$478
2) Lumber	$5131
3) Wire and screen	$1900
4) Boiler	$4170
TOTAL	$11,679

The total amount of $11,679 may seem high, but in building this third house, we used a better boiler, lumber, wire, and screen. Our first house was in service for 10 years with less expensive components, so we hope to get at least 15 years from this house.

As stated earlier, we feel it is to our advantage to use this system with certain types of plants such as *Cupressus arizonica* 'Blue Ice' [syn. *C. arizonica* var. *glabra* 'Blue Ice'] and 'Carolina Sapphire', *Cephalotaxus* cultivars, *Cryptomeria* cultivars, and upright junipers. Our percentage of rooted cuttings is approximately 85% to 90% on our needled evergreens.

The Controversy Continues: Comparisons of Propagation Techniques of *Magnolia grandiflora*

Pat McCracken
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INTRODUCTION

Southern magnolia (*Magnolia grandiflora)* is prized for landscaping due to its lustrous, evergreen leaves and large, fragrant flowers. In the past, southern magnolia was traditionally propagated from seed. Seedlings exhibit highly variable growth characteristics. Selections have been made for hardiness, growth habit, leaf shape, large flowers, and dark-colored, textured leaf undersides (Dirr, 1990). Named cultivars are recognized by landscape architects and designers, and are being requested in increasingly larger numbers. This increase in demand has made it necessary to utilize asexual propagation techniques (Berry, 1991). These techniques include rooting, budding, grafting, and tissue culture. Each of these techniques has certain advantages and disadvantages. The purpose of this paper is to address the advantages and disadvantages of each of these techniques and to present rooting results on southern magnolia.

Controversy in Propagating Southern Magnolias. Rooting southern magnolia has been a controversial process. Every propagator has their own preference for rooting medium, auxin source and application method. Vermiculite and perlite have been used as rooting media but tend to produce tender or brittle roots that are easily damaged during transplanting (Brailsford, 1993; Dirr, 1990), which can retard subsequent plant growth (Dirr and Heuser, 1987). Sand, perlite : sand, and pumice have been used (Curtis, 1981), but poor drainage can result in reduced rooting. My preference is pine bark and perlite.

Propagators also vary widely in their use of auxin source and delivery method. Naphthaleneacetic acid (NAA) at 0.5% to 1.0% and quick-dips of indole-3-butyric acid (IBA) at 0.5% to 2.0% have been used with 50% ethanol (Dirr, 1990; Stadtherr, 1967). A talc formulation of IBA (0.8%) has also been used (Hartmann, et al., 1990).

The purpose of this study was to evaluate the effects of auxin treatment and media on rooting of *M. grandiflora* 'Brown Velvet'.

MATERIALS AND METHODS

Terminal, hardwood cuttings 15 cm (6 in.) long were collected 27 August 1990. Leaves were removed from the basal 5 cm (2 in.) of each cutting. The cuttings received two heavy wounds 2.5 cm (1 in.) long on opposite sides of the stem. Cuttings were treated with auxin and stuck in 36 cm × 51 cm × 10 cm (14 in. × 20 in. × 4 in.) flats filled with media, then placed in a poly-covered greenhouse with average day/night temperatures of 27C (80F)/16C (60F). Intermittent mist was provided as needed and contained the bromicide, Agribrom, at 5 to 7 ppm to reduce pathogens. Bottom heat at 24C (75F) was supplied by a Biotherm system. All cuttings were treated with the fungicides—Benlate or Manzate as needed.

Auxin treatments included 0.3% IBA in talc, and 0.5% NAA in 50% ethanol as a 5-sec quick-dip plus 0.3% IBA in talc, and a 5-sec quick-dip of full-strength Dip

'N Grow (1.0% IBA and 0.5% NAA). These treatments were selected based on rooting trials from the previous 2-years.

Media treatments consisted of 100% pine bark, pine bark and perlite (3 : 1, v/v), pine bark and perlite (1 : 1, v/v), pine bark and perlite (1 : 3, v/v), and 100% perlite. Media contained 3.9 kg m^{-3} (6.5 lb yd^{-3}) Osmocote (18N-6P-12K), and 0.9 kg m^{-3} (1.5 lb yd^{-3}) S.T.E.P. (soluble trace element package, Scotts Co.). Flats were arranged in a completely randomized design, and 1800 cuttings were used in the experiment.

Cuttings were removed from the flats on 29 March 1991 and evaluated for: root number per cutting, root length (50% maximum rootball diameter), degree of secondary root formation (visual rating on a scale of 1 to 5 were 1 = no secondary roots and 5 = highest number of secondary roots), and rooting percentage.

Data were collected and subjected to ANOVA and mean separation was by Duncan's new multiple range test.

RESULTS AND DISCUSSION

There was no interaction among rooting factors, so results due to media and auxin effects are presented separately.

All pine bark media produced higher rooting percentages than perlite alone (Table 1). Data for root length and secondary root formation followed a similar trend. Media did not affect root number (data not shown). Data suggest that pine bark

Table 1. Effect of media on rooting of stem cuttings of *Magnolia grandiflora* 'Brown Velvet'.

Medium	Volume ratio	Rooting (%)	Root length[z] (cm)	Secondary root formation[y]
Pine bark	--	78.8a[x]	13.8a	3.0ab
Pine bark : perlite	3:1	81.8a	12.9ab	3.2a
Pine bark : perlite	1:1	82.9a	12.4bc	3.0ab
Pine bark : perlite	1:3	79.1a	11.4c	2.7b
Perlite	--	68.0b	9.0d	2.1c

Table 2. Effect of auxins on rooting of stem cuttings of *Magnolia grandiflora* 'Brown Velvet'.

Auxin treatment	No. roots per cutting	Secondary root formation[y]
0.3% IBA talc	4.1c[x]	3.0a
0.5% NAA quick-dip + 0.3% IBA in talc	5.0b	2.7b
1.0% IBA + 0.5% NAA quick-dip	5.7a	2.7b

[z] Root length = 50% maximum rootball diameter.

[y] Visual rating from 1 to 5 where 1 = no secondary roots and 5 = highest number of secondary roots.

[x] means within columns followed by the same letter are not significantly different at the 0.05% level according to Duncan's New Multiple Range Test.

is more effective than perlite in promoting root development of *M. grandiflora* 'Brown Velvet' cuttings. Cuttings rooted in perlite had more brittle roots and were easily damaged during repotting. Another disadvantage of perlite is its high cost in comparison with pine bark.

The 1.0% IBA + 0.5% NAA quick-dip produced the highest number of roots (Table 2). Although the 0.3% IBA in talc produced the lowest number of primary roots, it had the highest level of secondary root formation. Root length and rooting percentage (76% to 80%) were not affected by auxin treatment.

The quick-dip treatment resulted in the highest number of primary roots per cutting, whereas the IBA in talc resulted in the greatest formation of secondary roots. Further research is needed to determine which parameter is more significant in the subsequent growth of cuttings. However, since high auxin levels can inhibit subsequent bud growth and development, the lower 0.3% auxin in talc may be less detrimental to buds than the quick-dip method with higher auxin concentration.

Wounding did not appear to be beneficial. Most roots initiated from the proximal 1.3 cm (0.5 in.) of the stems. The few roots that developed above that point originated mostly from the non-wounded areas.

Rooting *M. grandiflora* 'Brown Velvet' cuttings can be accomplished using a wide range of media and hormone treatments. However, it appears that a 100% pine bark medium and either 0.3% IBA in talc or 1.0% IBA + 0.5% NAA quick-dip are the preferred treatments. Asexual propagation is a feasible means of propagating *M. grandiflora* cultivars while maintaining their desirable characteristics.

Review of Commercial Propagation Practices. Southern magnolia can be propagated successfully by several techniques. Each propagator has reasons to utilize one or more of these techniques. Each propagator must evaluate their resources to determine which techniques are best suited to their production schedule. At Taylor's Nursery, Inc., we utilize budding and rooting because these techniques work the best in our propagation schedule.

Comparison of Propagation Techniques. The following is a listing of advantages and disadvantages of various propagation techniques for southern magnolia.

Rooting Advantages and Disadvantages:

- Highly skilled labor is not needed.
- Cultivar characteristics are maintained.
- Cold-hardy cultivars will have cold-hardy root systems.
- Bottom heat is needed and is costly.
- Many cultivars root in very low percentages.
- A large number of stockblock plants is needed due to the large quantity of propagules required.
- Heated greenhouses are needed, which makes greenhouse space more costly.

Budding Advantages and Disadvantages:

- Plants often bloom heavily the first year.
- Plants tend to branch very densely as compared to other propagation techniques.
- Vigorous rootstock systems produce larger plants more quickly.
- Budding percentage is usually very high—even on cultivars that are very difficult to root.

- A large number of stockblock plants is not needed, due to more efficient utilization of propagule units (i.e. from dormant containerized plants or stockplants, quite a few buds can be taken from each section of scion wood).
- Greenhouse space is not needed.
- Crop is usually very uniform.
- Highly skilled labor is needed — which is often not available and quite costly.
- Vigorous rootstock may alter scion cultivar characteristics.
- Rootstock will sucker and must be maintained.

Grafting Advantages and Disadvantages:

- Vigorous rootstock system produces larger plants more quickly.
- Grafting percentage is usually high.
- Highly skilled labor is needed — which is often not available and quite costly.
- Vigorous rootstocks may alter cultivar characteristics.
- A large number of stockblock plants is needed due to the large quantity of propagules required.
- Heated greenhouses are needed, which makes greenhouse space more costly.
- Plants tend to branch less densely, compared to other propagation techniques.
- Rootstock will sucker and must be maintained.

Tissue Culture Advantages and Disadvantages:

- Cultivar characteristics are maintained.
- A large number of new plantlets can be produced from a limited number of stockplant sources, and subculturing can be done to bulk-up plant numbers.
- Cold-hardy cultivars will have cold-hardy root systems.
- Growth rate is often slow for the first year.
- Very costly laboratory facilities are needed.
- Highly skilled labor is needed — which is often not available and quite costly.

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Propagation of *Magnolia grandiflora* Cultivars

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GRAFTING AND BUDDING

Grafting and Budding Production of *Magnolia grandiflora* Cultivars. Grafting and budding require rootstocks which vary in growth response, winter hardiness, transplanting adaptability, and are compatible with selected scion cultivars. Although, only a limited number of plants can be generated by each worker, skilled grafters have a high grafting success with most cultivars. March is the best month for grafting and budding in South Carolina—but March is very busy with the nursery shipping season, and greenhouse space is generally limited.

Each cultivar has a root system morphology that is unique to itself and this is also true of *M. grandiflora* seedling rootstocks. Seedling rootstocks have a direct influence on the phenotypic development of the scion cultivar. Rootstock effects on scions have been shown with many plant species and cultivars. Differences in root growth and root size can be seen by examining root development of different *M. grandiflora* cultivars.

The uniqueness of *M. grandiflora* cultivars are only achievable if the cultivar is grown on its own root system. The goals of plant propagators should be: (1) developing uniformity of plant cultivar performance in container and field production nurseries, (2) maintaining uniformity of plant height as a given cultivar matures, and (3) maintaining uniformity of growth once the finished plant is transplanted into the landscape.

CUTTING PROPAGATION

Advantages of Propagating *Magnolia grandiflora* Cultivars by Stem Cuttings. There are many advantages of propagating *M. grandiflora* cultivars by cuttings compared to grafting and budding systems. Over the years, stem cutting propagation has proven to be the most economical method of propagating cultivars of this species.

Magnolia grandiflora cultivars have been difficult to produce from stem cutting in large numbers on a consistent basis. The problem is it is very cultivar specific—hence, some cultivars are more readily available in the nursery trade than others. For example, Shady Grove Nursery's Cultivar 'Claudia Wanamaker' is consistently propagated in many different regions of the southeastern U.S. Most cultivars that lack or have moderate pubescent hairs on the abaxial side (underside of leaf, furthest away from the axis of the stem) are generally easier rooted than those cultivars which are heavily pubescent with a ferruginous color on the abaxial leaf surface. There is a great demand for difficult-to-root cultivars (the above mentioned, aesthetically attractive "brown-backed" cultivars—and those cultivars that are continuous flowering) such as 'Hasse', 'Little Gem', 'D.D. Blanchard', 'Brakens Brown Beauty', 'Coco', 'Russet', 'Samuel Sommer', 'Teddy Bear', and other cultivars.

Cultivars, such as 'Little Gem' and 'Hasse' have become very popular due to their blooming habits, small leaf size, and growth habits. These cultivars are in high demand with landscape designers, architects, home gardeners, and nurserymen. The demand for significant quantities of medium-size, high-quality, own-root, container-grown, readily available, southern-grown liners of these and many other cultivars—has spurred many propagators to look for improved stem cutting propagation methods for more consistent rooting of *M. grandiflora* cultivars.

Tips for Successful Rooting. The fact is: if you try enough methods, enough times throughout the year you will find the right set of conditions that give consistent, yearly results.

No one cultivar roots with the same requirements as another cultivar!

Some cultivars will root well from old (10+-year-old) stock plants, even better than more juvenile plants of other cultivars, while some will not!

"Brown-back" cultivars are harder to root. The heavy felt on the leaves and stem cause too much rooting hormone to stick to cutting base and moisture control on foliage is more difficult.

Stem cuttings taken July through November, March, and April have been successfully rooted at our nursery.

Most of the time, terminal buds should be mature (hardened-off) and not forcing into new growth—there are always exceptions to this.

Cuttings do not have to be tip cuttings with terminal buds. The condition of the wood in relation to starch and auxin build-up has the most to do with how well the cuttings root, survive, and break bud and start to grow.

Cuttings should have at least two leaves, and depending on cultivar leaf size, up to four leaves. Leaves may need to be cut to reduce the size to allow economical numbers of cuttings to be stuck per unit area of propagation space. You need to have sufficient area for air circulation and light penetration around each cutting—which is an index of how much foliage to retain and how close to space cuttings.

Wounding encourages rots, the less you do the better—but some cultivars need a single or double wound on the cutting base to encourage callus development.

Rooting media can be any material that drains well—perlite; peat, perlite, and vermiculite (1 : 1 : 1, by volume); bark; bark and perlite (1 : 1, v/v); bark, perlite, peat, and clean builders sand (1 : 1 : 1 : 1, by volume), and any combination of these materials.

Magnolias can be rooted in 5.7-cm (2.3 in.) pots, 7.6-cm (3 in.) pots, 0.95-liter (quart), or 3.8 liter (gal) containers—to large, deep flats or in outdoor beds. The cutting should be stuck no more than 50% of the depth of the container or a maximum 6.4 cm (2.5 in.) deep.

Environmental Conditions for Rooting Magnolias. Cuttings in propagation structures can be under full-sun exposure to 70% shade. The geographical region, time of year, and frequency of irrigation dictates the need and degree of shade.

Irrigation is the *most difficult* factor to keep uniform across the propagation area! The propagator will have to vary the irrigation intervals each day. This is the "sixth sense" a propagator learns in his/her education by *rotting* and *rooting* enough cuttings to gain propagation knowledge of the cultivars.

Magnolias *like it hot*, and this is necessary to help mature or harden the cutting wood, callus the cuttings, and initiate rooting. We have also observed that higher

temperature suppress disease formation. In cold weather, maintaining a minimum bottom heat of the rooting media at 16C (60F) is advisable.

Auxins. Auxins are needed to root *M. grandiflora* cultivars and concentrations vary for 1000 to 15,000 ppm depending on the cultivar, age of stock plants, location on the stem that the cutting was taken from, time of year, mist irrigation interval, rooting media, and whether the cutting was wounded. Generally, 3000 to 8000 ppm of IBA, NAA, or the potassium salt formulations—K-IBA and K-NAA give the best rooting response. These auxins speed up the initiation of roots and stimulate a higher rooting percentage. Rootone, Woods rooting compound (concentrate and H_20, [1 : 1, v/v]), and Dip-N-Grow (concentrate and H_20, [1 : 1, v/v]) are commercial rooting formulations that enhance rooting of most cultivars.

Rooting time varies from 4 weeks to 4 months, and is based on stored carbohydrates, nutrients, and metabolites of the cuttings under environmental conditions that support cutting survival.

Rooting of 'Little Gem' Cuttings. 'Little Gem'cuttings stuck in August in South Carolina will root by February. Propagation media should be kept at a minimum of 16C (60F) for optimal rooting. Cuttings can be single wounded, and quick-dipped for 5 sec in (concentrate and H_20, [1 : 1, v/v]) of Dip-N-Grow, Woods rooting compound, or Rootone. Intermittent mist should be set for 30 sec at 15-min intervals from 10 AM to 6 PM. The mist interval will need to be adjusted daily as the weather changes. Mist irrigation should be decreased to 3 to 4 hand waterings or heavy mistings each clear dry day, and further reduced to once daily as roots emerge; this will require the "sixth sense" propagators develop with experience. Large quantities of own-rooted, uniform-growing 'Little Gem', 'Hasse', and other *M. grandiflora* cultivars will allow the nursery industry to profit from this magnificent southern native and its spectacular cultivars.

CONCLUSION

- The reality of rooting *M. grandiflora* cultivars is that no single cookbook recipe guarantees every propagator rooting success.
- All the above listed requirements hinge on taking cuttings from nutritionally fit stock plants. Excessive nitrogen fertilization without adequate balance of the other macro- and microelements will lead to low rooting percentages.
- Responses from callus formation, root initiation, bud forcing of rooted cuttings, resisting disease invasion—will vary with the cultivar, from stem to stem of the same cultivar, stage of growth, and the seasonal period that each cultivar reaches for optimal rooting by cuttings.
- Everblooming cultivars such as 'Little Gem', 'CoCo', and 'Brackens Brown Beauty' are more difficult to root than less precocious cultivars.

The Importance of Propagation to a New Nursery

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OBJECTIVE

The objective of this paper is to show how I used propagation to assist me financially in the rapid establishment of a 25-acre nursery in 6 years with only $60,000 of financial assistance from the bank.

BACKGROUND

I grew up in a small town in North Carolina where I was exposed at a very early age to the field of agriculture. My grandfather farmed on 72 acres. On this farm he raised a wide range of crops including tobacco, beans, corn, vegetables, blackberries, blueberries, and livestock. From the time I was 4 years old, when I rode the tractor with my grandfather plowing the fields; I had a great interest in agriculture. In high school I studied agriculture and horticulture along with farming 25 acres of beans to earn money for my college education. I attended North Carolina State University where I studied horticultural science and worked for 2 years with a local landscape contractor and 2 years at the N.C.S.U. Arboretum. In 1989, I graduated with a B.S. in horticultural science. At this time I had made the decision to go into the nursery business.

GOALS OF THE NURSERY

Upon making the decision to enter the nursery business, I felt that I first needed to establish the goals for my nursery business. The family farm on which I was going to begin this nursery is located 12 miles south of Raleigh, N.C., and the Research Triangle Park. The area was voted one of the best places to live and do business in the country—therefore the market for plants was wide open, with the rapid expansion of residential and commercial construction. My goal was to take advantage of this market and produce a variety of trees, shrubs, and groundcovers for the local market on our 13-ha (32 acre) family farm.

INFRASTRUCTURE NEEDED TO ACHIEVE GOALS

Master Plan. A good friend and fellow nurseryman, Richard Currin, told me before I began this process of building a nursery that a master plan of my nursery would be needed. In creating this plan, I tried to come up with the necessities that would be needed and assign a cost to each of these areas. The list is as follows:

(1) Equipment

Tractors (3)	$30,000
Loader (1)	22,000
Dump truck (1)	14,000
Pickup Truck (1)	15,000
Equipment Trailer (1)	1500
Box Trailer (1)	3000
Nursery Trailers (20)	10,000

Golf Carts	5000
Misc. Equipment	10,000
TOTAL	**$110,000**
(2) Structures	
Pump Houses (3)	$ 25,000
Production/Storage Building (1)	5000
Office (1)	12,000
TOTAL	**$ 42,000**
(3) Growing Facilities	
Propagation Houses (15)	$ 23,250
Groundcover Houses (12)	65,100
Liner Houses (12)	65,100
Growing Beds (23 Acres)	$270,000
TOTAL	**$423,450**
(4) Winter Protection	**$ 95,000**
(5) Pots, Media, Etc. (average cost)	**$205,000**
(6) Labor	**$600,000**
(7) Plants (average cost)	**$458,791**

OVERALL PROJECTED COST — FINANCIAL GOAL: $1,934,242

In studying these numbers, I felt that I was unable to change any cost, with the exception of the outlay for plants.

METHOD OF ACHIEVING FINANCIAL GOAL

How does one go about achieving the financial goal? In attempting to answer this question, I looked at four different ways to reach this financial goal:

- **Partnership:** One could take on several partners to financially back the nursery for future profits on their investment.
- **Corporation:** a local land developer sold investors shares for $25,000 each per share to raise capital to purchase the land and develop it to sell lots. He retained control with 51% of the shares, and no personal money invested in his project. This route was decided against, because the average nursery takes 7 years to break even.
- **Bank:** One could borrow the $1.9 million. This number computed to over $25,000 per month for 10 years, which I decided against.
- **Propagation Nursery and Landscape Business:** In starting the nursery I began a small landscape business to get instant capital to purchase equipment that would be needed to build the nursery. The landscape business continued for 2 years while I began building the propagation nursery. I was told the average finished plant took 24 to 36 months to grow from a rooted cutting. If I began trying to produce finished plants the initial cost would

be too great and the return on my investment would be too slow. By beginning with propagation, the investment could be very small (comparatively speaking) and the return on the investment would be much faster. At this time the profits could be used to expand the nursery. For these reasons, I chose to begin with the combination of landscaping and propagation.

STARTING THE PROPAGATION NURSERY

The propagation nursery was started by building several very small and inexpensive cold frames measuring 1.5 m × 6.1 m (5 ft × 20 ft) in the summer of 1989. Many cuttings were successfully rooted that summer which would later be potted into 1-gal containers. During the winter of 1989 and 1990, the first 10 of the 12.2 × 3.7 m (40 × 12 ft) propagation houses were built and filled with winter cuttings. That spring the first two growing beds were put in, which covered about 0.4 ha (1 acre) in area. During the early summer of 1990, we began potting plants and immediately filled the two beds. That spring, summer, and fall the nursery was able to start selling some of the rooted cuttings. In 1991 over 150,000 cuttings were propagated of which many were sold for profits to construct beds number three and four as well as the first six groundcover and six liner houses. By this time the nursery was beginning to sell some 1-gal liners and build the 3-gal inventory.

We were no longer landscaping. All of the financial support was coming from the nursery. We then constructed growing bed number five and six more of each groundcover and liner production houses in 1992. At this time the nursery was propagating over 300,000 plants, producing over 150,000 liners, and growing over 150,000 groundcovers which are all short-term crops. We were producing a large number of 1-gal plants and building a large inventory of 3-gal plants as well as starting the production of 1/2-bushel-plant material. In 1993, three more growing beds (no. 6 to 8) were built, and an expansion of approximately 1.4 ha (3.5 acres) on which we potted nearly 240,000 1-gal plants. Also in 1993, five more propagation houses were built which brought the total to the current number of 15 propagation houses measuring 12.2 × 3.7 m (40 × 12 ft) each. We began rooting more cuttings and selling over 250,000 liners annually, while producing over 300,000 1-gal liners for the purpose of selling a percentage for profits to continue the nursery expansion and a percentage to shift to 3- and 5-gal containers.

In 1994 the nursery expanded with four acres of growing beds, 60% of which was used to add an additional 110,000 1-gal plants while the remaining 40% was used to grow 1/2-bushel, 10-gal, and 20-gal plants. As of this year, the nursery is selling many 1-gal plants and fewer liners as the liners are needed for our own in house production.

Currently, our objective for selling liners is this: to produce a surplus of what is needed for the nursery's use and, if we have excellent success, the excess liners will be for sale. We began the winter of 1995 with the addition of 0.6 ha (1.5 acres) used to produce yet 60,000 more 1-gal plants. At this time the nursery is producing over 500,000 1-gal plants annually, 100,000 3-gal plants, 16,000 5-gal plants, 7000 7-gal plants, 5000 10-gal plants, 2000 15-gal plants, and 2000 20- and 25-gal plants. All nursery assets that have been acquired were done so by using propagation to obtain profits with the exception of one bank loan debt of $60,000 which has been completely repaid.

The Proof of the Pudding. The theory behind our approach in financing the nursery was to maintain a minimum debt by producing short turnover crops to quickly raise capital. The nursery used propagation to root and sell cuttings for profit, build the infrastructure, and produce more 1-gal plants for larger profits per plant unit. We did, however, sacrifice some turnover. But, as the numbers of plants in 1-gal production increased, the profits were greater, which in turn generated more capital for the construction of more beds and investment in larger plants—which helped in achieving our financial goal.

The current expansion plans for the fall of 1995 through the spring of 1996 seasons are to take a 1.2 ha (3 acre) property and put approximately 5000 each of 15- and 25-gal pots in the ground for pot-in-pot production of shade trees and larger screening and specimen plants.

IMPORTANCE OF PROPAGATION TO OUR FUTURE

Now that the nursery is more established, the profits are there to begin propagating less and buying more liners. At this time our decision is to continue production of our own liners with the exceptions of the plants that we do not economically propagate or to fill shortages. Since we are no longer selling many rooted cuttings, the goal is to stay 6 to 12 months ahead of our potting schedule with our liner production. For example, *Juniperus sargentii* is a plant that we want to produce approximately 20,000 1-gal plants and approximately 7,000 3-gal plants annually. The window for propagating this plant in North Carolina is very narrow, and occurs in the months of January and February. Also, the window for potting this plant as a bare-root cutting is very narrow, and occurs between 1 April and 15 May. The problem with this is that we consume a tremendous amount of space for 12 to 18 months and have very many plants ready to sell at one time. Our 1-gal production would work much better by dividing this into three different crops. This is especially true since we now are working with open spaces in the nursery that are approximately 223 m^2 (2400 ft^2) as opposed to 1.6 ha (4 acre) tracts. How did we go about solving this problem?

Better Utilization of Propagation Space and Windows of Time for Optimum Propagation. We are now taking advantage of the propagating window, and rooting the number of cuttings needed in community flats to conserve space. We also stage out the cuttings in a 2½-inch pot so that they can be potted in the spring, summer, or fall. Trying to work this out with a propagator can be difficult, due to the changes in marketing projections versus actual sales. Propagating your own liners gives you more control of when you want the liners available and having the plants in the ideal growth stage for potting. Production of your own liners will give you more control over staging your cuttings for quicker turnover of your plants to create greater profits for you and your business.

SUMMARY

In summary, I hope that I have shown how one can use propagation to assist financially in the establishment of a nursery. By producing liners for quick profit, one can use these profits to construct a nursery without going into large debt.

Death, Taxes, and Weeds

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INTRODUCTION

When was the last time you said "I did not have any weed problems last year"? I have never heard anyone make that statement. Why are weeds so dependable that you can always count on having weed problems. This article will examine the reasons that weeds are as dependable as death and taxes.

A common definition of a weed—is a plant out of place. Weeds range from oak seedlings to daylilies to prostrate spurge growing in areas where they are not wanted. This definition does not distinguish between plants that possess truly weedy characteristics from those that are only occasional nuisances. A weed is a weed because it possesses certain definable characteristics that set it apart from other plant species. A better definition might be weeds are plants that are competitive, persistent, and pernicious. In other words, a true weed is a plant out of place and intends on staying there. True weeds exhibit the following characteristics:

- Competitive and aggressive
- Able to grow, survive, and reproduce almost anywhere
- Prolific seed producers
- Resistant to control
- Easily spread

Weeds produce large number of seeds (Table 1). The average weed produces about 2000 seeds per plant. In addition, weed seeds can remain viable in the soil for years. So they are able to build a large reserve of seeds in the soil.

Table 1. Weed seed production.

Weed species	Number of seeds
broadleaf plantain - *Plantago major*	36,000
common purslane - *Portulaca oleracea*	52,000
common ragweed - *Ambrosia artemisiifolia*	15,000
curly dock - *Rumex crispus*	40,000
evening primrose - *Oenothera*	119,000
Pennsylvania smartweed - *Polygonum pensylvanicum*	3000
redroot pigweed - *Amaranthus retroflexus*	117,000
yellow nutsedge - *Cyperus esculentus*	2400

WEED IDENTIFICATION AND LIFE CYCLE

The first step in developing a successful weed management program is identifying

your weeds and their associated life cycle. Knowing the correct name helps to understand the herbicide labels and control recommendations. Several pictorial guides are available for identifying weeds (Table 2). The weed's life cycle provides information on timing of germination and method of reproduction. In addition, the life cycle determines its adaptability to various management systems and its susceptibility to control measures.

Table 2. Weed identification manuals.

Weeds of Southern Turfgrass Publication Distributions Center, IFAS Building 664, P. O. Box 110011, University of Florida, Gainesville, Florida 32611, (904-392-1764) ($8.00).
Weeds of Arkansas (MP 169) University of Arkansas, Cooperative Extension Service, P.O. Box 391, Little Rock, Arkansas 72203, Attn.: Cheryl Fraser (501-671-2038), $5.00.
Identifying Seedling and Mature Weeds Publications Office, Box 7603, North Carolina State University, Raleigh, North Carolina 27695-7603, ($7.00).
SWWS Weed Identification Guide Southern Weed Science Society, 1508 West University Ave., Champaign, Illinois 61821-3133 (217-352-4212). Call for cost.

All weeds fall into one of four life cycles: summer annuals, winter annuals, biennials, and perennials. Summer annual weeds germinate in the spring (around dogwood bloom in North Carolina), flower and produce seed in mid- to late summer and die in the fall. Common summer annual grass and broadleaf weeds are listed in Table 3. Winter annual weeds germinate from late summer to early spring, flower and produce seed in mid- to late spring and die in the summer. However, depending upon the location winter annual weeds can germinate and grow year-round. For example, in containerized plant production hairy bittercress can germinate and survive throughout the entire year. Common winter annual grass and broadleaf weeds are listed in Table 4. Annual weeds tend to germinate in largest numbers at the beginning of the season as soon as climatic conditions are favorable. However, both summer and winter annual weeds will continue to germinate in reduced numbers throughout their respective seasons.

Biennial weeds are plants that live for two growing seasons. Seed germinate in the spring, summer, or fall of the first year and plants overwinter as a basal rosette of leaves with a thick storage root. After the shoot tips are exposed to cold, the plants flower and produce seed in the summer of the second year and die in the fall. Wild carrot, bull thistle, common mullein, and common burdock are common biennial weeds.

The traditional definition of a perennial weed is that it lives for more than 2 years. However, perennial weeds will live forever. Perennials are classified according to their method of reproduction as simple or creeping. Creeping perennial weeds can both overwinter and produce new independent plants from vegetative reproductive structures. Most can also reproduce from seed. Vegetative reproductive structures include:

Table 3. Common summer annual weeds.

Grasses
barnyard grass - *Echinochloa crus-galli*
broadleaf signal grass - *Brachiaria platyphylla*
broomsedge - *Andropogon virginicum*
crabgrass (smooth) - *Digitaria sanguinalis*
crabgrass (large) - *Digitaria ischaemum*
crowfootgrass - *Dactyloctenium aegyptium*
dayflower - *Commelina diffusa*
doveweed - *Murdannia nudiflora*
fall panicum - *Panicum dichotomiflorum*
giant foxtail - *Setaria faberii*
green foxtail - *Setaria viridis*
goose grass - *Eleusine indica*
jungle rice - *Echinochloa colonam*
southern sandbur - *Cenchrus echinatus*
yellow foxtail - *Setaria glauca*

Broadleaves
annual lespedeza - *Lespedeza striata*
bitter sneezeweed - *Helenium amarum*
black medick - *Medicago lupulina*
carpetweed - *Mollugo verticillata*
common groundsel - *Senecio vulgaris*
common purslane - *Portulaca oleracea*
common ragweed - *Ambrosia artemisiifolia*
daisy fleabane - *Erigeron strigosus*
dogfennel - *Eupatorium capillifolium*
eclipta - *Eclipta prostrata*
hemp sesbania - *Sesbania exaltata*
fireweed - *Erechtites hieracifolia*
gaillardia - *Gaillardia pulchella*
horseweed - *Conyza canadensis*
narrowleaf vetch - *Vicia sativa* ssp. *nigra*
narrow cudweed - *Gnaphalium falcatum*
poorjoe - *Diodia teres*
prostrate knotweed - *Polygonum aviculare*
prostrate spurge - *Euphorbia supina*
smooth pigweed - *Amaranthus hybridus*

Table 4. Common winter annual weeds.

Grasses
annual bluegrass - *Poa annua*
little barley - *Hordeum pusillum*
sweet vernalgrass - *Anthoxanthum odoratum*

Broadleaves
annual sowthistle - *Sonchus oleraceus*
bedstraw - *Galium aparine*
Carolina falsedandelion - *Pyrrhopappus carolinianus*
Carolina geranium - *Geranium carolinianum*
common chickweed - *Stellaria media*
corn speedwell - *Veronica arvensis*
cutleaf eveningprimrose - *Oenothera laciniata*
hairy bittercress - *Cardamine hirsuta*
hairy buttercup - *Ranunculus sardous*
henbit - *Lamium amplexicaule*
hop clover - *Trifolium aureum*
knawel - *Scleranthus annuus*
parsley-piert - *Aphanes microcarpa* [syn. *Alchemilla microcarpa*]
purple deadnettle - *Trifolium arvense*
rabbitfoot clover - *Trifolium arvense*
shepherdpurse - *Capsella bursa-pastoris*
short buttercup - *Ranunculus parviflorus*
spiny sowthistle - *Sonchus asper*
thistle - *Cirsium spp.* (some species)
venus lookingglass - *Triodanis perfoliata*
Virginia pepperweed - *Lepidium virginicum*

Table 5. Common perennial weeds.

Grasses
bahiagrass - *Paspalum notatum*
Bermudagrass - *Cynodon dactylon*
broomsedge - *Andropogon virginicum*
carpetgrass - *Axanopus affinis*
dallisgrass - *Paspalum dilatatum*
johnsongrass - *Sorghum halepense*
Kentucky bluegrass - *Poa pratensis*
nimblewill - *Muhlenbergia schreberi*
orchardgrass - *Dactylis glomerata*
purpletop - *Tridens flavus*
quackgrass - *Elytrigia repens* [syn. *Agropyron repens*]
sweet vernalgrass - *Anthoxanthum odoratum*
tall fescue - *Festuca elatior* [syn. *F. arundinacea*]

Table 5. Common perennial weeds. (*Continued*)

Other weed species

rush - *Juncus spp.*
yellow nutsedge - *Cyperus esculentus*
wild garlic - *Allium vineale*
wild onion - *Allium canadense*

Broadleaves

broadleaf plantain - *Plantago major*
buckhorn plantain - *Plantago lanceolata*
catsear dandelion - *Hypochoeris radicata*
chicory - *Cichorium intybus*
cinquefoil - *Potentilla canadensis*
common vetch - *Vicia sativa*
common violet - *Viola spp.*
curly dock - *Rumex crispus*
dandelion - *Taraxacum officinale*
dichondra - *Dichondra repens*
honeysuckle - *Lonicera* spp.
horsenettle - *Solanum carolinense*
field bindweed - *Convolvulus arvensis*
Florida betony - *Stachys floridana*
greenbrier - *Smilax glauca*
ground ivy - *Glechoma hederacea*
mockstrawberry - *Duchesnea indica*
mouse-ear chickweed - *Cerastium fontanum* ssp. *vulgare* [syn. *C. vulgatum*]
mugwort - *Artemisia vulgaris*
pennywort - *Hydrocotyle* spp.
poison ivy - *Toxicodendron radicans*
red sorrel - *Rumex acetosella*
trumpetcreeper - *Campsis radicans*
Virginia dwarf dandelion - *Krigia virginica*
Virginia buttonweed - *Diodia virginiana*
white clover - *Trifolium repens*
wild strawberry - *Fragaria virginiana*
winter vetch - *Vicia villosa*
yellow woodsorrel - *Oxalis dillenii*

Table 6. Optimum application rates and timing of glyphosate to obtain 90% or better control one season later.

Weeds	Rate*	Optimum timing
aster (*Aster*), goldenrod (*Solidago*), dog fennel (*Eupatorium*)	1%	First flowering
Bermudagrass (*Cynodon*)	2%	First flowering
blackberry (*Rubus*)	1 to 1.5%	Fall and early winter
honeysuckle (*Lonicera*)	1 to 1.5%	Full bloom (early summer)
kudzu (*Pueraria lobata*)	1.5 to 2%	Full bloom (early summer)
lespedeza (*Lespedeza*)	1%	Full bloom (midsummer)
perennial grasses (quackgrass, johnsongrass, fescue)	1%	First flowering
poison ivy (*Toxicodendron radicans*)	2%	2 weeks either side full bloom
trumpet creeper (*Campsis radicans*)	1.5%	Later summer to mid-fall
Manufacturer does not claim effectiveness on the product label for the following species		
clematis vine (*Clematis*)	1%	After bloom until fall
English ivy (*Hedera helix*)	2 to 3%	3 -5 expanded new leaves (early spring)
greenbrier (*Smilax*)	3%	5 fully expanded leaves (early spring)
Japanese knotweed (*Polygonum japonicum*)	2%	Late summer to early fall before frost
mugwort (*Artemisia*)	1.5 to 2%	Full flower (later summer to fall)
passion flower (*Passiflora*)	1%	Bloom to first fruit
sericea lespedeza (*Lespedeza cuneata*)	1%	Full bloom (midsummer)
Virginia creeper (*Parthenocissus quinquefolia*)	1%	Later summer to early fall
wisteria (*Wisteria*)	1.5 to 2%	6 to 8 weeks after bloom

* 1% = 1.25 fl. oz. Roundup 4L per gallon of water.

Rhizomes: Elongated horizontal underground stems—Bermudagrass, yellow nutsedge, quackgrass, horsenettle, red sorrel.

Tubers: Thickened underground stems borne on the ends of rhizomes—yellow nutsedge.

Bulbs: Leaf tissue modified for food storage and borne on a small plate of stem—wild garlic.

Stolons: Horizontal aboveground stems—mockstrawberry, white clover, Bermudagrass.

Creeping roots: Roots modified for food storage and reproductive vegetative reproduction—Canada thistle, red sorrel.

Simple perennial weeds overwinter by means of a vegetative structure such as a perennial root with a crown and they reproduce almost entirely from seed. It normally takes 2 years for these weeds to complete a perennial cycle from seed. Simple perennial weeds have no natural means of spreading vegetatively (stolons, rhizomes, etc.). There roots are usually fleshy and can grow very large. Examples include common dandelion, curly dock, buckhorn plantain, and broadleaf plantain. Common perennial grass and broadleaf weeds are listed in Table 5.

STAGE OF GROWTH

There are four stages of plant growth: (1) germination, (2) seedling, (3) vegetative, and (4) flowering and seed production. The stage of growth that you are trying to control plays a big role in your management choices and how successful you will be. Germinating seeds and very young plants are most susceptible to control methods. Dormant seeds are not effected by most weed control practices. The most resistant stage of plants that develop from seed occurs after flowering. Not only do they achieve maximum resistance but the main objective of preventing seed production and stand replenishment has been lost.

The growth stages of perennial weeds are different in that they do not start each year from a germinating seed. To get acceptable control of perennial weeds, the root system must be controlled. Perennial weeds are most susceptible to control measures during active periods of growth and carbohydrates (food manufactured in the leaves) are moving downward toward the roots. This commonly occurs from early spring growth until flowers open. Once flowers open resistance to control measures often increases. The second susceptible window with perennial weeds occurs during the fall when the plant is once again moving carbohydrates downward to the roots which carries the herbicide along with it. The optimum rate and timing for several tough to control perennial weeds are listed in Table 6.

Benzyladenine-Induced Offset Formation in Hosta Dependent on Cultivar

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Ten hosta cultivars were treated with either 0, 1250, 2500, or 3750 ppm benzyladenine (BA). Response to BA treatment was cultivar dependent, with BA promoting offset formation in half of the cultivars tested. At 30 days after treatment (DAT), increases in offsets ranged from 116% for 'Francee' to 3500% for 'Francis Williams' at 3750 ppm BA. At 60 DAT, responses to 3750 ppm BA ranged from 150% with 'Royal Standard' to 2250% with 'Francis Williams'. The number of unfurled leaves on offsets (stage of development) was cultivar and BA dependent. However, all cultivars treated with 3750 ppm BA had an average offset stage of development of three unfurled leaves or greater at 60 DAT. Control plants of 40% of cultivars averaged less than three unfurled leaves. No phytotoxic symptoms were noted in any cultivars, and growth index was either increased or not affected by BA rate.

INTRODUCTION

Hostas are conventionally propagated by annual division of the crown or by tissue culture. However, there are certain limitations to these techniques. Division yields relatively few plants per clump, and tissue-cultured explants are costly and frequently may not be true to type. Increase in plant numbers and introduction of new cultivars may be impeded by these factors.

Vegetative buds and roots of hosta grow from rhizomes, and the rhizomic apex suppresses outgrowth of lateral axillary and rhizomic buds by apical dominance. Although the precise mechanisms of apical dominance are not fully understood, a primary factor in this phenomenon is the interaction of the plant hormones auxins and cytokinins (Cline, 1991). Cytokinins, such as benzyladenine (BA), release lateral buds from inhibition when applied exogenously, and previous studies have demonstrated the efficacy of BA in promoting the outgrowth of rhizomic and axillary buds in hosta (Keever, 1994). Furthermore, it has been demonstrated that offsets formed from BA-induced buds can be removed from the mother plant soon after elongation and rooted under intermittent mist with a higher percentage of rooting for offsets at a more advanced stage of development (Keever et al., 1995). Earlier studies were conducted using only *H. sieboldiana,* however, and considerable differences in response to BA application may be expected among the diverse range of hosta cultivars available. The objective of this study was to determine differences among hosta cultivars in response to BA application.

MATERIALS AND METHODS

Dormant, bareroot, divisions of 10 hosta cultivars were potted in 1-gal containers on 20 February 1995. Cultivars included *Hosta fortunei* var. *obscura* 'Aureo-

marginata' (AM), *H.* 'Big Daddy' (BD), *H.* 'Francee' (FR), *H.* 'Frances Williams' (FW), *H.* 'Gold Standard' (GS), *H.* 'Krossa Regal' (KR), *H. montana* 'Aureomarginata' (MA) [Bot. Ed. note: *H. montana* is one of the parents and the correct name is *H.* 'Aureomarginata'], *H.* 'Royal Standard' (RS), *H. undulata* var. *albomarginata* (UA), and *H.* 'Wide Brim' (WB). Plants were grown under 47% shade in an amended pine bark medium and irrigated by overhead rotary nozzles twice daily for 30 min.

On 7 July 1995, single-eye (no offsets) plants were selected for uniformity, and 10 single-plant replicates of each cultivar were assigned to each of four BA rates (0, 1250, 2500, or 3750 ppm BA). Buffer-X, 0.2%, was added to all BA solutions as a surfactant prior to foliar application at 1.9 liters m^{-2} (2 quarts 100 ft^{-2}). At 30 and 60 days after treatment (DAT), growth index [(height + width at widest point + width 90° to first width) ÷ 3], and visible offset count were determined for each plant. At 60 DAT offset stage of development (SOD) was determined for each offset, with SOD 1= elongated buds with first leaf furled, SOD 2 = one unfurled leaf, SOD 3 = 2 unfurled leaves, etc.

RESULTS AND DISCUSSION

Offset formation in response to BA application was cultivar dependent. With increasing BA rate, offset counts increased in cvs. FR, FW, and RS at 30 DAT (Table 1). Compared to controls, increases in offset counts ranged from 116% (FR) to 3500% (FW). In cultivar KR, optimal response was achieved at an intermediate rate. In cultivar BD, offset counts were greater with treated plants compared to controls but were similar among BA rates. Offset counts for treated plants were similar to that for controls in cultivars AM, GS, MA, UA, and WB. Offset counts generally increased between 30 and 60 DAT, and at 60 DAT response of most cvs. (AM, BD, FW, GS, KR, RS, UA, and WB) to BA was similar to that observed at 30 DAT. In FR, sufficient offsets had formed in control plants at 60 DAT such that offset counts were similar to those of treated plants. In contrast to 30 DAT, MA offset counts among BA-treated plants were greater than those of controls at 60 DAT.

Among control plants at 30 DAT, GS, RS, and WB formed more offsets than BD, FW, KR, or MA, while at 60 DAT, AM, FR, GS, RS, UA, and WB formed more offsets than BD, FW, KR, or MA. Among treated plants, BD, GS, KR, and RS formed more offsets at both 30 and 60 DAT than other cultivars in the study. Cultivars BD and KR which did not readily form offsets in the absence of BA were seen here to produce more offsets than other cultivars when treated with BA.

Influence of BA on offset stage of development (SOD) was also cultivar dependent. Offset SOD increased with increasing BA rate in cvs. BD, FW, KR, and MA, and decreased in GS, WB, and RS. With RS it appeared that the formation of a greater number of offsets decreased average offset SOD. In cvs. AM, FR, and UA, there was no difference in SOD between BA-treated plants and controls at 60 DAT. Offset SOD is an important factor for propagators of hosta. Results of earlier studies showed that offset stem cuttings in a more advanced stage of development rooted more readily. Rooting percentage for offsets with 3 unfurled leaves (SOD 4) was greater than 85%, compared to 56% rooting for elongated buds with the first leaf yet furled (SOD1) (Keever et al., 1995). Based on results of the aforementioned study it appears that offset stage of development has a direct effect on propagation

Table 1. Offset counts of hosta cultivars treated with four BA rates[z].

BA rate (ppm)	Cultivars									
	AM	BD	FR	FW	GS	KR	MA	RS	UA	WB
30 DAT										
0	2.1c[y]	0.4d	1.9c	0.1d	3.9a	0.5d	0.2d	2.9abc	2.5bc	3.4ab
1250	3.1bc	4.7ab	2.5cd	1.0de	5.9a	5.2a	0.1e	6.3a	2.2cd	2.7cd
2500	3.2bc	4.1b	2.9bc	1.6c	3.4bc	6.9a	1.5c	8.6a	2.2bc	2.7bc
3750	2.6de	4.8c	4.1cd	3.6cd	4.6c	5.4b	0.7e	10.4a	3.3cd	2.5de
0 vs. BA[x]	NS	***	NS	**	NS	***	NS	***	NS	NS
BA rate	NS[w]	Q**	L**	L***	NS	Q***	NS	L***	NS	NS
60 DAT										
0	3.4a	0.5b	3.7a	0.2b	4.4a	0.8b	0.5b	4.4a	4.0a	3.7a
1250	3.7bc	5.4ab	2.9cd	0.9de	5.6ab	5.7ab	0.5e	6.7a	5.0ab	2.9cd
2500	4.6b	4.3b	4.6b	1.9d	4.6b	7.7a	2.4cd	9.0a	5.5b	3.9bc
3750	3.0cd	5.6b	4.5bc	4.7bc	4.2bc	5.7b	2.1d	11.0a	5.1bc	3.1cd
0 vs. BA	NS	***	NS	**	NS	***	**	***	NS	NS
BA rate	NS	Q*	NS	L***	NS	Q***	L***	L***	NS	NS

[z] Cultivar × BA interaction significant ($p < 0.01$) at 30 and 60 DAT; see materials and methods for listing of cultivars.
[y] Mean separation within rows by Duncan's multiple range test, P = 0.05.
[x] NS,*, **, ***: nonsignificant, or significant at the 5% (*), 1% (**) or 0.1% (***) level.
[w] NS, L, Q: nonsignificant, linear, or quadratic response, respectively, at the 5% (*), 1% (**), or 0.1% (***) level; control included in regression analysis.

Table 2. Mean offset stage of development (SOD) by cultivar and BA rate, 60 DAT[z].

BA rate (ppm)	Cultivars									
	AM	BD	FR	FW	GS	KR	MA	RS	UA	WB
0	5.8bc[y]	1.8d	5.8bc	1.4d	9.0a	3.1cd	1.8d	9.7a	8.1ab	9.2a
1250	5.4bc	4.4cd	4.3cd	2.3de	8.2a	6.1abc	1.5e	7.9ab	6.0abc	6.3abc
2500	5.3abc	4.0cd	4.7abcd	2.7d	5.7abc	6.0abc	4.4bcd	6.4ba	6.8a	5.0abc
3750	4.6d	5.0cd	7.2abc	4.9d	7.1abc	7.4ab	5.3bcd	8.3a	8.9a	7.3ab
0 vs. BA[x]	NS	***	NS	NS	*	***	NS	***	NS	*
BA rate	NS[w]	L***	Q**	L*	L**	L***	L**	Q***	NS	Q*

[z] Cultivar x BA interaction significant ($p < 0.01$) at 30 and 60 DAT; SOD 1 = elongated bud, first leaf furled, SOD 2 = 1 unfurled leaf, SOD 3 = 2 unfurled leaves, etc; see materials and methods for listing of cultivars.

[y] Mean separation within rows by Duncan's multiple range test, P = 0.05.

[x] NS,*, **, ***: nonsignificant or significant at the 5% (*), 1% (**) or 0.1% (***) level.

[w] NS, L, Q: nonsignificant, linear, or quadratic response, respectively, at the 5% (*), 1% (**), or 0.1% (***) level; control included in regression analysis.

Table 3. Growth index of hosta cultivars treated with four BA rates[z].

BA rate (ppm)	Cultivars									
	AM	BD	FR	FW	GS	KR	MA	RS	UA	WB
30 DAT										
0	28.1b[x]	21.5c	27.4b	32.8a	32.6a	22.1c	26.9b	34.9a	32.0a	25.1bc
1250	29.7b	25.3d	26.7bcd	34.3a	35.5a	29.1bc	25.6cd	34.9a	28.2bcd	25.5cd
2500	30.5cd	25.0f	31.3cd	32.7bc	37.2a	33.2bc	28.8de	34.7ab	30.0cde	27.1ef
3750	23.8e	25.6de	31.3b	33.4ab	32.9ab	31.8b	27.9cd	35.0a	31.0bc	27.2d
0 vs. BA[y]	NS	**	*	NS	NS	***	NS	NS	*	NS
BA rate[x]	NS[w]	L**	L***	NS	Q*	Q**	NS	NS	Q*	NS
60 DAT										
0	30.0bc	22.7d	30.6bc	33.0ab	32.3ab	21.7d	27.2c	35.6a	33.1ab	27.0c
1250	30.4c	26.8d	27.0d	35.2a	35.0ab	31.7bc	27.2d	35.9a	32.6abc	25.0d
2500	30.4def	27.1f	31.7cde	35.2bc	34.3bcd	36.2b	31.3cde	40.4a	34.0bcd	28.2ef
3750	27.1f	27.0f	34.7bc	36.3ab	31.8cd	34.4bc	30.8de	38.6a	34.4bc	28.2ef
0 vs. BA	NS	**	NS	NS	NS	***	*	NS	NS	NS
BA rate	NS	Q*	Q*	NS	Q*	Q**	L**	L*	NS	NS

[z] Cultivar × BA interaction significant ($p < 0.01$) at 30 and 60 DAT, growth index = (height + width at widest point + width 90° to first width) ¸ 3, *in cm*; ; *see materials and methods for listing of cultivars.*

[y] Mean separation within rows by Duncan's multiple range test, P = 0.05.

[x] NS,*, **, ***: nonsignificant or significant at the 5% (*), 1% (**) or 0.1% (***) level.

[w] NS, L, Q: nonsignificant, linear, or quadratic response, respectively, at the 5% (*), 1% (**), or 0.1% (***) level; control included in regression analysis.

of hosta by stem cuttings. With few exceptions, offset SOD of plants treated with BA was at stage 4 or greater, whereas, among control plants 40% of cultivars averaged less than SOD 4 (Table 2).

Growth index (GI) either increased or was not affected by BA rate. Growth index generally increased with increasing BA rate in BD, FR, and KR at 30 DAT, and BD, FR, KR, MA, and RS at 60 DAT. In general, cvs. FW, GS, and RS showed greater increase in growth index at both 30 and 60 DAT than other cvs. (Table 3). At 30 DAT cvs. AM, FW, GS, MA, RS, and WB did not show differences in GI between controls and treated plants. This trend was also seen at 60 DAT in cvs. AM, FW, GS, UA, and WB. No phytotoxic symptoms were noted in any cultivars in this study, and plant appearance was not adversely affected by BA. In many cases, plant appearance was enhanced by BA application. For example, GI increased for treated KR plants at all BA rates while growth index declined for controls between 30 and 60 DAT due to foliar necrosis in the mother plants. Expansion of BA-induced offsets appeared to enhance growth and appearance of this cultivar and account for the difference in GI.

These results indicate a cultivar-dependent response to BA for the hosta cultivars evaluated. Offset counts increased with increasing BA rate in FR, FW, KR, MA and RS, but were similar to controls in AM, GS, UA, and WB. Offsets generally increased between 30 and 60 DAT. Generally, offsets developed more readily in control plants of cvs. AM, FR, GS, RS, UA, and WB than for BD, FW, KR, or MA. Among BA-treated plants, however, BD, GS, KR, and RS formed more offsets than AM, FR, FW, MA, or UA. Growth index either increased or was not affected by BA rate, and FW, GS, and RS showed the greatest increases among the cultivars in this study. Plants displayed no phytotoxic symptoms as a result of BA application, and plant appearance was often enhanced by the outgrowth and development of BA-induced offsets. BA application generally enhanced offset SOD, and 90% of all BA-cultivar combinations showed an average SOD ≥ stage 4. Offset SOD of plants in most BA-cultivar treatments at 60 DAT was so advanced that division would have provided offsets with roots, thus requiring minimal care for establishment. Based on earlier research (Keever et al., 1995), earlier removal would have yielded rootable stem cuttings. A practical system for the rapid production of hosta that employs BA application may be of benefit to growers by allowing them to produce a wide range of cultivars efficiently and economically, including certain cultivars which are otherwise slow to produce offsets. These findings are a significant step toward development of such a system. Understanding cultivar-dependent response to BA application appears to be a key factor in BA-induced offset formation and development.

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Timing and Potassium Indole-3-Butyric Acid Treatments on Rooting Stem Cuttings of *Cephalotaxus harringtonia*

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Stem cuttings from a prostrate clone of *Cephalotaxus harringtonia* (Forbes) K. Koch (Japanese plum-yew) were taken monthly from Sept. 1994 through Aug. 1995, treated with 0 or 10,000 ppm K-IBA, placed in a greenhouse under intermittent mist, and evaluated after 16 weeks. Cuttings taken from December to Feburary, and treated with K-IBA averaged 85% rooting, 10 roots per cutting, and 35 cm total root length. The next highest rooting percentages (78%) were noted for nontreated cuttings taken from March to May. Poorest rooting occurred for cuttings taken from June to August and September to November. Chemical name used: potassium indole-3-butyric acid (K-IBA).

INTRODUCTION

Cephalotaxus harringtonia (Japanese plum-yew), and its botanical varieties and cultivars offer unlimited landscape potential for U.S.D.A. hardiness Zones 5 through 8 (U.S.D.A., 1990). Plants are heat and drought tolerant, sun and shade adaptable, and resist deer browsing (Dirr, 1990; Tripp, 1994). Consumer demand for these taxa has increased steadily in the past three years. In 1994, the low growing forms (*C. harringtonia* var. *drupacea* and 'Prostrata') were named Georgia Gold Medal Award recipients, which resulted in depletion of nursery inventory in Georgia. In addition, demand for plants exists because *C. harringtonia* contains alkaloids with antitumor activities (Delfel and Rothfus, 1977; Perdue et al., 1970; Powell et al., 1972).

Plants can be propagated by seeds (Creech, 1986; Dirr and Heuser, 1987), although seeds are not readily available and germination requirements are not well defined. Asexual propagation by tissue culture has been reported, but has emphasized alkaloid production and not plant regeneration (Delfel, 1980; Delfel and Rothfus, 1977; Wickremesinhe and Arteca, 1991). Wickremesinhe and Arteca (1993) regenerated plantlets from callus cultures, but reported limited establishment (<5%). Janick et al. (1994) successfully propagated plants from zygotic embryos cultured in vitro; however, this approach does not ensure phenotypic uniformity. Stem cutting propagation of *C. harringtonia* is not well defined, although most plants are propagated by cuttings (Dirr, 1992; Tripp, 1994). Tripp (1994) reported that stem cuttings can be rooted year-round except during the spring growth flush period, with or without auxin treatment. Rooting percentages of mid March cuttings treated with indole-3-butyric acid (IBA) as a talc formulation and nontreated cuttings were similar (Dirr and Heuser, Jr., 1987). According to commercial growers, rooting may take six months or longer and plants often develop slowly because of sparse root systems. The production of a salable plant often takes two to three years (Tripp, 1994). This study was initiated to determine the effects of timing and auxin treatment on the rooting of *C. harringtonia* stem cuttings.

MATERIALS AND METHODS

Eighty, terminal, 15-cm long cuttings of *C. harringtonia* were taken monthly from 15 Sept. 1993 through 15 Aug. 1994, from a prostrate clone growing on the campus of the University of Georgia, Athens. Cuttings were pruned to a 10-cm length and the needles were removed from the basal half of the stem. Half the cuttings were quick-dipped to a depth of 2.5 cm for 5 sec in 10,000 ppm K-IBA (potassium indole-3-butyric acid) in water, while the remaining were nontreated (control). Bases of the cuttings were air-dried for 20 min before insertion into cells (7.62 cm × 7.62 cm × 7.94 cm) filled with a medium of perlite and peat (3 : 1, v/v). Cuttings were maintained under natural photoperiods and irradiance with day/night of 30/21C. Intermittent mist operated daily 2.5 sec every 5 min from 8:30 AM until 6:00 PM. Misting was extended in the summer to compensate for longer days. Bottom heat (21±3C) was provided from Dec. through Mar. A completely randomized design was used with five replicates per treatment, and eight cuttings per replicate. Rooting percentages, number of roots and root lengths were determined after 16 weeks. Roots ≥ 5 mm in length were included in the data, and a cutting having one or more root(s) was classified as rooted. Data were grouped into four, 3-month periods (seasons) because there were seasonal trends in rooting responses. Significant differences between the nontreated and K-IBA treatments were tested for each season. Data were subjected to ANOVA.

RESULTS AND DISCUSSION

Timing and K-IBA treatment affected rooting of *C. harringtonia* (Table 1). Cuttings taken in Dec. to Feb. and treated with K-IBA had significantly higher percent rooting (PR), mean number of roots (NR), and mean total root lengths (TRL) than the nontreated cuttings. These cuttings also had the highest PR, NR, and TRL compared to the other seasons and treatment. Cuttings taken in Mar. to May and treated with K-IBA had significantly higher NR than the nontreated cuttings, although there were no significant differences in PR and TRL. The Mar. to May control cuttings averaged 5 roots/cutting and 13 cm TRL. Percent rooting, although not significantly different from K-IBA treated cuttings, was 11% higher. The effects of IBA and K-IBA on the rooting of *Cephalotaxus* taxa have not been clearly documented (Dirr and Heuser, 1987; Tripp, 1994). The inconsistencies in rooting response are possibly related to the season when the cuttings were taken. In this study, cuttings were responsive to exogenous K-IBA application in Dec. to Feb. and to a lesser degree in Mar. to May. In Sept. to Nov., treatment effects were nonsignificant. However, K-IBA treatment significantly reduced rooting in June to Aug. The June to Aug. cuttings were soft and were maintained as terminal cuttings even when new growth was present. Although K-IBA dissolved in water is generally less injurious to cuttings than the free acid of IBA dissolved in an organic solvent, the 10,000 ppm rate induced basal necrosis on the majority of cuttings. In retrospect, a lower K-IBA rate may have been both noninjurious and stimulatory.

The June to Aug. and Sept. to Nov. cuttings that rooted never attained the quality standards, i.e., NR and TRL, of the Dec. to Feb. and Mar. to May cuttings (Table 1). Low temperature preconditioning has improved the rooting of many gymnosperms including *Abies* Miller (fir) (Dirr and Heuser, 1987); *Chamaecyparis* Spach. (falsecypress) (Hartmann et al., 1990); *Juniperus* L. (juniper) (Barnes, 1993; Dirr and Heuser, 1987; Hartmann et al., 1990); *Picea* Dietr. (spruce) (Mitsch, 1975);

Taxus L. (yew) (Barnes, 1993; Hartmann et al., 1990); and *Thuja* L. (arborvitae) (Barnes, 1993). The Dec. to Feb. cuttings and the Mar. to May cuttings rooted in 10 to 12 weeks. It is possible the nontreated cuttings from June to Aug. and Sept. to Nov. would root if given more time. Growers report sticking cuttings in summer and waiting 12 months or longer for complete rooting. Nontreated and treated (8000 ppm and 20,000 ppm IBA-talc) mid March cuttings of *C. harringtonia* var. *drupacea* 'Duke Gardens' rooted 63%, 70%, and 73%, respectively, when examined two years later (Dirr and Heuser, 1987). Cuttings of 'Duke Gardens' taken in late Sept. and treated with 3000 ppm K-IBA failed to root by April although they were in excellent condition.

Table 1. The effects of timing and K-IBA on rooting percentage, root number, and root length of stem cuttings of *Cephalotaxus harringtonia*.

	Season			
Auxin Treatment	Sept. - Nov.	Dec. - Feb.	Mar. - May	June - Aug.
	Rooting (%)			
Nontreated	30.0	21.8	78.3	55.8
K-IBA	34.2	84.9	66.7	0.8
	NS	***	NS	***
	Mean no. roots[1]			
Nontreated	1.6	2.3	4.9	3.5
K-IBA	3.6	10.0	7.8	0.2
	NS	***	***	***
	Mean total root length (cm)[1]			
Nontreated	2.7	6.1	13.1	9.7
K-IBA	6.0	35.0	14.4	0.5
	NS	***	NS	***

[1] Means are per rooted cutting.
NS, *** Nonsignificant or significant at P=0.001.

The taxonomy of *Cephalotaxus* species and cultivars is confusing (Tripp, 1994). Differences possibly exist in the rooting responses of the various taxa. A study is currently underway to collect and accession as many taxa as possible for chemotaxonomic and propagation studies. Based on our work with the low-growing clone of *C. harringtonia,* cuttings should be taken in Dec. to Feb. or Mar. to May and treated with 10,000 ppm K-IBA.

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Field Production of *Cornus* Cultivars

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INTRODUCTION

At Shadow Nursery we are propagating *Cornus florida*, *C.* and *C. florida* × *C. kousa* cultivars by T-budding. This is the eighteenth year we have used this propagation method in producing these dogwoods on a commercial basis.

SEEDING PRODUCTION

Seed Collection and Handling. *Cornus florida* seed are collected by local people and brought to the nursery where we purchase the seed by the pound. The seed are soaked in water for two days before being cleansed with a mechanical seed cleaner. The cleaned seed are then spread on burlap or shade cloth to air dry preferably in light shade. The seed are then sacked in burlap or loosely woven bags and hung until planting time.

Sowing Period. During October or November, when weather conditions are good, the seed are planted in 6-ft rows which have been ridged and a v-shaped furrow 5 cm (2 in.) deep has been pressed into it. The furrow is then covered with hardwood sawdust and cultipacked to lessen wind erosion of the sawdust. The middles are then broken with a submoisture plow for optimum rain penetration and to prevent soil erosion.

We plant the seed with a Plantet Junior vegetable seed planter. This is the most economical way we have found to plant the seed without cracking them. The seed are thickly planted so that the emerging seedlings help protect each other. Another advantage in using this method is there are less side branches to remove. I have seen the first emerging seedlings get killed from a late frost and yet there would be enough seed to germinate for a sufficient stand for budding.

Seedling Growth. The dogwood seed begin to germinate about 15 March to 1 April, depending on weather and soil conditions. This is a crucial time period in the germination process. If water puddles on the germinating seed for 12 to 24 h the seedlings are lost. Also, seedlings may need to be protected from frost if possible. As soon as the seedlings are 2 to 3 in. high, drip irrigation, fertilizer, fungicides, and insecticides are applied as needed.

BUDDING

Budwood Selection. Budwood is cut from appropriate cultivar stock blocks or from 1-year buds that are in good growing condition. It is important that the budwood and buds be in a good growing condition. This can be accomplished with irrigation, if necessary.

T-budding. Our normal budding schedule is usually 15 Aug. to 1 Oct. About 2 weeks are needed for the bud to knit before any frost occurs. Before budding begins the seedlings are thinned by cutting the unwanted seedlings underground with clippers.

This prevents the needed seedlings from being loosened. We thin the seedlings to approximately 5 to 8 cm (2 to 3 in.) apart. The seedlings are extremely tender at this point and extreme caution must be made in handling both the seedling and the bud to prevent bruising. The bud is cut from the budstick and inserted into the seedling and wrapped with a rubber budstrip. The T-bud is budded as low as possible on the southwest side of the seedling. Since this is the direction of the prevailing winds, we get less breakage from wind storms.

The budded seedlings are root pruned after becoming dormant. This is usually about the middle of November. This helps to insure a good fibrous root system. The following spring (late Feb. to early March) the seedlings are cut off just above the buds and all suckers removed to give optimum conditions for the bud to swell and grow. Drip irrigation, fertilizer, weed control, fungicides, and insecticides are applied during the growing season as needed.

By fall, if we have not experienced an adverse act of mother nature (hail storm, wind storm, etc.) we should have a good crop of *Cornus* cultivars.

Marketing Wetland Natives and Endangered Plants Under Federal and State Permitting Regulations

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INTRODUCTION

The topic I have been asked to cover is really two rather different subjects. Each could be the subject of a much more lengthy presentation. They relate in that they both involve native plants, natural ecosystems, environmental regulations, and the Green Industry.

I will try to briefly discuss wetland native plants and spend a little more time on the subject of endangered plants and the attendant ethical and legal considerations.

Legislation to Protect the Environment and Endangered Species. In the 1970s during the Nixon administration, sweeping federal environmental legislation including the Clean Air Act, the Clean Water Act, and the Endangered Species Act became law. These federal laws from the 1970's plus other state and federal environmental laws since that time have affected the green industry in various ways well known to most of you. Legal requirements to protect wetlands have severely restricted development in many areas. Restoration of damaged wetlands or creation of new wetlands to mitigate losses have created a new demand for appropriate plant material and its installation.

Plant Species for New and Disturbed Wetland Sites. While new or disturbed wetland sites are naturally invaded and occupied by aquatic plant species, the desired species mix may require planting and management. Much of this know-how was developed years ago by state, federal, and private interests who have for most of this century managed thousands of wetland acres throughout the country for waterfowl hunting or as wildlife refuges.

In the Southeast, Florida has perhaps been the state most involved in wetland projects and has been a major source for much of the wetland plant material used on big projects elsewhere in the Southeast. Several Florida nurseries specialize in wetland plants for large projects. Charleston Aquatic Nursery, visited during this conference, is an example of a nursery which supplies water plants primarily for ornamental use. Woody plants for wetland use are usually produced by ordinary commercial nurseries using standard tree and shrub propagation and production techniques.

While herbaceous aquatic plants propagated by seed and division are routinely grown in some nurseries, much of what is sold is collected from natural wetlands. Although this activity is sometimes conducted irresponsibly, wetlands are remarkably resilient and it may be rare that significant or long-term damage is done by occasional removal of moderate percentages of a given species. In any case, care should be taken to avoid endangered species or special areas which are ecologically unique. Collecting on public property or trespassing on private property without clear authorization is of course illegal.

Federal Endangered Species Act. The Federal Endangered Species Act of 1973 is intended to identify, locate, and develop protection and recovery strategies for populations of native species of animals and plants which are in imminent danger of extinction. The U.S. Fish and Wildlife Service, Department of the Interior, is the agency responsible for administering and enforcing the Endangered Species Act.

Common law as applied to animals and plants differs in that land ownership includes ownership of flora but not fauna. Efforts to save rare animals are widely publicized and have generally received more public attention and support than have efforts to save endangered plants. As plant propagators, we will be looking at the situation as it applies to threatened and endangered plants. As plant propagators, we should have been much more involved than we have been.

How Plants Become Endangered Species. Plants become endangered for various reasons. Relatively few have been intentionally exploited—but human activity, directly or indirectly, is largely responsible. Loss or scarcity of suitable habitat is by far the major factor. Some species which were once widespread have been made rare by loss of habitat to development, agriculture, forestry, mining, drainage, impoundments, fire suppression, invasive exotic species, insects, diseases, etc. Other species require very specific habitats which have always been very scarce. These plants were never known to have been common and their fate as naturally occurring populations is tied to preservation of very specific rare and highly localized ecosystems.

Certain native plants have historically been exploited for various purposes. A number are heavily collected for the medicinal trade. A few plants, notably certain cacti and orchids have been severely impacted by unscrupulous and unethical collecting for horticultural purposes. Unfortunately this has given the entire horticultural community a "bum rap". It has made us the convenient "bogeyman" for zealous regulators and environmental activists. Restrictions on interstate and international commerce and elaborate permitting procedures regulating sale of any plant species listed as threatened or endangered are part of the present law. Some view this as an important means of protecting endangered plants from commercial exploitation.

While the US Fish and Wildlife Service has spent a lot of money aggressively pursuing the capture and captive breeding of rare animal species it has shown little interest in applying proven, less-costly, and less-risky horticultural techniques to endangered plants. Those involved in enacting and administering endangered plant programs should be educated to the following points:

- Only a relatively small percentage of threatened and endangered plant species are of any horticultural interest, but horticultural techniques could help save many.
- There is a big difference between the destructive and unethical collecting and selling of rare plants, and the potential benefits offered by artificial propagation.
- Horticultural use is a legitimate value, and should not be ignored or denied when conservationists seek to justify the preservation of endangered plants.
- A number of rare plants with horticultural value have been propagated and maintained in cultivation for years without

impacting wild populations. While preserving wild populations is paramount, a few species exist today only because they have been preserved in cultivation.

- Many rare plants are easily propagated and could be artificially increased ad infinitum, thus making removal of wild plants from native populations unjustifiable on any grounds. Also such propagation could provide quantities of plants for conservation purposes such as introduction or reintroduction into suitable habitats.

Re-authorization of the Endangered Species Act. The Endangered Species Act is up for re-authorization and several House bills have been introduced. One, H.R. 2275, awaits floor action. Conservationists strongly oppose H.R. 2275 and are lobbying for a more acceptable bill. Any re-authorization will probably not happen before early in 1996. Hopefully a final bill will provide for the protection of critical habitats and will include realistic provisions to encourage, rather than discourage, the propagation of threatened and endangered plants. Trade restrictions on plants which have been artificially propagated from legitimately obtained stock should be relaxed to allow sale by nurseries which have been inspected and certified. Please contact your senators and representatives with your views.

Meanwhile the US Fish and Wildlife Service can provide information on current regulations and the plant species which now have legal status as threatened or endangered. In addition it is important to understand the laws of each state where you do business if you wish to buy, sell, or possess rare native plants which might be protected under state law. Your state department of natural resources will be able to advise you concerning state laws.

Plants With Commercial Promise

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INTRODUCTION

With the word "commercial" in the title, this has become a conservative selection list of plants easy-to-propagate, relatively fast, relatively "known", and with propagation stock available. Perhaps the greatest factor in profitability of nursery stock today is speed of growth with ease of culture. The following plants are offered as examples of plants either presently expanding rapidly in usage, or projected to do so in the near future.

HERBACEOUS PERENNIALS

Verbena—such perennials as 'Homestead Purple'—very easily propagated; exceptionally fast growing; long season of color; low maintenance—all are vastly superior to annual types being grown as bedding plants; U.S.D.A. Zones 7-9.

***Pachysandra terminalis* 'Green Sheen'**—superior pachysandra for the south; heat tolerant; spreads quickly; glossy leaves; U.S.D.A. Zones 3-9.

***Ardisia japonica* 'Chirimen'**—most cold-hardy cultivar from the North Carolina State University Arboretum (NCSU) Arboretum trials; 3 to 4 in. tall; fine texture; easy and fast growing; U.S.D.A. Zones 7-9.

Muhlenbergia dumosa, Bamboo Muhley—very different fine-textured grass from Arizona; fast growing from seed; U.S.D.A. Zones 7-9.

***Canna ×generalis* 'Stuttgart'**—new white variegated foliage cultivar from Stuttgart, Germany via Brooklyn Botanic Garden; U.S.D.A. Zones 7-9.

***Helleborus* sp. and cvs**. — see new English and German books on modern types; many colors; cultivars exciting and will be seed grown from self-pollinated plants.

***Euphorbia* sp. and cvs**.—widely variable types of long-season interest; easy to propagate by cuttings and fast growing.

VINES

***Bignonia capreolata* 'Tangerine Beauty'**—selection of native "cross vine" intermediate in color between the species and 'Atrosanguinea'—reblooms; evergreen; very easy from cuttings and fast growing; U.S.D.A. Zones 6-9.

***Campsis grandiflora* 'Morning Calm'**—NCSU Arboretum introduction from Korean collection; showy orange flowers in mid-summer; has juvenile/adult tissue (juvenile root easily but are slower to flower; adult are difficult to root but heavy flowering); U.S.D.A. Zones 6-9.

***Wisteria* sp. and cvs.**—with new Australian book *Wisterias* by Peter Valder, the market will need a good range of known superior cultivar plants; use only cutting-grown materials.

DECIDUOUS SHRUBS

Strong direction in last 5 years to fast gallons—*Caryopteris*, *Buddleja*, *Spiraea*, etc.—good cheap long-season color.

***Zenobia pulverulenta* 'Woodlander Blue'**—Ericaceous plant with white flowers; blue foliage; great gold/red fall color; easily propagated from softwood cuttings; U.S.D.A. Zones 6-9.

Rhododendron prunifolium—summer flowering native azalea; red flowers; fragrant and hummingbird interest tie-ins; U.S.D.A. Zones 5-9.

Syringa oblata* var. *dilatata, Korean lilac—huge market for south; looks and smells like a "real" lilac; tissue-culture propagation; U.S.D.A. Zones 5-9.

***Aesculus parviflora* 'Rogers'**—with new softwood cutting pioneered by Bir, potential cultivars are an option; this selection with longer inflorescences; U.S.D.A. Zones 5-9.

Daphne species are finally coming to south—with great profits for those who master them—*D. odora, genkwa, mezereum, caucasica*.

Stachyurus salicifolius—the only true rare "newcomer" to this list; evergreen; long, narrow, graceful foliage; chains of yellow flowers; U.S.D.A. Zones 7-9 (possibly).

TREES

***Magnolia* ×*kewensis* 'Wada's Memory'**—most emphasis in Magnolias is on the ephemeral flowers whereas foliage and overall form are more important for commercial street tree use—this in one of the best for such purpose; white flowers; superior dark green foliage; outstanding form; U.S.D.A. Zones 4-8.

***Magnolia virginiana* 'Santa Rosa'**—over the last decade cultivars of *Magnolia grandiflora* have achieved great commercial success; there is now a great need for cultivar sweet bay magnolias in trade; much variation among seedlings; this form from Woodlanders Nursery, Aiken, GA; most evergreen in our trials; very vigorous; large flowers; U.S.D.A. Zones 6-9.

CONIFERS

Huge variety and worthy of a several-hour-long talk; many new references available; diverse color, texture, size, form, production speed; much more useful in south than thought—see Atlanta Botanic Garden plantings for uncommon taxa.

***Cupressus arizonica* 'Carolina Sapphire' [syn. *C. arizonica* var. *glabra* 'Carolina Sapphire']**—fastest growing conifer with 5 to 6 ft per year possible when young; blue foliage; does not age well— but market will not care when they can buy them cheaply; U.S.D.A. Zones 6-9.

***Cryptomeria japonica* 'Yoshino' and 'Benjamin Franklin'**—fast screening materials and good specimens—already extremely popular and growing; U.S.D.A. Zones 6-9.

***Thuja* 'Giganteoides'**—hybrid of *T. occidentalis* × *T. plicata*; very fast with 4 to 5 ft per year; probably the next Leyland Cypress in the mass market; U.S.D.A. Zones 5-9.

Cephalotaxus—many species and cultivars; too slow to be truly mass market but may be so good as to overcome that; deer-proof; U.S.D.A. Zones 5-9.

Taxus chinensis—easy to propagate; fast growing; heat tolerant; with uses as specimen, sheared hedges, and Christmas trees; U.S.D.A. Zones 5-9.

Taxodium distichum* and *T. distichum* var. *imbricatum—huge need for cultivar production in south for commercial uniformity; U.S.D.A. Zones 5-9.

OTHER PLANT MATERIALS WITH PROMISE

Many other plants exist which are excellent garden plants with many merits—yet may have limited "normal" commercial opportunities for a variety of reasons. Three examples of such "good but not mass commercial plants" include: *Cercis canadensis* var. *texensis* 'Oklahoma'—outstanding leathery glossy foliage and dark maroon flowers; *C. canadensis* 'Appalachian Red'—stunning color, closest to red of any redbud, iridescent color; and *Mahonia* ×*intermedia* cultivars such as 'Arthur Menzies'—dramatic foliage, showy mid-winter fragrant flowers. All three have propagation problems that limit speed and extent of commercial build-up for marketing.

CONCLUSION

The future determinants of mass commercial potential will move from the plant qualities to the marketing techniques.

Advertising, color photographs, and innovative packaging will increasingly determine the mass sellers. Good ornamental characteristics, though important, won't be enough for success. New sales formats such as CD-ROM catalogs; World Wide Web marketing; computer and video choices; TV shopping by mail will increasingly dominate customer views and purchase of new plants.

A Message of Congratulations on the 2nd Annual Conference of IPPS Japan Potential Region

S. Tsumura, Mayor of Miyazaki City

It is a great pleasure for me to express congratulations on the 2nd Annual Conference of IPPS Japan Potential Region in Miyazaki, and also to welcome overseas and home participants. In addition, I have a deep respect for the communication opportunities among people concerned in production, marketing, consumption, and research.

Because it is mild in winter and sunshine is abundant all the year round, Miyazaki is an important centre for the production of horticultural crops in Japan, especially the glasshouse production of pumpkin, sweet pepper, and cucumber. At present, we are facing big changes in horticulture and agriculture on an international scale. Therefore, the creation of good cultivars and the introduction of new technology into the field are necessary. Recently, there have been remarkable advances in biotechnology, and we await the application of these advances to the production and management of crops.

I believe the presentations and communications during this Conference will be very productive for the promotion of agriculture and horticulture.

There are a lot of sight-seeing places in Miyazaki City, for example "Paradise of Sea and Earth", "Seagaia". The number of tourists to Miyazaki has reached 5 million per year. I hope you will be able to enjoy at your leisure the sight-seeing places.

Finally I pray that the conference will be successful and I wish you good health.

Drawing a Picture on the Earth

T. Watanabe, President of Miyako-City

Miyazaki prefecture is well known as a tourist resort. In former times, however, Miyazaki was not well known as there were no tourist attractions or hot springs. One man's vision was responsible for developing Miyazaki as you see it today, his name was Mr. S. Iwakiri. He was born in Miyazaki City in 1893. After graduation from Tokyo University he entered the head office of Sumitomo Co., and soon came back to Miyazaki.

In 1926, Mr. Iwakiri bought four used buses from Ford Co. and founded the Miyazaki Motorcar Company. In 1931, sight-seeing buses began running between Miyazaki and Aoshima. At that time, the bus guides of the Miyazaki Traffic Co. had the best reputation in Japan. Nevertheless, the number of tourists visiting Miyazaki was not large because there was no hot spring. Mr. Iwakiri thought that it was necessary to develop alternative tourist venues.

Mr. Iwakiri became interested in the Phoenix palm and from 1931 he started planting Phoenix palms on the Nichinan coast. Iwakiri had an idea of drawing a picture on the earth and he dreamed of making a beautiful roadside park. Through his efforts, the fame of the southern country of Miyazaki grew. Iwakiri also dreamed

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Drawing a Picture on the Earth

T. Watanabe, President of Miyako-City

Miyazaki prefecture is well known as a tourist resort. In former times, however, Miyazaki was not well known as there were no tourist attractions or hot springs. One man's vision was responsible for developing Miyazaki as you see it today, his name was Mr. S. Iwakiri. He was born in Miyazaki City in 1893. After graduation from Tokyo University he entered the head office of Sumitomo Co., and soon came back to Miyazaki.

In 1926, Mr. Iwakiri bought four used buses from Ford Co. and founded the Miyazaki Motorcar Company. In 1931, sight-seeing buses began running between Miyazaki and Aoshima. At that time, the bus guides of the Miyazaki Traffic Co. had the best reputation in Japan. Nevertheless, the number of tourists visiting Miyazaki was not large because there was no hot spring. Mr. Iwakiri thought that it was necessary to develop alternative tourist venues.

Mr. Iwakiri became interested in the Phoenix palm and from 1931 he started planting Phoenix palms on the Nichinan coast. Iwakiri had an idea of drawing a picture on the earth and he dreamed of making a beautiful roadside park. Through his efforts, the fame of the southern country of Miyazaki grew. Iwakiri also dreamed

of filling Miyazaki with flowers—under his guidance, many flowers were planted in Miyazaki City. Mr. Iwakiri was 92 years old when he died in 1985.

Seeing the beautiful environment of Miyazaki, we cannot help remembering the vision of Mr Iwakiri.

Environmental Control in Plug Production

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INTRODUCTION

The commercial use of seedling plugs (called plugs hereafter) has recently increased rapidly worldwide in horticulture. They have many benefits, such as easier transplanting, faster growth, and greater uniformity compared with conventional nursery plants. However, the scheduling of plug production is still a common problem because of the difficulty in controlling plug growth in glasshouses. The precise control of environmental factors is needed to produce high quality plugs with rapid turnover. Short and thick stems (i.e. short height) is essential for quality plugs. This article summarizes the responses of plugs to environmental factors from an environmental control point of view.

ENVIRONMENT INSIDE THE PLUG STAND

In general, the environment inside the plug stand in a glasshouse is characterised as follows: high relative humidity (RH), high daytime air temperature, and low nighttime air temperature when compared with the temperatures outside the plug stand, low light intensity at the lower part of the stand, and lower CO_2 concentration under a higher light intensity. These characteristics often cause poor and/or uneven growth of the plugs.

RESPONSES OF PLUGS TO ENVIRONMENTAL FACTORS

When the temperature varies from the optimum temperature recommended, the growth and quality of the plugs is adversely affected. The leaf temperature of the plugs will affect the growth and quality more directly than the surrounding air temperature, and will be 2 to 3C higher than the air temperature around the plugs in sunlight. The height of many ornamental plants increases with the increase in the difference in air temperature between day and night, known as "DIF" (Heins et al., 1988). Plants become taller with greater positive DIF value, i.e. when day temperature is higher than night temperature, and shorter with greater negative DIF value, i.e. when day temperature is lower than night temperature.

Low relative humidity will often induce water stress in plugs and thus inhibit photosynthesis, because the transpiration rate of the leaves would be higher than the water absorption rate of the roots. On the other hand, higher relative humidity in general makes plug stems longer. The relative humidity is often observed to be 10% to 20% higher under the canopy of plug stands than above it.

The photosynthetic rates of plugs are dependent on a photon flux in a spectral

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The photosynthetic rates of plugs are dependent on a photon flux in a spectral

range between 400 and 700 nm. Light quality (blue: 400 to 460 nm, red: 620 to 680 nm, far-red: 700 to 800 nm) affects the morphogenesis of plugs. Plug height decreases with increasing photon ratios of red to far-red regions and of blue to red regions.

Increases in the net photosynthetic rate and thus the growth rate of plugs are expected by increasing the atmospheric CO_2 concentration. Therefore, CO_2 enrichment in glasshouses will be effective in accelerating turnover in plug production.

CONCLUSION

The growth and morphology of plugs are strongly influenced by their environment. Environmental control is becoming essential to improve the quality of plugs and to reduce the production cost of plugs through rapid turnover. The methodology and techniques for plug production should be developed by means of environmental control.

LITERATURE CITED

Heins, R., J. Erwin, R. Berghage, M. Karlsson, J. Biernbaum, and **W. Carlson.** 1988. Use of temperature to control plant height. Greenhouse Grower 6: 32-34.

Cultivar Differences in Shoot Proliferation and Rooting of Japanese Plum (*Prunus salicina* Lindl.)

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Cultivar differences in shoot proliferation and rooting of *Prunus salicina* were investigated. The number of shoots on woody plant medium (WP) containing 2 μM BA was greater in cultivars Ooishi-nakate and Santa Rosa. While the cultivars, Ooishi-wase, King, Cocheco, Sordum, Manchurian, and Methley showed low proliferation rates. Maximum shoot length was found in 'Cocheco'. 'Sordum' had the poorest shoot elongation.

Rooting ability was higher in cultivars Ooishi-wase, King, Cocheco, Santa Rosa, Manchurian, and Methley, but that of Ooishi-nakate and Sordum were low. In most cultivars tested, IBA was more effective for rooting than NAA.

INTRODUCTION

Japanese plum (*Prunus salicina* Lindl.) originated in China. It was brought to the United States about 100 years ago, and was hybridized with *P. cerasifera, P. simomi, P. americana*, and other species to produce important cultivars. Therefore, Japanese plum cultivars have a diverse and complex genetic background. Although micropropagation methods have been successfully applied to many fruit trees in the genus, very few studies have been reported for *P. salicina* (Rosani et al., 1980; Uematsu and Akihama, 1987).

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In this study, we examined cultivar differences in shoot proliferation and rooting of *P. salicina*.

MATERIALS AND METHODS

Initiation Culture. Shoot culture was established from the axillary bud of an elongating shoot in each cultivar (Ooishi-wase, Ooishi-nakate, King, Cocheco, Manchurian, Sordum, Methley). Potted trees were moved into the glasshouse in early spring. The shoots (about 15 cm long) sprouting from the buds were used to provide material for the experiments. Each shoot after leaf removal was cut to about 2 cm long. The stems were sterilised with 70% ethyl alcohol for 1 min and then with 5% sodium hypochlorite solution (0.25% active chlorine) containing 0.05% Tween-20 for 15 to 20 min. After sterilisation, stems were rinsed with sterile water three times and trimmed to 5 mm long. These nodal explants were cultured on the culture medium. Woody Plant (WP) medium (Lloyd and McCown, 1981) supplemented with 2 μM BA, 0.8% agar, 3% sucrose, was used for the initiation culture. Shoots from axillary buds were subcultured in the same shoot proliferation medium. The pH of the medium was adjusted to 5.6-5.8 with 0.1 N NaOH before autoclaving. Medium (10 ml) was dispensed into 20 mm × 120 mm culture tubes, capped with a polypropylene closure. Culture tubes containing media were sterilised in an autoclave at 121C for 15 min. The cultures were incubated at 26 C under 16-h photoperiod (40 μmol m^{-2} s^{-1}) provided by cool white fluorescent tubes (Mitsubishi FLR40SW). The cultures were transferred onto fresh medium every 30 days.

Cultivar Difference in Shoot Proliferation. After 5 to 6 subcultures, shoots of each cultivar were cultured on WP medium supplemented with 2 μM BA, 1% agar, and 3% sucrose. Because shoot growth of 'Sordum' on the sucrose medium was very poor and the subculture of these shoots was not possible, WP medium containing 3% sorbitol was used for this cultivar. After 4 weeks, the number of shoots and shoot length were recorded.

Cultivar Difference in Root Formation. Shoots of each cultivar, about 7 mm long were cultured on WP medium supplemented with 0.1 μM IBA or NAA. The cultures were incubated at 26 C under 16-h photoperiod (40 μmol m^{-2} s^{-1}) provided by cool white fluorescent tubes (Mitsubishi FLR40SW). After 4 weeks, the number of roots per rooted shoot and the root length were recorded.

RESULTS AND DISCUSSION

Shoot Proliferation. Table 1 shows the shoot growth of each cultivar on WP medium. The number of shoots on WP medium containing BA was greater in cultivars Ooishi-nakate and Santa Rosa, while other cultivars, Ooishi-wase, King, Cocheco, Sordum, Manchurian, and Methley, showed low proliferation rates. Greatest shoot length was obtained in the cultivar Cocheco, followed by King, Ooishi-wase, Methley, Santa Rosa, Ooishi-nakate, and Manchurian. 'Sordum' had the least shoot elongation. When single shoots of plum were placed in the medium, the shoot proliferation rate was low in most cultivars. However, when a clump with 2 to 3 shoots was placed in the medium, a large number of shoots was obtained in many cultivars after 30 days of culture (data not shown).

Table 1. Cultivar difference in shoot proliferation of Japanese plum.

Cultivar	No. of shoots	Maximum shoot length (mm)
Ooishi-wase	1.5±0.2[1, 2]	9.3±0.4
Ooishi-nakate	4.1±0.6	8.6±0.4
King	1.8±0.3	9.9±0.4
Cocheco	2.1±0.3	14.2±0.7
Santa Rosa	3.8±0.6	8.9±0.6
Sordum	1.6±0.2	4.2±0.2
Manchurian	1.6±0.2	8.4±0.4
Methley	1.2±0.1	9.0±0.3

[1] mean±S.E.
[2] Each value represents the mean of 15 replicates.

Root Formation. Table 2 shows the rooting ability of each cultivar on WP basal medium (auxin-free) and on WP medium supplemented with IBA or NAA.

Cultivars Ooishi-wase, King, and Manchurian showed higher rooting percentages on the auxin-free medium. Rooting ability was higher in cultivars Ooishi-wase, King, Cocheco, Santa Rosa, Manchurian, and Methley, but that of Ooishi-nakate and Sordum was low. In most cultivars tested, IBA was more effective for rooting than NAA.

Rosati et al. (1980) reported that shoot proliferation of Japanese plum cultivar Calita was greatest on modified MS medium supplemented with 1 mg liter^{-1} BA, 0.1 mg liter^{-1} GA_3, and 0.1 mg liter^{-1} IBA. Uematsu and Akihama (1987) reported that shoot proliferation of Japanese plum cultivars Ooishi-wase and Taiyou was greatest on ½ MS medium supplemented with 4PU or BA. In our preliminary study, results indicated that the survival rates of shoots during subcultures were higher on WP medium than on MS medium, especially for cultivars King and Sordum. Therefore, we used WP medium for this study. The results in this study indicated that there are cultivar differences in shoot proliferation rates and rooting ability among Japanese plum cultivars. However, the relationship between these cultivar differences in proliferation rate and rooting, and the genetic background of each cultivar was not clear. For example, although 'Ooishi-wase' and 'Ooishi-nakate' have a similar genetic background, their rooting abilities were very different.

It has been suggested that the genotype is one of the most influential factors in determining proliferation or rooting responses. In the rooting of apples, differences among cultivars have been found in response to auxin concentration (Zimmerman et. al., 1985). In apricots, Marino et. al, (1991,1993) showed that shoot multiplication was influenced by carbon sources in the media. In our study, shoot growth of 'Sordum' on sorbitol medium was greater than that on sucrose medium, which indicates that there may be cultivar differences in sugar requirement for shoot growth and rooting. Further studies involving sugar and hormone requirements are needed to determine the cause of cultivar differences in shoot proliferation and rooting.

Table 2. Cultivar difference in rooting of Japanese plum.

Cultivar	Auxin	Rooting (%)	No. of roots	Maxmum root length (mm)
Ooishi-wase	HF[1]	15.0[2,3]	1.3±0.2	36.5±2.5
	IBA	80.0	1.5±0.2	21.4±2.3
	NAA	60.0	1.3±0.1	37.9±2.1
Ooishi-nakate	HF	0	-	-
	IBA	20.0	1.0±0.0	32.8±3.4
	NAA	10.0	2.0±0.4	37.3±3.4
King	HF	65.0	1.7±0.2	29.1±2.9
	IBA	55.0	3.3±0.3	13.3±1.5
	NAA	60.0	2.2±0.2	9.3±0.9
Cocheco	HF	21.1	1.0±0.0	30.5±4.3
	IBA	95.0	3.4±0.4	9.5±1.3
	NAA	75.0	1.7±0.2	13.0±2.2
Santa Rosa	HF	25.0	1.2±0.1	73.1±5.8
	IBA	100	2.9±0.4	32.4±2.4
	NAA	90.0	2.4±0.3	35.7±3.5
Sordum	HF	5.0	1.0±0.0	6.0±0.0
	IBA	20.0	1.5±0.2	37.0±4.3
	NAA	40.0	2.3±0.2	18.2±2.2
Manchurian	HF	90.0	2.5±0.2	38.4±1.7
	IBA	90.0	2.9±0.4	26.8±2.9
	NAA	95.0	2.7±0.4	11.4±0.9
Methley	HF	17.6	1.0±0.0	9.5±1.6
	IBA	94.7	1.8±0.4	16.1±1.9
	NAA	60.0	2.0±0.3	19.1±3.1

[1] HF: Hormone free
[2] Mean ± S.E.
[3] Each value represents the mean of 15 replicates.

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Cultivar Differences in Shoot Proliferation and Rooting of Apricot (*Prunus armeniaca* L.) in Vitro

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Using seven cultivars of apricot (Heiwa, Mochi-anzu, Yamagata-3, Jinshirou, Shinshu-ohmi, Alfred, and Goldcot), differences in shoot proliferation and rooting ability were investigated. Woody Plant (WP) medium was more effective for the culture establishment of apricot compared with B5 and MS media. High proliferation rates were obtained in 'Alfred' and 'Goldcot', but 'Jinshirou', 'Yamagata-3', and 'Heiwa' gave low rates of shoot proliferation. For shoot length, 'Goldcot' and 'Alfred' gave the best elongation, but poor elongation occurred with 'Yamagata-3', 'Jinshirou', and 'Heiwa'. Rooting ability differed among the four cultivars tested, Heiwa and Mochi-anzu had the highest rooting rate at more than 50%, by comparison a rooting rate of less than 20% occurred in Alfred and Goldcot.

INTRODUCTION

Propagation of apricot (*Prunus armeniaca* L.) cultivars by cuttings has not been successful because they are difficult-to-root species (Snir, 1984). Therefore, they have been propagated by grafting to non-uniform seedling rootstocks resulting in uneven tree growth in the orchard. In vitro propagation is an appropriate method for the mass propagation of clonal rootstocks or own-rooted trees, and results in efficient and uniform orchard management. Recently many kinds of woody plants have been successfully propagated in vitro, but only a few papers have been published on the tissue culture of apricot cultivars (Marino et al., 1993; Snir, 1984). In this study, the differences in micropropagation of apricot cultivars was investigated.

MATERIALS AND METHODS

In late April, about 30-cm-long shoots of seven cultivars (Heiwa, Yamagata-3, Mochi-anzu, Shinshu-ohmi, Jinshirou, Alfred, and Goldcot), collected from mature trees growing under glass, were cut into 3-cm-long segments. These were sterilised by soaking in 70% ethanol for 2 min, immersing in 1% sodium hypochlorite solution for 25 min, and rinsing at least three times in sterile water. Using sterilised scissors they were finally cut into 1-cm-long segments each containing one axillary bud. These explants were used for the following experiments.

Screening Basal Medium to Culture Axillary Buds. Three media [MS, (Murashige and Skoog ,1962), B5 (Gamborg, 1966) and WP, (Lloyd and McCown, 1980)] were used for screening the basal media. Glass tubes (25 mm × 120 mm) with polypropylene caps were used as the culture vessels. Each contained 10 ml of agar-solidified medium. The explants of 'Heiwa' with one axillary bud were planted onto three types of media containing 2 μM BA, 3% sorbitol, and 0.7% agar at pH 5.8. Unless otherwise stated, the WP medium contained 2 μM BA, 3% sorbitol, and

0.7% agar. After 30 days of culture, the survival rate of explants and shoot length from axillary buds on each basal medium were recorded. In all experiments, cultures were kept at 26C with a 16-h photoperiod (40 μmol m^{-2} s^{-1}).

Cultivar Differences in Shoot Proliferation and Elongation. Shoots of seven cultivars as described above were proliferated on WP medium and subcultured on the same fresh medium every 3 weeks. Shoots from several subcultures were used for this experiment. In order to evaluate the differences between cultivars in shoot proliferation, shoots of each cultivar were cultured on WP medium. After 30 days of culture, the number of shoots longer than 2 mm and the maximum shoot length were recorded.

In vitro Rooting. The in vitro rooting ability of four apricot cultivars was tested. Shoots 1.5 cm long from subcultures were planted on WP medium containing 0 or 1 μM IBA, 3% sorbitol, and 0.7% agar. After 30 days of culture, the rooting rate, and number of roots per rooted shoot in each cultivar were recorded.

RESULTS AND DISCUSSION

Culture Establishment. The survival rate of explants on both WP and B5 media was 100%, while that on MS medium was 84%. The effectiveness of the tested media on shoot elongation from axillary buds was ranked as WP > MS > B5. When shoots from axillary buds were subcultured on the same fresh media, WP and B5 media gave high proliferation rates. However, MS medium gave a low proliferation rate (data not shown). Generally in woody plant species, media supplemented with a low concentration of nitrogen are used for culture establishment (Banno et al., 1989). The nitrogen concentration of WP and B5 media is less than that of full strength MS medium. Therefore, it is considered that nitrogen at high concentrations is not required for culture establishment. Judging from these results, WP medium is the most suitable for the culture establishment of apricots.

Table 1. Cultivar difference in shoot proliferation of apricot.

Cultivar[1]	Number of cultures	Number of shoots	Maximum shoot length (mm)
Mochi-anzu	20	2.6±0.2[2]	13.5±0.9
Heiwa	20	1.6±0.2	9.1±0.7
Yamagata-3	20	1.3±0.1	6.8±0.3
Alfred	20	11.0±0.9	16.9±1.3
Goldcot	20	6.5±0.9	17.3±1.6
Jinshirou	20	1.3±0.1	7.2±0.6
Shinshu-ohmi	20	2.5±0.3	11.6±0.6

[1] Each cultivar was cultured on WP medium containing 2 μM BA, 3% sorbitol, and 0.7% agar. Data were taken after 30 day-culture.
[2] Standard error.

Shoot Proliferation and Elongation. The data for shoot proliferation and elongation are shown in Table 1. The shoot proliferation rate and elongation differed among the seven cultivars tested. The shoot proliferation rate ranged from 1.3 to 11.0. 'Alfred' had the highest proliferation, while 'Yamagata-3', 'Heiwa', and 'Jinshirou' gave very low rates ranging from 1.3 to 1.6. Maximum shoot length ranged from 6.8 to 17.3 mm.

Maximum shoot length of 'Goldcot' and 'Alfred' was greater than that of the other five cultivars, while 'Yamagata-3', 'Jinshirou', and 'Heiwa' gave poor elongation.

In Vitro Rooting. The difference in rooting ability is shown in Table 2. 'Mochi-anzu' and 'Heiwa' gave a high rooting rate, over 50%. However, 'Alfred' and 'Goldcot' gave a low rooting rate of less than 20%. No rooting occurred in any cultivar on WP medium without IBA (data not shown). With reference to the number of roots, 'Mochi-anzu' formed three roots, 'Heiwa', 'Alfred', and 'Goldcot' about one root. In many woody species in the Rosaceae (Nemeth, 1986), rooting has depended on genotype. Mature shoots of other woody species are also variable in their response to rooting treatments (Arrilaga et al., 1991). Therefore, similar results might occur in this experiment.

Table 2. Cultivar difference in rooting ability in vitro of apricot.

Cultivar	Number of microcuttings	Rooting (%)	Roots/rooted microcuttings
Mochi-anzu[1]	15	80.0	3.0±0.4[2]
Heiwa	14	57.1	1.5±0.2
Alfred	17	17.6	1.0±0.0
Goldcot	20	25.0	1.2±0.2

[1] Microcuttings in each cultivar were planted on WP medium containing 1 μM IBA, 3% sorbitol, and 0.7% agar. Data were taken after 30 day-culture.
[2] Standard error.

From these results, it was found that there were cultivar differences in shoot proliferation and rooting ability. Further experiments are required to clarify optimal conditions for shoot proliferation and rooting.

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Micropropagation of Venus Fly-Trap (*Dionaea muscipula* Ellis)

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Experiments were carried out on a large-scale propagation of Venus fly-trap through leaf explant culture. When whole leaf explants excised from a donor plant grown in vitro were cultured on half-strength LS media with different concentrations of BA, adventitious shoots were mainly formed from the petiole of the explants, and few formed from the leaf blade of the explants. The medium supplemented with 2 mg liter^{-1} BA was the most effective for organogenesis. The shoots grew into plantlets which were transferred to the medium with 0.1 mg liter^{-1} NAA. The differentiation and subsequent growth of the rhizomes was better in the medium solidified with Gelrite than in that with agar. The adventitious shoots formed in a row on the rhizome in the medium. These shoots were excised from the rhizome and were transferred to the medium for further proliferation. By these procedures, a large number of regenerated plantlets were obtained, and the plants after acclimatization have grown well in pots.

INTRODUCTION

Venus fly-trap (*Dionaea muscipula* Ellis) is an interesting insectivorous plant which belongs to the family Droseracea. The plant is native to the eastern coast of the United States, and wild species have been reported to be threatened with extinction (Ayensu, 1981). The plant can be used indoors as a potted ornamental plant, and is sometimes used as teaching material for children. The propagation of the plant is usually from seed, however, it is not easy. There are several reports on micropropagation of Venus fly-trap using shoot tips (Hutchinson, 1984), leaves

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Micropropagation of Venus Fly-Trap (*Dionaea muscipula* Ellis)

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Experiments were carried out on a large-scale propagation of Venus fly-trap through leaf explant culture. When whole leaf explants excised from a donor plant grown in vitro were cultured on half-strength LS media with different concentrations of BA, adventitious shoots were mainly formed from the petiole of the explants, and few formed from the leaf blade of the explants. The medium supplemented with 2 mg liter^{-1} BA was the most effective for organogenesis. The shoots grew into plantlets which were transferred to the medium with 0.1 mg liter^{-1} NAA. The differentiation and subsequent growth of the rhizomes was better in the medium solidified with Gelrite than in that with agar. The adventitious shoots formed in a row on the rhizome in the medium. These shoots were excised from the rhizome and were transferred to the medium for further proliferation. By these procedures, a large number of regenerated plantlets were obtained, and the plants after acclimatization have grown well in pots.

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(Parliman, 1982; Minocha, 1985; Kukulczanka, 1989), and rhizomes (Parliman,1982) as explants. These reports demonstrate that the use of cytokinin with auxin promotes in vitro proliferation of the plant through the formation of adventitious buds or lateral buds. The present paper describes the effect of benzyladenine (BA) on the formation of adventitious shoots from leaf petiole explants and the formation of adventitious shoots from the rhizome of the plant regenerated in vitro.

MATERIALS AND METHODS

Petiole segments (1.5 cm in length) were excised from a potted Venus fly-trap obtained from a market. After sterilization with 3% hydrogen peroxide, the segments were dipped in 1% citric acid solution for 5 min and placed on a half-strength Linsmaier Skoog (LS) medium which was solidified with 0.7% agar and supplemented with 1 mg liter^{-1} BA and 0.1 mg NAA liter^{-1}. The pH of the medium was adjusted to 5.8 before autoclaving. About 45 days after the beginning of culture, adventitious shoots were formed on the petiole explants. When the shoots attained about 1 cm in height, these were transferred to the medium for formation of the rhizome. The regenerated plantlets grew in the culture vessel into plants with many leaves through the induction of axillary buds. From the plants grown in vitro, leaf explants (about 1 cm in length) including petiole and leaf blade were excised, and cultured on a half-strength LS medium supplemented with BA of various concentrations. Plantlets formed from the petiole were separated from the explants and subcultured for the formation of rhizomes, on a medium which was supplemented with 0.1 mg 1^{-1} NAA and solidified with 0.2% Gelrite or 0.7% agar. The regenerated plants with fully developed rhizomes were transferred to pots (9-cm diameter) containing a vermiculite or sphagnum medium for acclimatization.

RESULTS AND DISCUSSION

When whole leaf explants excised from a donor plant grown in vitro were cultured on a half-strength LS medium, adventitious shoots were mainly formed from the petiole of the explant after 40 to 50 days culture, while little formed from the leaf blade of the explant. Figure 1 shows the formation of adventitious shoots from the petiole. Since formation of callus could not be observed on the cultures, the shoots were considered to be directly formed from the surface tissue of the petiole. Afterwards the explants were covered with the proliferated shoots. As shown in Table 1, 2 mg litre^{-1} BA was the most effective for the formation of adventitious shoots. In this case, the mean value of the number of shoots obtained per explant was six after 4 months of culture, and then further increases in the number of shoots were observed. Adventitious shoots were not formed from some explants, because their tissue showed a brown colour during culture and withered. The promotive effect of cytokinin on the formation of adventitious shoots from the petiole has been reported with various plants, e.g. *Smilax*

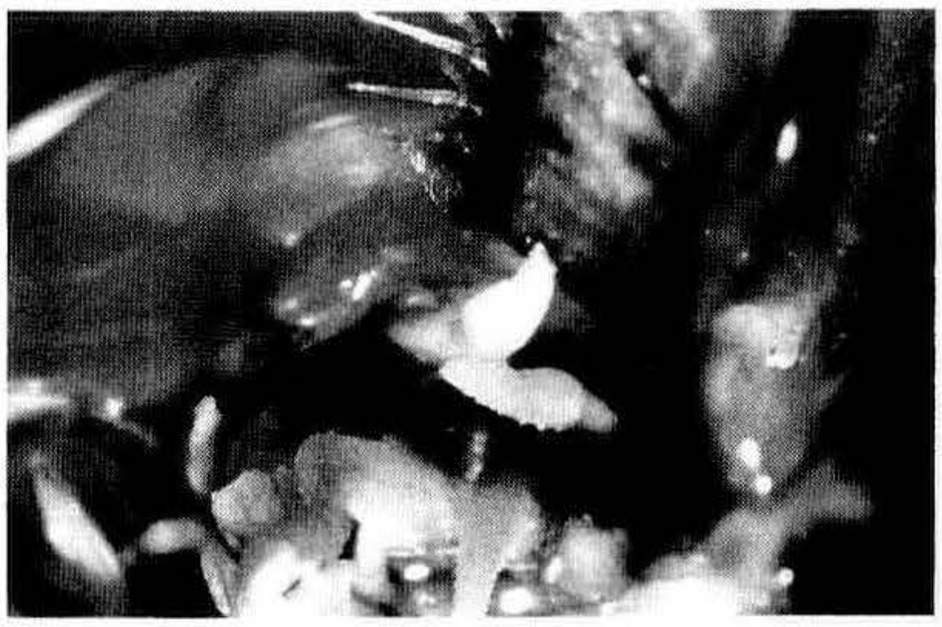

Figure 1. Formation of adventitious shoots from the petiole of leaf explant.

(Yamamoto, 1992) and *Vitis* (Cheng, 1989). The petiole can be considered to have a high regeneration potential because it has relatively young vascular tissue.

Table 1. Effect of BA on formation of adventitious shoots from leaf explant.

BA (*mg liter*$^{-1}$)	Explants with *shoots (%)*	Plantlets per explant
0	29[X]	2.7
1	60	4.5
2	68	6.0
3	42	3.4
4	44	2.1
5	50	2.7

[X] Values were scored after 4 months of culture. Basal medium was ½ LS with 0.2% agar.

The adventitious shoots in the culture vessel grew into plantlets having three to four leaves. The plantlets were separated from the explants, and cultured on the medium for rhizome formation. Table 2 shows the effects of hormones on the rate of rhizome formation after 17 days of culture. Each value is expressed as a percentage of the plantlets with rhizome. In the medium without NAA, the rate of rhizome formation decreased with the increase in BA concentrations in the shoot formation medium. This indicates the preventative effect of BA on rhizome formation. However, the effect of BA was suppressed by the addition of 0.1 mg liter^{-1} NAA to the medium (Table 2).

Table 2. Effect of hormones on formation of rhizome from the shoots.

Shoot formation medium (BA mg liter^{-1})	Support	Rhizome formation media 0	0.1(NAA mg liter^{-1})
0	G[X]	73[Y]	73
1	G	45	64
2	A	18	64
3	G	36	73

[X] G= Gelrite, A = Agar
[Y] Values (%) were scored after 17 days of culture in the rhizome formation media.

The differentiation and subsequent growth of the rhizome was better in the medium solidified with Gelrite than in that solidified with agar. When the rhizome developed fully, adventitious shoots were formed in a row on the rhizome in the medium as shown in Figure 2. More than 10 shoots could be excised from one rhizome, and these were subcultured for further proliferation. We can consider that

Figure 2. Formation of adventitious shoots on rhizome in the medium with 0.1 mg liter^{-1} NAA and 0.2% Gelrite.

Figure 3. The growth of regenerated Venus fly trap after acclimatization.

there is a two-step process in the propagation of Venus fly-trap in the present culture system. At first, the plantlets can be obtained through the formation of adventitious shoots from the petiole of explants. Next, adventitious shoots are formed from a fully developed rhizome of the plantlet. The former is promoted by use of the half-strength LS medium supplemented with 2 mg liter^{-1} BA, and the latter by use of the medium solidified with Gelrite and supplemented with 0.1 mg liter^{-1} NAA. Either media, vermiculite, or peat moss, are suitable for acclimatization. Figure 3 shows an example of the growth of a regenerated plant. At Shiba orchid nursery, a large number of Venus fly-traps are being produced by this method of micropropagation.

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Diurnal Changes of the Net Photosynthetic Rate and Evapotranspiration Rate of Plug Sheets in the Glasshouse

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INTRODUCTION

On-line estimation of evapotranspiration rates (F_w) and net photosynthetic rates (F_c) in situ of plug sheets is important for optimum control of the glasshouse environment and the soil mix moisture for growth of the plugs in a relatively small volume of soil mix.

MATERIALS AND METHODS

Absolute humidities (q_1 and q_2) and CO_2 concentrations (C_1 and C_2) were continuously measured at two heights (z_1 and z_2) above the plug sheets with a hygrometer and an infrared CO_2 analyser, and the weight of a plug sheet (plugs, soil mix, and tray) was continuously measured with an electronic balance. At time t, F_w was estimated based on the difference between the weights of the plug sheet at time $t-\Delta t/2$ and $t+\Delta t/2$. The diffusion coefficient, K; which is common to F_w and F_c, was then calculated using Equation 1. Finally, F_c was estimated using Equation 2. Using this on-line estimation method, F_w and F_c were estimated for the plug sheets (Table 1) under the environmental conditions shown in Table 2. The z_1 and Z_2 were, respectively, 20 and 50 mm above the plugs in the present experiment.

Table 1. Description of the plug sheets.

Plant material	Lettuce
Days after sowing	32 days
Leaf area index	6.6
Number of cells	200 cells/sheet
Planting density	1420 plants m^{-2}

Table 2. Description of environmental conditions in the greenhouse.

	Day	Night
Air temperature (C)	20 - 25	10 - 15
Relative humidity (%)	40 - 50	60 - 80
CO_2 conc. (μmol mol^{-1})	380 - 400	500 - 550
Wind speed (m s^{-1})	0.1 - 0.5	0.1

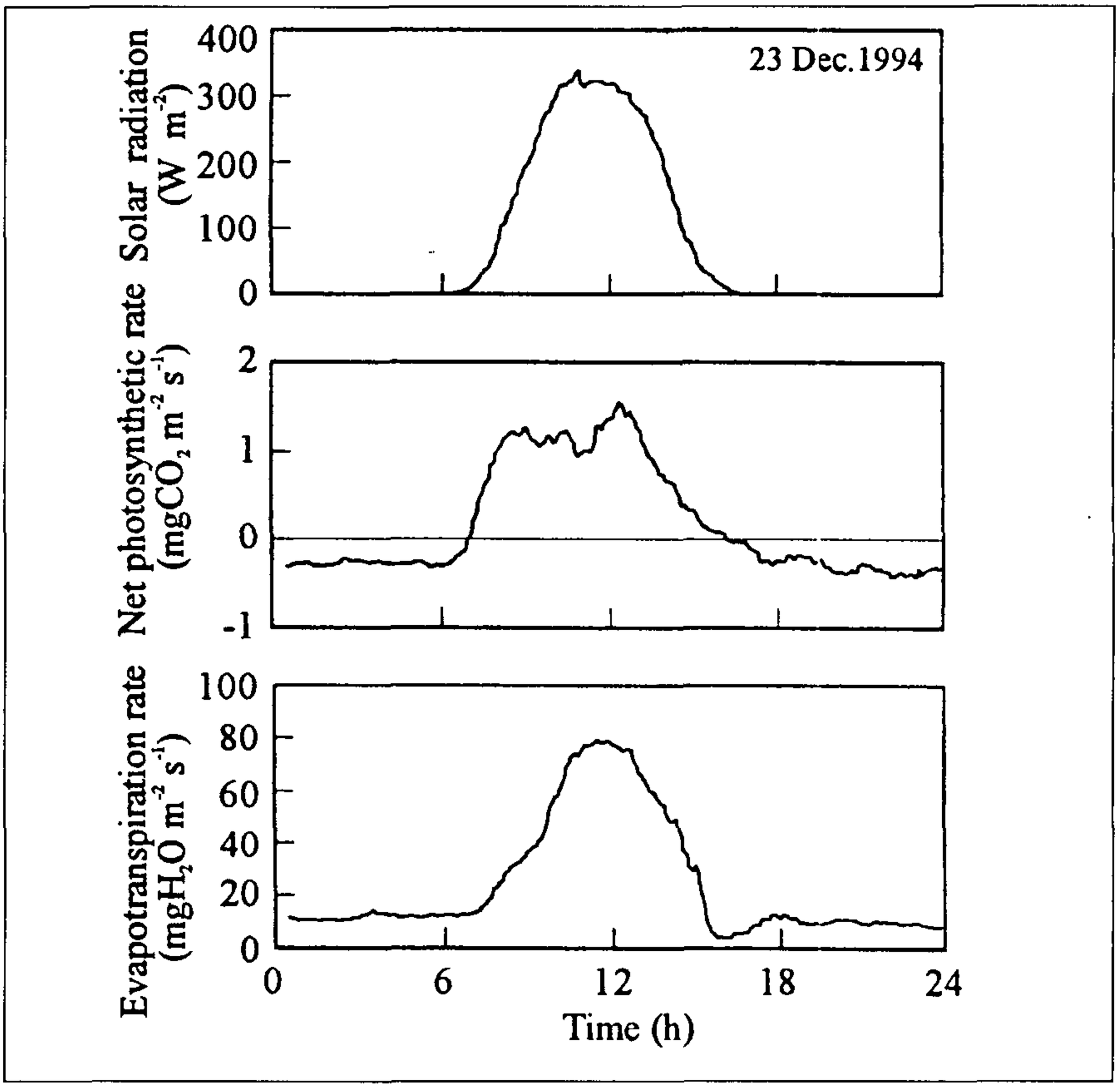

Figure 1. Time courses of solar radiation and net photosynthetic rate and evapotranspiration rate of plug sheets.

RESULTS AND DISCUSSION

Figure 1 shows changes in solar radiation, F_w and F_c for lettuce plug sheets during a measurement day. Figure 2 shows the effects of solar radiation on F_w and F_c of the plug sheets. The results indicate that F_w and F_c are functions of environmental factors including solar radiation, the growth parameters of the plugs, and the physical properties of the soil mix.

The F_w and F_c of plug sheets in the greenhouse were successfully estimated in situ based on the continuous measurements of absolute humidities, CO_2 concentrations, and weights of plug sheets. The application of this method of environmental control of the glasshouse and irrigation scheduling is underway.

Equation 1. $$F_w = K \frac{q_2 - q_1}{z_2 - z_1} \quad (1)$$

Equation 2. $$F_c = -K \frac{c_2 - c_1}{z_2 - z_1} \quad (2)$$

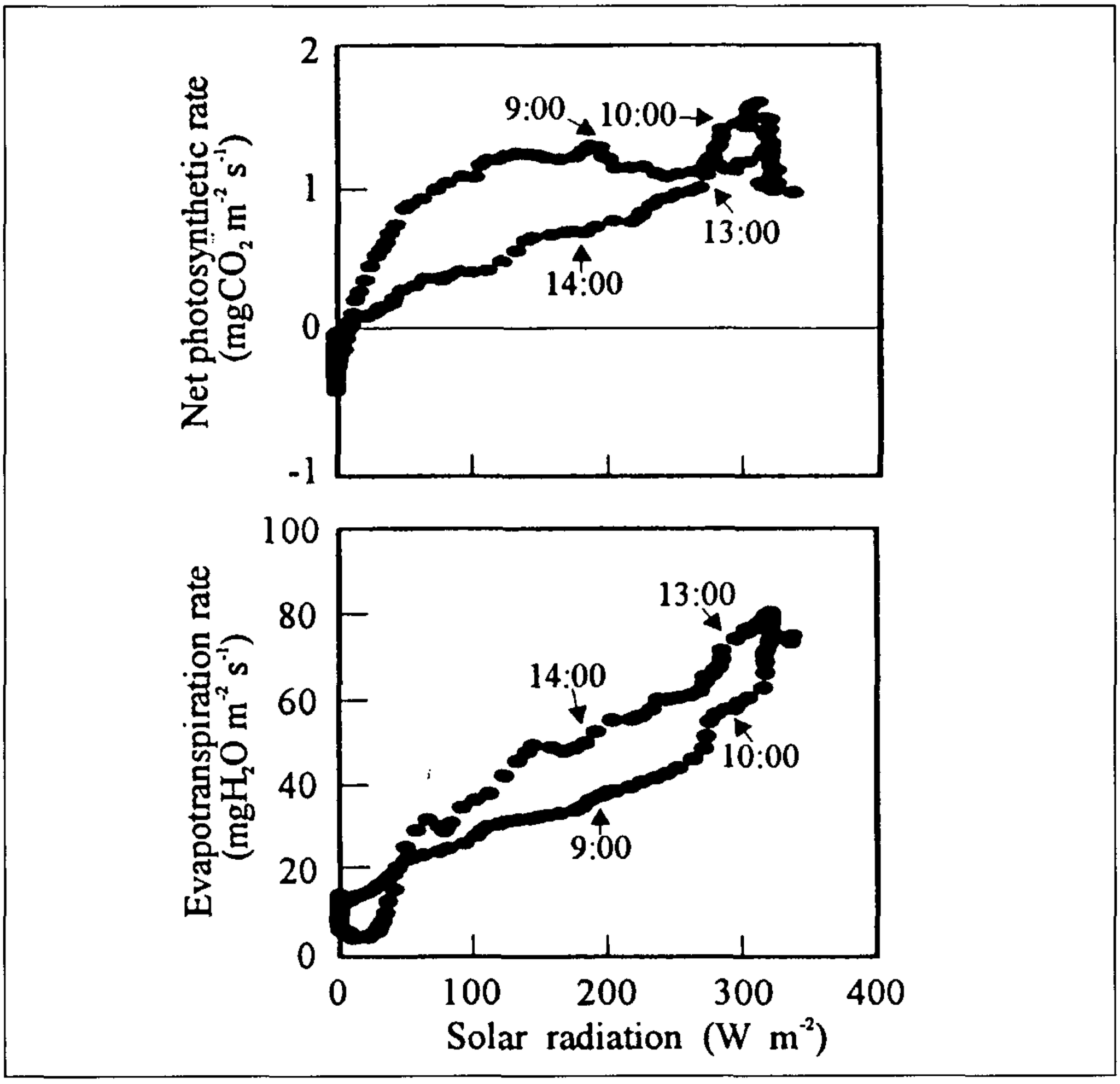

Figure 2. Effects of solar radiation on net photosynthetic rate and evapotranspiration rate of plug sheets.

The Production of Ground-Cover Plants

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Since olden times, in Japan, mosses and underplants have been used for gardening. More recently, however, so-called groundcover plants native to Japan or foreign countries have begun to be produced and popularized widely. Our company which has existed for 20 years began the mass propagation of groundcover plants 10 years ago. At present, we have about 500 taxa, and are producing 8 million potted plants per year. The propagation methods of some representative plants in our nursery are shown as follows:

1) Stem cuttings

Climbing plants: *Hedera helix*, *Gelsemium sempervirens*
Woody shrubs: *Hypericum*, *Cotoneaster salicifolius*
Perennial herbs: *Phlox subulata*

2) Leaf petiole cuttings

Perennial herbs: *Mesembryanthemum spectabilis*, *Ajuga reptans*

3) Root cuttings

Woody shrubs:*Ardisia japonica*, *Hypericum calycinum*, *Pachysandra terminalis*
Perennial herbs: *Hosta* ssp., *Phlox subulata*
Bamboo grass: *Shibataea kumasasa*, *Sasa veitchii*

4) Division

Woody shrubs: *Pachysandra terminalis*
Perennial herbs: *Calanthe* ssp., *Hemerocallis* ssp.

5) SEEDLINGS

Climbing plants: *Parthenocissus tricuspidata*
Lonicera japonica, *Akebia quinata*
Perennial herbs: *Hemerocallis* ssp., *Farfugium japonicum*, *Agapanthus africanus*

Container Culture for Oak-Tree Production from Seed

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In Japan, the container production of green plants started around 1965. At that time, the cultivation techniques were not fully understood and for many nurseries it was a case of trial and error when it came to problems with soil condition, plant height, container size, production facilities, etc. Also, no one knew exactly whether or not the market would increase. In 1974, I began the container production of green plants, especially oak trees. I shall now trace my efforts in oak-tree container production.

SEED PROPAGATION OF OAK TREES

Seeds are collected in the nearby forest. Natural hybridisation is frequent in oaks, so, we must remember which trees produce seeds plentifully and, what is more important, true to type. Variation of plant habit is frequently observed from plant to plant.

The seeds, once collected, are stored as soon as possible under moist conditions for the winter. In January, the seeds are sown in seed boxes. After the new seedlings emerge (about April), they are planted in vinyl pots (10.5 cm in diameter). The soil is a mixture of clay (35%), peat moss (35%), perlite (10%), vermiculite (10%), and Kanuma-do (a local Japanese volcanic soil, 10%). After 15 to 20 days, when the new roots are reaching the bottom, fertilizer is applied. Three months later, an additional application of fertilizer is made. By autumn, the biggest plants are saleable. If 1-m-high plants are required, they are replanted into 15-cm pots and grown on until the next spring. Elite plants of high quality have close nodes, a main stem with several side branches, and healthy leaves free from disease and pest infection. When taller plants are required, they are replanted and grown on for one more year until 1.5 m in height. To produce large plants, adequate spacing in the nursery bed is most important. Irrigation is done by hand, not by automatic control, with a careful watch kept on the condition of the plants.

The overriding principle in the production of high quality plants is the maintenance of good management practices, carried out at the correct times with proper care and attention.

In these days, the demand for oak trees is gradually increasing for landscaping in city areas. So, container-grown oak trees which establish readily when planted, are much sought after.

Changes in the Root Systems of Trees in Container Production

Shouzou Watanabe
Shi-Kashi-Tsubaki-Ryokuju Ltd., Kamayama-76, Ohi, Minami-chita-machi, Chita-gun, Aichi

In general, the container production of trees often results in root circling. Complex changes in root systems occur under conditions of high temperature and high humidity in Japan. Root circling is caused by the roots having few lateral and fibrous roots. This results in an inhibitory effect on stem enlargement, bud formation, and leaf expansion. From personal observation I believe that the root circling within the container is caused by two apparently contradictory factors, i.e., drainage and water holding capacity of the soil in the container. Therefore, it is very important to increase the number of lateral and fibrous roots by adequate watering of the soil in the container. By following this procedure, it became possible to promote the rapid growth of trees as shown in the pictures.

Horticultural Production in New Zealand

Peter Waugh
Carann Horticulture Supplies, P.O.Box 34, Matangi, New Zealand

Geographically, New Zealand is widely spread, from 33° South to 48° South. Specific crop-related activities are concentrated in close proximity to either population concentrations or favourable growing microclimates. Most forestry propagation occurs within the vicinity of established forests. These are throughout the South Island but most especially in the north, south, and west coastal regions and in the North Island on the central plateau.

Vegetable production and supporting propagation activities are centred in South Auckland (Metropolitan Auckland has a population 1 to 1.5 million), south of Palmerston North to service the capital Wellington, and on deep volcanic pumice soils on the west side of the central North Island, particularly around Ohakune. South Island production occurs north and south of Christchurch, and in the region of Nelson and Blenheim in the northern South Island.

Ornamental production is widespread with concentrations in the Auckland, Hamilton, Tauranga, Hawkes Bay, and Taranaki regions of the North Island, and the Christchurch locality in the South Island, these being the areas of greatest population density.

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Growing and Flowering of in vitro Propagated *Lilium japonicum* Thunb.

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Lilium japonicum **Thunb., sasa-yuri, proliferated by scale culture and enlarged in vitro, were investigated with regard to growth and flowering in the field. When the annual growth of bulbs in the field was observed, leaf emergence of the first year bulbs was seen to be low, but the second year bulbs showed a high leaf emergence rate regardless of bulb weight. Bulbs weighing 1.5 g and more at transplanting had flowers in the second year. A bulb's weight at harvest time was clearly related to stem leaf emergence and length of shoot. The lilies with long shoots and many leaves had larger bulbs. The flowering rate was higher on the larger bulbs, and 80% of the bulbs, which weighed more than 6 g, had flowers. It is, therefore, possible to produce flowers in the field during the second year of cultivation, provided the bulbs are grown up to 6 g or more during the first year.**

INTRODUCTION

Lilium japonicum occurs naturally in various parts of Japan, it has a nice fragrance and light pink flowers. So, it is one of the lilies which Japanese people have loved very much for a long time. However, nowadays its natural habitats are decreasing due to environmental pollution and plant numbers are decreasing due to excessive gathering. Commercial cultivation is not undertaken as it is very slow to grow and difficult to propagate. *Lilium japonicum* seen for sale are mostly removed from the wild. Therefore, propagation and cultivation techniques need to be established in order to protect and increase the populations of the plant in the wild.

In recent years, micropropagation methods for *L. japonicum* have been established (Fukui et al., 1989; Tanaka et al., 1991; Kawarabayashi, 1993). Also, Niimi (1995) and Mizuguchi and Ohkawa (1995) have reported on the growth of micropropagated bulbs of *L. japonicum* in the field. However, the detailed flowering characteristics of the bulbs are not yet clear. So in this research we investigated the growth and flowering of *L. japonicum*, micropropagated and enlarged in vitro, in the field.

MATERIALS AND METHODS

The original *L. japonicum* bulbs were gathered in Miyama, Gifu Pref., and were cultured in accordance with the methods of Fukui et al. (1989) and Nagase et al. (1990) by shoot tip culture. Propagation of the bulblet was accomplished by scale culture on MS medium supplemented with 3% sucrose and 0.7% agar. Formed

Table 1. Annual growing of cultured bulbs.

First Year					Second year						
		Weight of the bulbs at digging (g)							Weight of the bulbs at digging (g)		
Weight of bulbs at transplanting (g)	Rate of leaf emergence (%)	Leaf emerging bulbs	Leaf non-emerging bulbs	Ave.	Rate of leaf emergence (%)	Length of shoot (mm)	Number of leaf	Rate of flowering (%)	Stl[X]	Sl[W]	Ave.
2 - 2.5	14.3 (2.8)[Z]	4.53	2.12	2.6	100 (5.5)	220.0	6.4	11.1 (11.1)[Y]	4.87	2.13	4.5
1.5 - 2	8.6 (2.8)	4.45	1.82	2.02	97.1 (2.8)	205.0	6.1	5.5 (5.5)	4.64	2.96	4.5
1 - 1.5	2.9 (0)	3.23	1.23	1.29	88.9 (25)	168.9	5.3	0	3.53	2.09	3.2
0.5 - 1	22.9 (20)	1.01	0.81	0.86	91.7 (66.7)	183.2	5.7	0	3.17	2.10	2.3

Z Figure in parentheses are rate of scale leaf emergence
Y Figure in parentheses are rate of having flower bud
X Stem leaf : stem leaf emergence
W Scale leaf : scale leaf emergence

bulblets were placed on MS medium supplemented with 10% sucrose, 0.7% agar, and NAA (α-naphthaleneacetic acid) 10^{-7} M, and subcultured every 2 months under dark conditions for 10 months. After culturing, the bulbs were stored at 5 C for 8 weeks. Following cold treatment, all bulbs were cultivated in a vinyl glasshouse with 70% shading. Liquid fertilizer (10N-10P-10K) was applied once or twice every 2 weeks and water was applied by sprinkler once or twice per week.

Experiment 1. Annual Growth Rates. Bulbs were selected by weight from 0.5 g to 2.5 g and transplanted on 25 March 1993. After confirming that the above-ground parts of the plants had withered, bulbs were dug and weighed on 24 Nov. 1993. The bulbs were planted again on 8 Dec. 1993 and length of shoot, number of leaves, number of flowers, and flowering time were investigated the next spring. Then, bulbs were dug and weighed on 22 Nov. 1994.

Experiment 2. Effect of Bulb Weight on Flowering and Growth. After low temperature treatment, the bulbs were grown in the field for one season from March to November 1993, and then were selected by weight from 0.5 g to 9 g and transplanted on 8 Dec. 1993. The length of shoot, number of leaves, number of flowers, and flowering time were investigated and bulbs were dug and weighed on 29 November 1994.

RESULTS

Experiment 1: Annual Growth Rates. Table 1 shows the annual growth rates achieved. Leaf emergence of the first year's bulbs was low, but the second year's bulbs had high leaf emergence rates of about 90%, regardless of the weight of the bulbs. Moreover, it was seen that a lot of scale leaves appeared on the smaller bulbs. The leaves of the bulbs weighing between 0.5 and 1 g at the end of the second year were 66.7% scale leaves.

Bulb weight at harvest time is related to leaf emergence. The lilies with plenty of leaves had larger bulbs, but those with little leaf growth did not produce large bulbs in the first year. The lilies which produced stem leaves had much larger bulbs at the end of the second year compared with those producing only scale leaves. In the second year of cultivation, bulbs weighing less than 1.5 g at transplanting did not flower. The flowering rate on 2.0 to 2.5 g bulbs was 11.1% (Table 1).

Experiment 2: Effect of Bulb Weight on Flowering and Growth. Table 2 shows the effect of bulb weight on flowering and growth in the second year. The leaf emergence rate was about 100% on all bulbs, although the rate of scale leaves was 62.5% on 0.5- to 1-g bulbs. The shoot length was higher in proportion to the bulb weight at transplanting, reaching 300 mm on bulbs weighing 5 g and more. Also, the number of leaves increased proportionately. Shoot length is shown in Figure 1. Leaves had emerged by 10 April and extended rapidly by 20 April, regardless of the weight of the bulbs. However, the degree of extension was different in relation to bulb weight, being larger on large bulbs. Leaf extension was not observed after the beginning of May. The flowering rate was higher on the larger bulbs, and 80% of the bulbs weighing more than 6 g had flowers (Table 2). From this it was clear that bulb weight and flowering are related. Each flower was single white-pink in colour, no mutation occurred (Fig. 2). All bulbs began flowering within a few days of each other.

Table 2. Effect of bulbs weight on flowering and growing for the second year.

Weight of bulbs at transplanting (g)	Rate of leaf emergence (%)	Length of shoot (mm)	Number of leaf	Rate of flowering (%)	Flowering day (1994)	Weight of bulbs at digging(g)
9 - 10	100	445.0	12.0	100 (100)[Y]	5/30	8.2
8 - 9	100	392.0	10.8	80 (80)	5/30	9.6
7 - 8	100	357.8	9.6	55.5 (77.8)	5/31	5.4
6 - 7	100	397.2	9.1	81.3 (81.3)	5/31	7.6
5 - 6	100	320.2	9.0	33.3 (47.6)	5/31	5.6
4 - 5	100	287.0	7.7	20.8 (20.8)	6/1	6.7
3 - 4	95.2	253.5	7.5	0	-	5.8
3 - 2.5	100 (5.2)[Z]	220.8	7.1	0	-	5.7
2.5 - 2	91.7	181.4	5.8	0	-	3.9
2 - 1.5	100	162.1	5.4	0	-	3.6
1.5 - 1	100 (12.5)	144.5	5.1	0	-	3.7
1 - 0.5	100 (62.5)	137.2	4.9	0	-	2.3

[Z] Figure in parentheses are rate of scale leaf emergence
[Y] Figure in parentheses are rate of having flower bud.

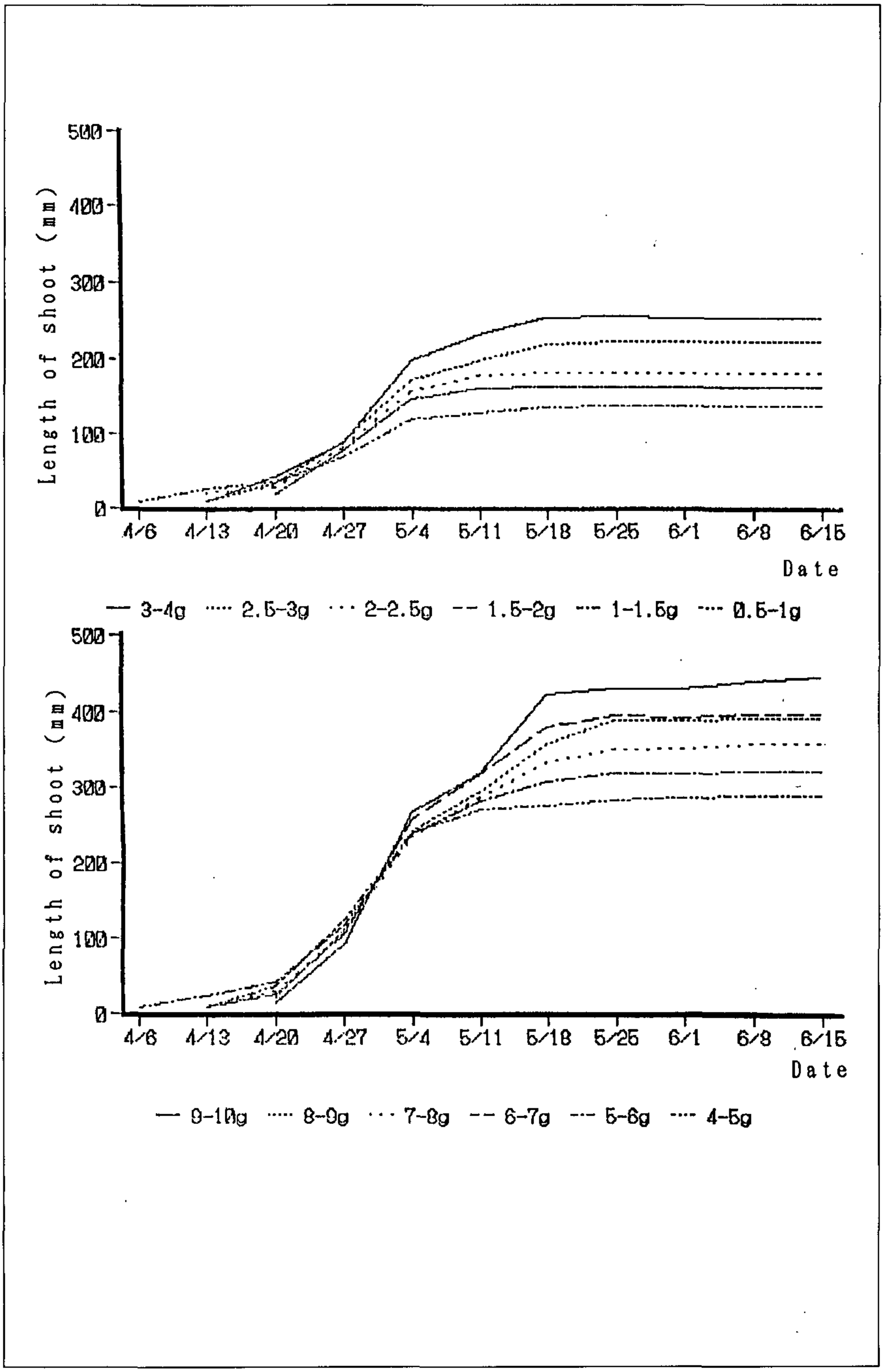

Figure 1. Shoot length of bulbs after transplanting in soil.

Bulb weight at harvest did not increase much on bulbs weighing more than 5 g, at transplanting, but a threefold increase occurred in bulbs weighing 0.5 to 1 g. Figure 3 shows the relation between the weight of bulbs at harvesting, the length of shoot, and the presence of the flower bud. The weight of bulbs at harvesting correlated with the length of shoot, regardless of the weight of the bulb at transplanting. It was clear that bulbs were larger in proportion to the length of the shoot. On the other hand, the bulbs which had no flower bud increased in weight to 8 g, but the bulbs which had a flower bud only increased to 4 g. So it is seen that the presence of a flower bud had an influence on the enlargement of the bulbs. A lot of bulbs above 5 g had a flower bud. Therefore, it was thought that flower bud formation caused a decrease in the weight of the bulbs above 5 g.

DISCUSSION

Takayama (1982) reports that a high sucrose concentration in the medium brings about deep dormancy of *L. auratum* bulbs. Bulblets cultured on a medium which contains 90 g liter^{-1} sucrose require low temperature treatment for a longer period than bulblets cultured on medium which contains 30 g liter^{-1} sucrose. Niimi (1995) reports that bulblets of *L. japonicum* cultured on medium which contains 5% sucrose require low temperature treatment at 4C for 12 weeks, and that short-term treatment produces less leaves. In the current experiment, the low rate of leaf emergence might be caused by insufficient broken dormancy, due to the 8-week period of low temperature treatment being too short.

The enlargement of the bulb in the field differs with the form of leaf which emerges, the lilies which produced stem leaves had the biggest bulbs in the field. Mizuguchi et al. (1995) also reported that bulbs producing stem leaves grew larger than those producing only scale leaves. It has also been reported that the type of leaf produced is affected by the size of the bulb and the light condition under culture in vitro and that bulblets which grew up to 400 mg and more under dark conditions produced stem leaves (Niimi, 1995). From this experiment it can be seen that the length of shoot and presence of flower buds affected the enlargement of the bulbs. It would appear also that the length of shoot is closely related to the number of leaves. The rate at which the shoots lengthened increased as the number of leaves and the consequent rate of photosynthesis increased. Also, it was thought that flower bud growth stimulated an increased consumption of carbohydrates.

As for *L. japonicum*, it takes 4 to 5 years to flower from seed (Shimizu, 1987). A 45-mg bulblet of *L. japonicum* produced by scale culture had a flower after 3 years and 3 months (Mizuguchi et al., 1995). In this experiment, *L. japonicum* flowered after 1 year and 3 months in comparison with the 3 to 4 years required when cultivated from seed. It would appear that the bulbs are enlarged enough during the 10 months of subculture and this equates to 3 years cultivation in the field. Takayama et al., (1990) also reported that the flowering of in vitro-propagated *L. auratum* bulbs is about 2 to 3 years faster than conventional methods of growing from seed. Micropropagation through tissue culture may be an effective propagation method for Oriental lilies that grow slowly and take a long time to germinate from seed. It is thought that *L. japonicum* differentiates flower buds in late autumn during dormancy (Ohkawa, 1989). We would like to try flower bud differentiation in vitro in order to shorten the cultivation period required to flowering.

Figure 2. *Lilium japonicum* flowering in the second spring after transplanting.

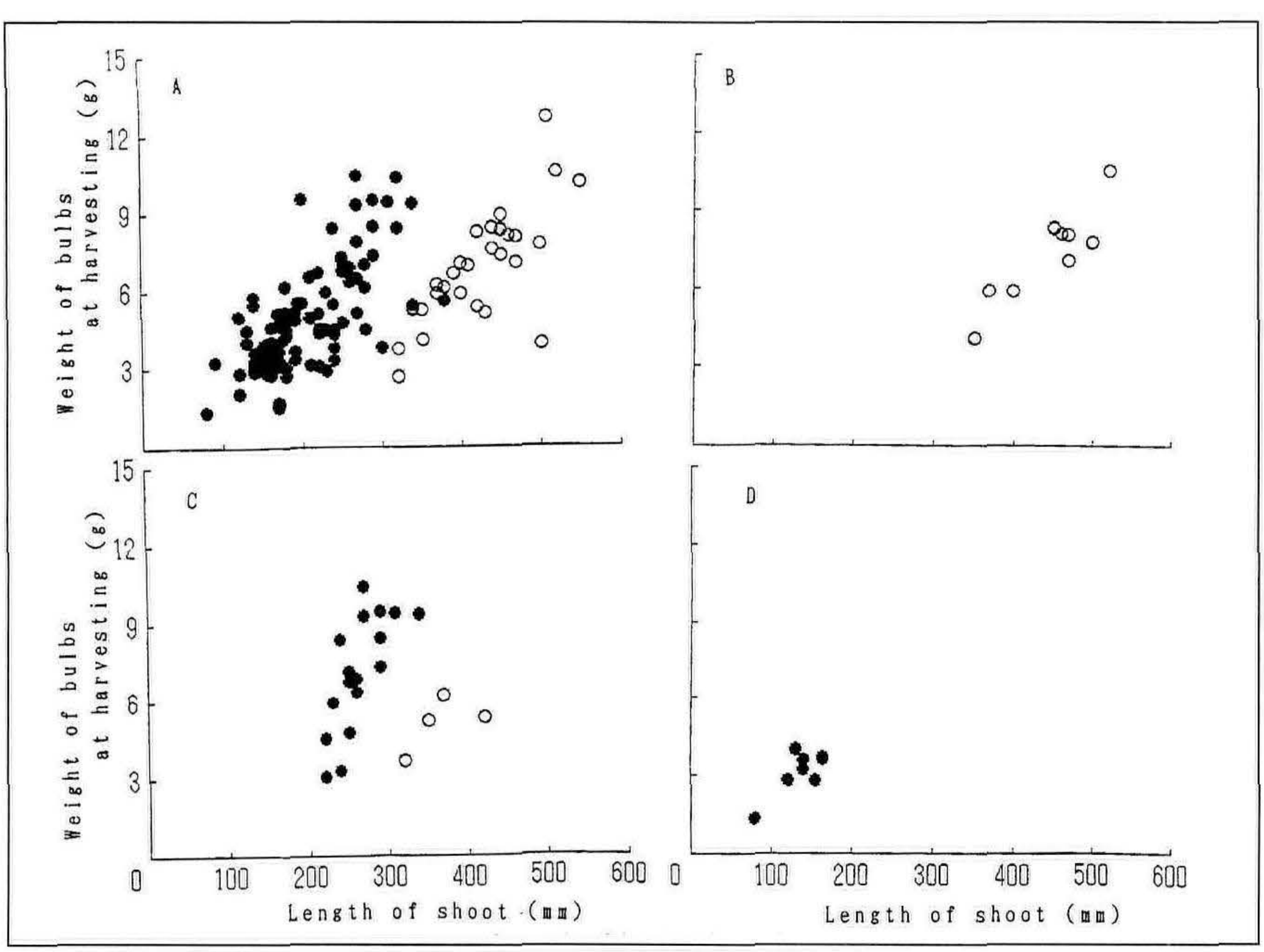

Figure 3. Effect of shoot length and the presence of the flower bud on bulb weight (○, having flower bud bulbs; •, non flower bud bulbs). The weight of bulbs at transplanting were as follows: A, 0.5-10 g; B, 6-7 g; C, 4-5 g; and D, 0.5-1 g.

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Productivity of Micropropagated Plants and Rooted Cutting Grafts of Rose cv. Madame Violet in Rockwool Culture

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Rose cv. Madame Violet was propagated by shoot tip culture, cutting graft, cutting, and softwood grafting, and was cultured on rockwool for 2 years. The productivity of micropropagated plants, rooted cutting-grafts, rooted cuttings, and softwood-grafted nursery plants was 9.7, 7.2, 7.6, and 4.9 flowers/plant-year, respectively, in the first year, and was 12.0, 11.1, 11.6, and 7.9 flowers/plant-year in the second year. The flowers were harvested from rooted cutting grafts and softwood grafted nursery plants every 50 to 60 days. Micropropagated plants and rooted cuttings had harvestable flowers continually. The formation of many leader shoots by rejuvenation produced the high rate and continual productivity of micropropagated plants. The length of stems, 75 to 80 cm, was the same in micropropagated plants, rooted cutting grafts, and rooted cuttings. The flowers cut from softwood grafted nursery plants were significantly shorter than those of the other plants and were below 70 cm. Of the softwood grafted nursery plants 31% were infected with crown gall.

INTRODUCTION

In Japan, there are many growers of roses for cut flowers and also the use of rockwool culture has increased. Rockwool culture has been used to root cuttings for nursery plants, and there has recently been a marked increase in the use of cutting grafts. In Holland, micropropagated plants are also used, and large-scale propagation in vitro has been done by rose nurseries.

Several researchers (Curir et al., 1986; Davies, 1980; Valles, 1987) have studied the micropropagation of roses, however, almost all of these reports are of in vitro studies. In this paper, the productivity of micropropagated plants was tested for 2 years in rockwool culture, and the productivity of rooted cutting grafts, rooted cuttings, and softwood-grafted nursery plants was also compared.

MATERIALS AND METHODS

'Madame Violet' was propagated by four methods; micropropagation, cutting graft, cutting, and softwood grafting. Micropropagated plants were initiated from shoot tips and were proliferated by subculture for 1 year on Murashige and Skoog (MS) medium plus 10^{-5} M BAP, 10^{-7} M GA_3, 3% sucrose, and 0.2% Gelrite (Fig. 1).

After root induction treatment for 6 weeks, the plants were potted in rockwool cubes (5 cm) by granular rockwool on 2 July 1991. Planting of cutting grafts, cuttings, and grafts took place on the same day. Rooted micropropagated plants, cutting grafts, and softwood grafts were kept under high humidity by mist spraying for 1 month and were then placed in a glasshouse. Micropropagated plants [(MP) 16 plants], rooted cutting-grafts [(CG) 18 plants], rooted cuttings [(RC) 17 plants],

and softwood-grafted nursery plants [(SG) 22 plants] were set on a rockwool bed on 2 September and these plants were checked every day.

After setting on the rockwool bed, the sprouted shoots under 8 mm diameter at the shoot base were turned down at the base, and the other shoots were cut back to a length of 25 cm. Flower shoots were cut off leaving two leaves with five leaflets. In July 1992, all shoots were bent at the base of the plants, and during August and September sprouting shoots were also turned down at the base.

Figure 1. Micropropagating plants on MS medium plus 10^{-5} BAP 10^{-7} GA_3, 3% sucrose, and 0.2% Gelrite

RESULTS AND DISCUSSION

The timing of cut flower production for 2 years is shown in Fig. 2. All nursery plants MP, CG, RC, and SC had four peaks of flower production in 1992 and five peaks in 1992-93. The first peak in 1992 was in early January about 120 days after setting on the rockwool bed. The period between peaks was about 60 days from November to March and about 50 days from April to June. Many leader shoots formed in MP, and RC also had leader shoots (Fig. 3). These shoots flowered between peak flowering times, therefore MP and RC had no clear break in harvesting. The productivity of MP, CG, RC, and SG was 9.7, 7.2, 7.6, and 4.9 flowers per plant-year, respectively, in 1992 and was 12.0, 11.1, 11.6, and 7.9 flowers per plant-year, respectively, in 1992-93.

The high productivity of MP seems to be related to rejuvenation because adventitious shoot initiation and much branching are one of the juvenile characteristics. Franclet et al. (1987) suggested that repetitive subculturing improved rejuvenation and the principal rejuvenation factor was the exposure of the explant

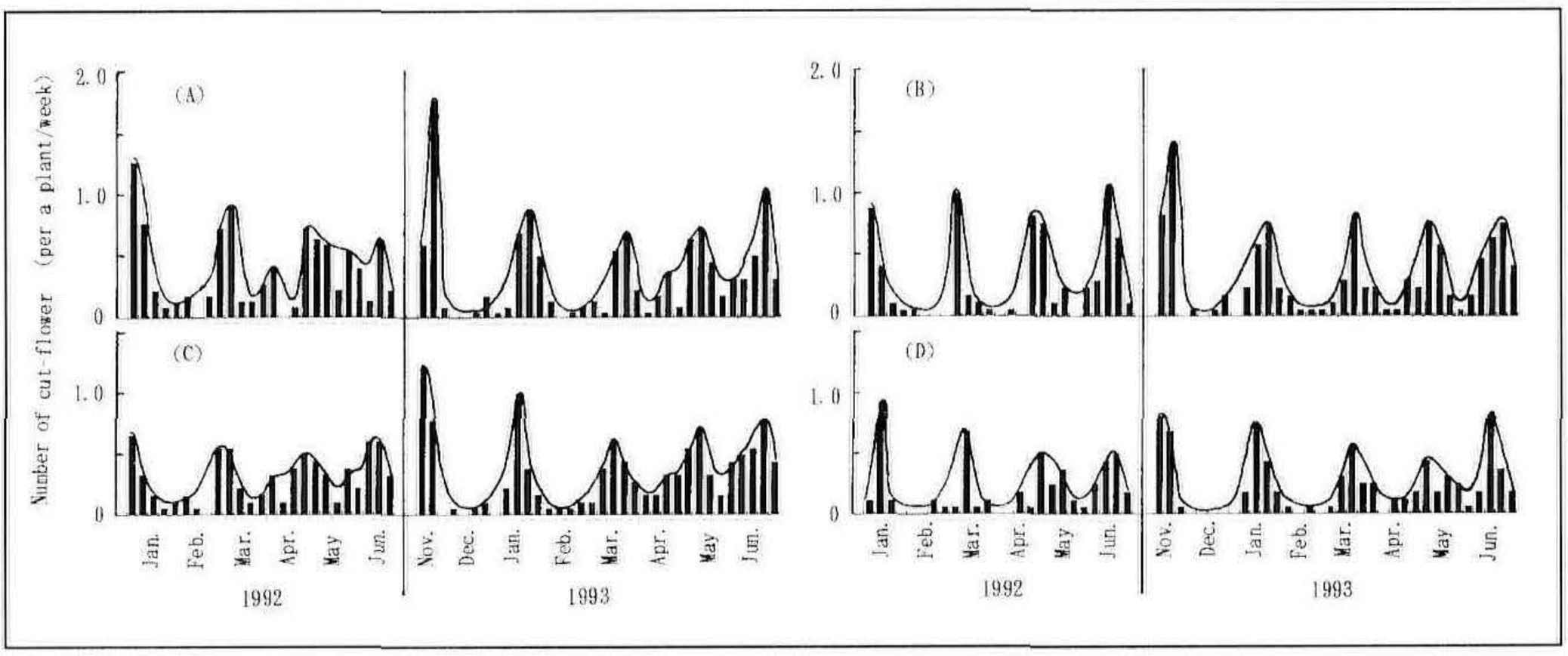

Figure 2. The periodicity of cut flower production in 1992 to 1993. A: MP (micropropagate plants), B: CG (rooted cutting grafts), C: RC (rooted cuttings), D: SG (softwood-grafted nursery plants).

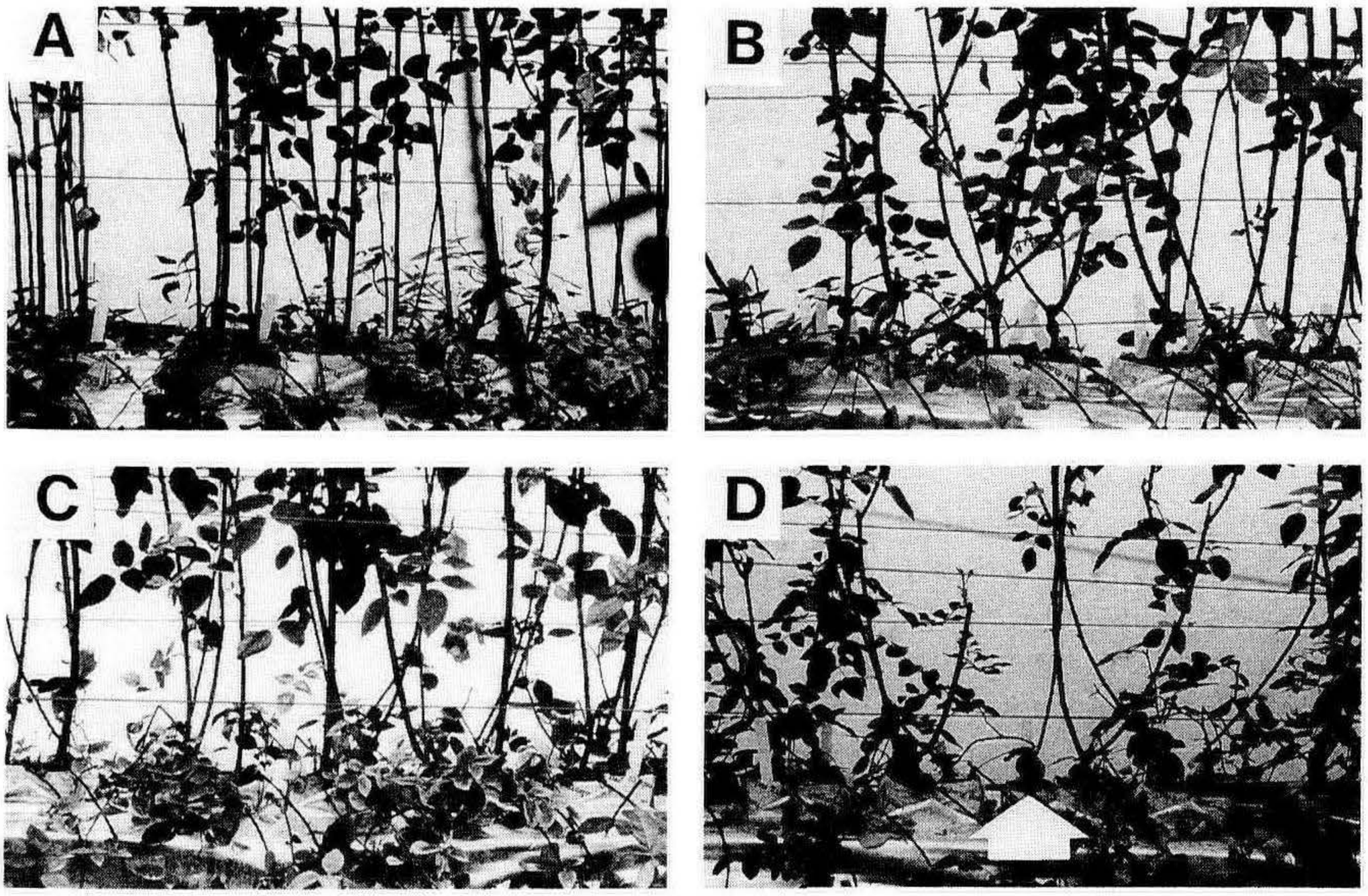

Figure 3. Sprouting shoots from A: MP (micropropagate plants), B: CG (rooted cutting grafts), C: RC (rooted cuttings), D: SG (softwood-grafted nursery plants) in July 1992. The arrow indicates crown gall.

to BAP in the medium. Jones (1994) and Dubois and Vries (1992) also reported that propagation in vitro encouraged rejuvenation of roots.

Many rose plants are infected with *Prunus* necrotic ringspot virus (Bjarnason et al., 1985) or *Prunus* virus S. These viruses reduce flower number and size, although these are often latent. The high productivity of MP may be due to its effectiveness in producing virus-free plants.

The productivity of SG was significantly lower than those of the other plants because 31% of these plants were infected with crown gall (Fig. 3).

The average length of cut flowers in 1992 showed no difference between MP, CG, and RC (Table 1), and about 50% of these cut flowers were over 80 cm. The flowers cut from SG were significantly shorter than those of other types, and most were between 60 to 70 cm in length.

In 1992-93, there was no significant difference among the nursery plants in the average length of flower stem, but the percentages over 80 cm were MP (38.9%), CG (33.5%), RC (29.8%) and SG (16.9%) (Table 1). The highest frequency of stems over 80 cm was from MP and CG, over 70 to 80 cm from RC and over 60 to 70 cm from SG. When flowers cut in 1992 are compared with those cut in 1992-93 the 1992-93 figures show more flower production but shorter stems were produced.

The flowers cut from SG were shorter than those of the other nursery plants, the most likely cause of this was the crown gall infection.

Kitamura et al. (1992) compared the field performance of micropropagated plants with that of softwood-grafted nursery plants in rose cv. Carl Red. The cut flower stem length of micropropagated plants was shorter than that of softwood-grafted nursery plants, although the micropropagated plants produced many leader shoots and much branching and therefore many flower shoots. In 'Carl Red',

Table 1. Distribution of flowers cut from MP (micropropagated plants), CG (rooted cutting grafts), RC (rooted cuttings) and SG (softwood-grafted nursery plants) for two years.

	1992						
	Stem length (cm)						
	Under 40	40-50	50-60	60-70	70-80	over 80	Average
MP	0.0[x]	0.9	4.2	20.1	25.2	49.5	77.9±11.7
CG	0.0	0.8	5.7	11.4	33.3	48.8	78.2±11.1
RC	0.0	0.7	3.0	15.6	30.4	50.4	80.4±12.8
SG	0.0	4.8	20.2	32.1	21.4	21.4	69.1±13.0

	1992 - 1993						
	Stem length (cm)						
	Under 40	40-50	50-60	60-70	70-80	over 80	Average
MP	0.0	1.9	13.7	22.5	22.9	38.9	75.6±16.0
CG	0.0	1.6	13.1	28.3	23.6	33.5	72.7±12.8
RC	0.0	3.4	12.5	23.6	30.8	29.8	74.1±15.2
SG	0.8	4.6	20.0	29.2	28.5	16.9	68.7±13.1

[x] Numbers expressed as percent.

the excess sprouting of shoots by rejuvenation, therefore, brought about a reduction in cut flower quality. The micropropagated Madam Violet used for this study sprouted many leader shoots without the excess sprouting, a known characteristic of this cultivar. The cut flower production of 'Madame Violet' was of a higher and better quality when compared with that of 'Carl Red'.

We expect to investigate cultivar differences in relation to the productivity of micropropagated plants and their sprouting ability.

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Photoautotrophic micropropagation of *Cymbidium:* Effects of CO_2 Concentration, Photosynthetic Photon Flux Density and Sucrose Concentration on Plantlet Growth

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Cymbidium plantlets are produced in vitro normally under heterotrophic or mixotrophic conditions in the presence of sucrose. Leafy nodes of other species have been grown successfully to plantlets through photoautotrophic culture (i.e. without sucrose) under CO_2 enrichment. Therefore, this study was undertaken to determine if cymbidiums in leaf can also be micropropagated without sucrose, and if so, to determine the optimum culture conditions.

Cymbidium PLBs with two or three leaves were cultured in vitro on half strength Murashige and Skoog (1962) medium under varying concentrations of sucrose, CO_2 and photosynthetic photon flux density (PPFD) for 42 days; the treatments were

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Cymbidium PLBs with two or three leaves were cultured in vitro on half strength Murashige and Skoog (1962) medium under varying concentrations of sucrose, CO_2 and photosynthetic photon flux density (PPFD) for 42 days; the treatments were

Table 1. Description of experimental conditions.

Plant material	*Cymbidium* cv. Marilyn Monroe
Medium	
Basal medium	Half strength Murashige & Skoog (1962)
Supporting material	Agar (7 g liter^{-1})
Growth regulator	None
pH	5.6 before autoclaving
Amount	70 ml/vessel
Vessel	
Type	Polycarbonate box (370 ml)
Number of air-exchange	5.4 h^{-1}
Culture room	
Photoperiod	16 h d^{-1}
Air temperature	Light period 19-22C
	Dark period 24-26C
Culture period	42 days

Table 2. Treatment descriptions.

Treatment code	$C0_2$ conc.[1] (μmol mol^{-1})	PPFD[2] (μmol m^{-1} s^{-1})	Sucrose conc.[3] (g liter^{-1})
AL00	500	50	0 - 0
AL03	500	50	0 - 30
AL30	500	50	30 - 0
AL33	500	50	30 - 30
AH00	500	100	0 - 0
AH03	500	100	0 - 30
AH30	500	100	30 - 0
AH33	500	100	30 - 30
BL00	1000	50	0 - 0
BL03	1000	50	0 - 30
BL30	1000	50	30 - 0
BL33	1000	50	30 - 30
BH00	1000	100	0 - 0
BH03	1000	100	0 - 30
BH30	1000	100	30 - 0
BH33	1000	100	30 - 30

[1] Concentration in the culture room.
[2] Photosynthetic photon flux density on the empty shelf.
[3] Concentration in the medium during the first and second culture period.

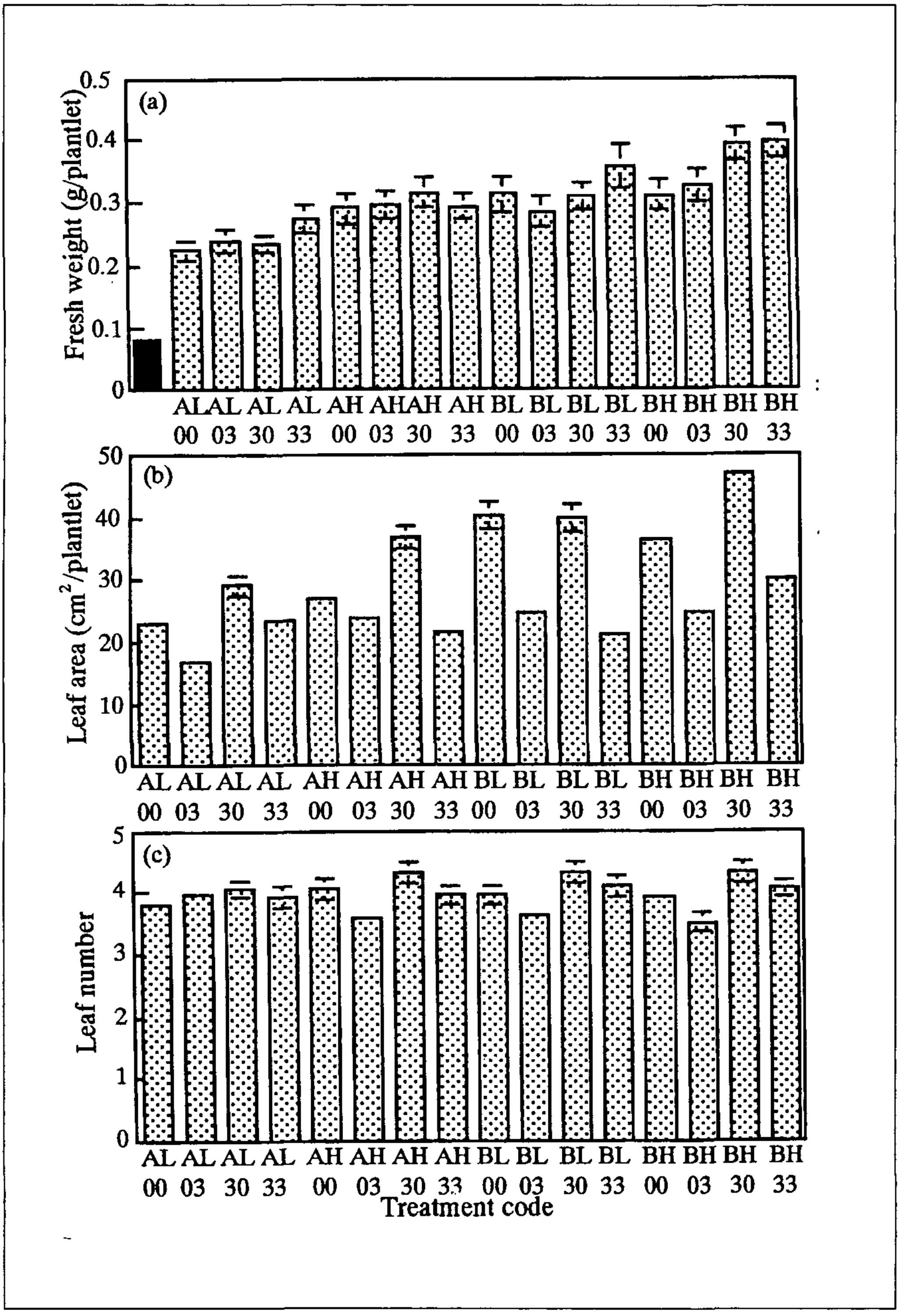

Figure 1. Total fresh weight (a), leaf area (b), and leaf number of (c) per plantlet on days 42 of *Cymbidium* plantlets (mean ±SE); ▪ represents total fresh weight on day 0.

divided into two periods: 0 to 14 days and 15 to 42 days (Tables 1 and 2). During each period sucrose concentration was maintained at 0 or 30 g liter^{-1}, CO_2 at 500 or 1000 μmol mol^{-1}, and PPFD at 50 or 100 μmol m^{-2} s^{-1}. PLBs were on one culture for the first period and changed to the new culture for the second period. At the end of each period, total fresh weight, leaf area, and leaf number per plantlet were measured.

At the end of the first period, leaf area was greater under the combination of no sucrose, 1000 μmol mol^{-1} CO_2, 50 μmol m^{-2} s^{-1} PPFD. The effect of the culture conditions on the total fresh weight and leaf number was not significant ($P \leq 0.01$) during this period. At the end of the second period, total fresh weight and leaf number were greater without sucrose under 1000 μmol mol^{-1} CO_2 and 100 μmol m^{-2}s^{-1} PPFD than under other treatments. When both periods are considered together, all the three parameters were greater under 30 g liter^{-1} sucrose, 1000 μmol mol^{-1} CO_2, and 100 μmol m^{-2} s^{-1} PPFD (first period), and 0 g liter^{-1} sucrose, 1000 μmol mol^{-1} CO_2, and 100 μmol m^{-2} s^{-1} PPFD (second period) (Table 3 and Figure 1).

The above results suggest that *Cymbidium* plantlets can be produced photoautotrophically under conditions of high PPFD and CO_2 enrichment. This could help reduce the micropropagation cost for cymbidiums.

Table 3. Statistical summary on treatment effects of *Cymbidium* plantlets.

	Growth criterion		
Variable	FW	Leaf area	Leaf number
Day 14			
$C0_2$ conc.	NS[2]	NS	NS
PPFD	NS	NS	NS
Sucrose conc.[1]	NS	**	NS
Day 42			
$C0_2$ conc.	**	**	**
PPFD	**	**	NS
Sucrose conc.[3] (g liter^{-1})	NS	**	**
0 - 0	a[4)]	ab	b
0 - 30	a	b	c
30 - 0	a	a	a
30 - 30	a	b	b

[1] Medium sucrose concentration in the first culture period (0 or 30 g liter^{-1}).
[2] NS and ** indicate nonsignificant or significant at the P 0.01, respectively (analysis of variance).
[3] Combination of sucrose concentration in the first period and second period.
[4] Means within a column followed by different letters are significantly different at the P 0.05.

Mass Propagation and Distribution of Rhododendron

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Akatsuka Shokubutsuen Co., 1868-3, Takano-o-chou, Tsu-shi, Mie 514-22

From 1972, Akatsuka Shokubutsuen has imported 400,000 pots of rhododendron and distributed them in Japan. During this time, tissue-culture propagation has been adopted for mass production and we now have planned production of nursery plants resulting in saleable pots of rhododendron. These tissue-cultured plants were registered as "Rhody". "Rhody" production was licensed with many agricultural corporations from the north (Fukushima Pref.) to the south (Miyazaki Pref.) of Japan. And recently, more hardy and heat-tolerant clones were registered under the name of "Super Rhody".

Use of PeSP Seedlings in the Production of Fruiting Vegetables

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A PeSP seedling is a kind of plug plant grown in a small cell which is a square of 14 mm and 23 mm in height. The production of fruiting vegetables in a glasshouse using PeSP seedlings has recently spread because the package of seedlings can be easily transported a long way. This study investigated the growth characteristics of PeSP seedlings. The results were summarized as follows: stem length, number of leaves, and the dry-matter weight of each organ of the PeSP seedlings of sweet pepper were larger than those of traditionally produced seedings one month after transplanting. An especially marked difference in the dry matter weight of the roots was noted between the two kinds of seedlings. Over the same period, the dry-matter weight of PeSP seedlings of tomato was also greater than that of traditionally produced seedlings. By increasing the basal dressing of nitrogen, the yield of tomato, using PeSP seedlings, was increased compared with traditionally produced seedlings, however, the ratio of good tomato fruits decreased. It was generally observed at the time of transplanting that seedlings produced by the standard method had a long tap root while PeSP seedlings had developed some adventitious roots. The rapid growth and higher yield of tomato are considered to be due to the active up-take of nutrients by the well developed root system of PeSP seedlings. In order to obtain good quality tomato fruits using PeSP seedlings, it is necessary to supply a considerable amount of top dressing instead of part of the basal dressing.

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From 1972, Akatsuka Shokubutsuen has imported 400,000 pots of rhododendron and distributed them in Japan. During this time, tissue-culture propagation has been adopted for mass production and we now have planned production of nursery plants resulting in saleable pots of rhododendron. These tissue-cultured plants were registered as "Rhody". "Rhody" production was licensed with many agricultural corporations from the north (Fukushima Pref.) to the south (Miyazaki Pref.) of Japan. And recently, more hardy and heat-tolerant clones were registered under the name of "Super Rhody".

Use of PeSP Seedlings in the Production of Fruiting Vegetables

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A PeSP seedling is a kind of plug plant grown in a small cell which is a square of 14 mm and 23 mm in height. The production of fruiting vegetables in a glasshouse using PeSP seedlings has recently spread because the package of seedlings can be easily transported a long way. This study investigated the growth characteristics of PeSP seedlings. The results were summarized as follows: stem length, number of leaves, and the dry-matter weight of each organ of the PeSP seedlings of sweet pepper were larger than those of traditionally produced seedings one month after transplanting. An especially marked difference in the dry matter weight of the roots was noted between the two kinds of seedlings. Over the same period, the dry-matter weight of PeSP seedlings of tomato was also greater than that of traditionally produced seedlings. By increasing the basal dressing of nitrogen, the yield of tomato, using PeSP seedlings, was increased compared with traditionally produced seedlings, however, the ratio of good tomato fruits decreased. It was generally observed at the time of transplanting that seedlings produced by the standard method had a long tap root while PeSP seedlings had developed some adventitious roots. The rapid growth and higher yield of tomato are considered to be due to the active up-take of nutrients by the well developed root system of PeSP seedlings. In order to obtain good quality tomato fruits using PeSP seedlings, it is necessary to supply a considerable amount of top dressing instead of part of the basal dressing.

Micropropagation of Mulberry (*Morus alba* L.) by Liquid-Shake Culture of Multiple-Bud Bodies

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INTRODUCTION

Mulberry is an important woody crop used for silkworm rearing and is cultivated in many temperate countries throughout the world. It is conventionally propagated by grafting or cuttings. In vitro micropropagation of mulberry has been studied for various species (Oka, 1985; Hossain et al., 1992; Jain et al., 1990; Yadav et al., 1990). In these studies, micropropagation through multiple shoot formation has been exclusively performed on solid media. Micropropagation by liquid-shake culture is employed in several vegetables and ornamental flowers (Takayama, 1991). In woody plants, however, only a limited number of studies have reported on micropropagation using liquid culture (Alvard et al., 1993; Hammerschlag, 1982). In preliminary work, we reported that multiple-bud bodies (MBB) could be induced from shoot tips of mulberry seedlings immediately after development of the first true leaves in the liquid-shake culture of a medium supplemented with CPPU, a urea-type cytokinin (Hayashi and Oka, 1995). In this report, the same culture system was applied to a mulberry cultivar commercially cultivated in Japan to obtain MBB with higher multiplication rates than shoot cultures in the conventional culture system using solid media.

MATERIALS AND METHODS

Initiation of Shoot Cultures. Winter buds of mulberry 'Kenmochi' were sterilized with sodium hypochlorite solution (1% effective chlorine) for 30 min. After rinsing three times with sterile water, meristems (3 to 5 mm long) were dissected from the winter buds after removing scale leaves, and cultured on Murashige and Skoog (1962) (MS) medium containing 3% fructose and 1 mg liter^{-1} benzyladenine (BA). The medium was solidified with 0.8% agar. The pH of the medium was adjusted to 6.0 before autoclaving at 120C for 15 min. After 1 month of culture at 25C under a 19-h photoperiod, developed shoots were transferred to a fresh medium with the same components as the shoot initiation medium. Shoot cultures thus established and subcultured monthly were employed as materials for further experiments.

Induction and Subculture of MBB. Shoot tips (1 to 2 mm) taken from in vitro-grown shoots were cultured in liquid MS medium containing 3% sucrose and BA or N-(2-chloro-4-pyridyl)-N-phenylurea (CPPU) (Fulmet: Kyowa Hakkou Kogyo). Explants were cultured either in Erlenmeyer flasks (100 ml) containing 30 ml liquid medium which were rotated horizontally at 120 rpm, or in tubes (24 mm × 120 mm) containing 10 ml medium which were placed on a drum rotating vertically at 2 rpm. The cultures were maintained at 25 C under a 19-h photoperiod with diffuse fluorescent light. MBB divided into small pieces including several buds were subcultured for maintaining stock cultures every 2 weeks in MS liquid medium with 3% sucrose and 1 mg liter^{-1} CPPU (pH 5.8).

Table 1. Multiple bud body (MBB) induction from shoot tips of mulberry (cv. Kenmochi). Shoot tips were cultured in flasks rotated horizontally (120 rpm) for 4 weeks.

Cytokinin (mg liter^{-1})	Percentage of explant with: Leaf development	Shoot elongation	MBB formation	No growth
BA[1] (1)	8	92	0	0
BA (2)	75	25	0	0
BA (5)	100	0	0	0
BA (10)	0	0	0	100
CPPU (2)	0	0	83	17

[1] Abbreviations: BA, benzyladenine; CPPU, N-(2-chloro-4-pyridyl)-N-phenylurea.

Table 2. Effects of rotation methods on multiple bud body (MBB) formation (cv. Kenmochi).

Rotation method	% MBB formation: 2 weeks	4 weeks	6 weeks	8 weeks	No. of buds per MBB after 8 weeks culture ±s.d.
Vertical (2 rpm)	0	0	46	58	10. 8±3. 9
Horizontal (120 rpm)	0	100	100	100	33.1±6.1

Table 3. Proliferation of a single bud excised from MBB (cv. Kenmochi) cultured for 3 weeks in medium with BA, TDZ, and CPPU[1].

Cytokinin (mg liter^{-1})	% explant with: Leaf development	Shoot elongation	MBB formation	No. buds/MBB ±s.d.
CPPU (2)	0	0	100	12.3±2.6
CPPU (5)	0	0	93	6.9±2.8
TDZ (2)	13	0	87	6.2±1.8
TDZ (5)	3	0	93	6.8±2.6
BA (2)	20	73	7	8.5±1.2
BA (5)	77	13	10	4.3

[1] Abbreviations: BA, benzyladenine; CPPU, N-(2-chloro-4-pyridyl)-N-phenylurea; TDZ, thidiazuron.

Plant Regeneration from MBB. Shoots were regenerated on MS solid medium (0.8% agar) containing 3% fructose and 1 mg liter^{-1} BA (pH 6.0) from bud explants excised from subcultured MBB. The regenerated shoots were transferred to MS medium with 0.1 mg liter^{-1} α-naphthaleneacetic acid (NAA) for root induction.

RESULTS AND DISCUSSION

MBB were formed from shoot tips when they were cultured in a medium with 2 mg liter^{-1} CPPU (Table 1). MBB were occasionally associated with small leaves but shoots never elongated while rotary culture was continued (Fig. 1). BA induced shoot elongation at 1 mg liter^{-1} and leaf development at 5 mg liter^{-1} from the shoot tips, but was ineffective for MBB formation even when its concentration was elevated to 10 mg liter^{-1} (Table 1). The optimum concentration of CPPU for inducing MBB was 2 mg liter^{-1}. Shoot tip explants initially grew very slowly, inducing MBB 4 to 6 weeks after culture initiation. Horizontal rotation (120 rpm) of the medium in flasks induced MBB more rapidly with a larger number of buds per MBB than vertical rotation (2 rpm) of the medium in tubes (Table 2); hence the following experiments were conducted using the horizontal rotation culture method. When a single bud excised from MBB was subcultured, its responses to cytokinins were different (Table 3). CPPU and thidiazuron (TDZ) regenerated MBB at higher rates than BA. On the other hand, BA stimulated leaf or shoot growth rather than MBB regeneration as was the case of the initial culture of the shoot tips. The multiplication rates of single buds excised from MBB on medium containing CPPU were quite stable, ranging from 16 to 20 per 4 weeks during three consecutive subcultures. When a single bud was transferred to MS medium containing either CPPU or BA at 1 mg liter^{-1}, shoot elongation occurred 14 to 21 days after transfer to the stationary culture conditions. Most of the regenerated shoots exhibited a substantially normal appearance with negligible vitrification. Over 50% of the explants cultured on medium supplemented with 0.1 to 1.0 mg liter^{-1} CPPU formed roots following shoot regeneration, while rooting frequency in the presence of BA was less than 20%. Furthermore, normal rooting from excised shoots was observed when they were cultured on a medium with 0.1 mg liter^{-1} NAA. The present study revealed that CPPU was specifically effective for inducing MBB in mulberry. Once MBB had been induced, subsequent subculture of MBB and shoot regeneration were so easy and stable that propagation using MBB showed promise, particularly in such cultivars as 'Kenmochi', in which the multi-

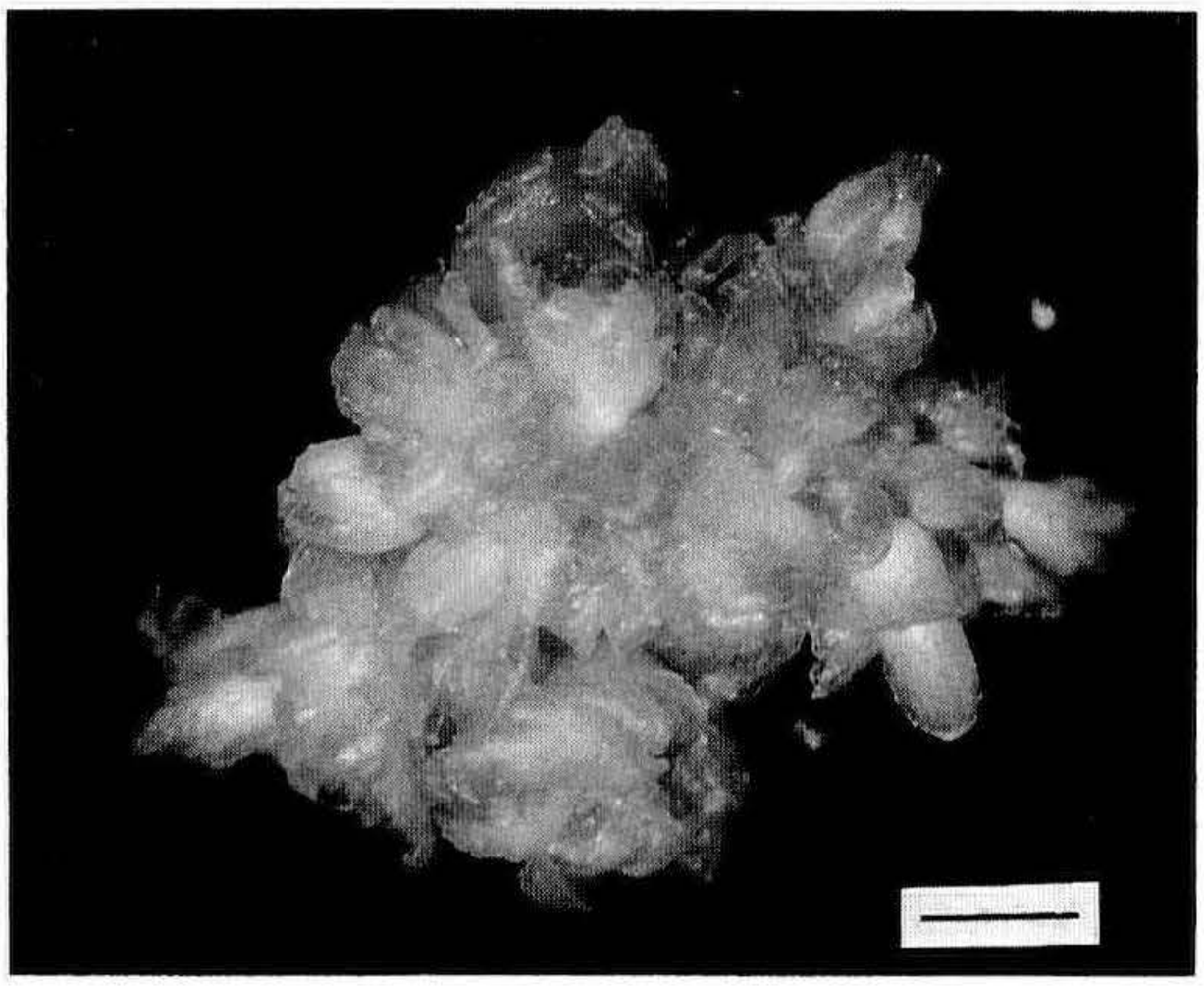

Figure 1. Multiple-bud body (MBB) of mulberry (cv. Kenmochi) induced from a shoot tip by liquid shake culture on MS medium supplemented with 2 mg liter^{-1} CPPU (N-(2-chloro-4-pyridyl)-N-phenylurea) (scale bar is 2 mm).

plication rate was remarkably increased compared to a rate of 3 to 4 per month by the conventional solid medium propagation system (Oka, 1985). TDZ, another urea-type cytokinin, shows stronger cytokinin effects such as more vigorous shoot proliferation than BA in many woody plant materials (Huetteman and Preece, 1993). In mulberry, however, CPPU was more effective than TDZ for inducing MBB, as shown in a previous study (Hayashi and Oka, 1995), indicating that the mode of action between the two cytokinins is different in this species.

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Accumulation of Benzyladenine in Green Globular Bodies in a Micropropagation System for *Pteris ensiformis*

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INTRODUCTION

The rhizome explants of several ferns produce a tissue (GGB, green globular body) on benzyladenine (BA)-supplemented medium in vitro. The surface of GGB is covered with meristematic tissues. The GGB was rapidly multiplied on a BA-supplemented medium, and plantlets regenerated on a BA-free medium. From these experimental results, we proposed a micropropagation system using GGB as the propagule (Fig. 1). However, the time required for the regeneration of plantlets from GGB segments and the frequency of subcultures gradually increased when our proposed system was applied to *Pteris ensiformis* 'Victoriae'. In this study, we examined the effect of transient transfer of GGB to BA-free medium on the rate of plantlet regeneration, and determined the content of BA in GGB.

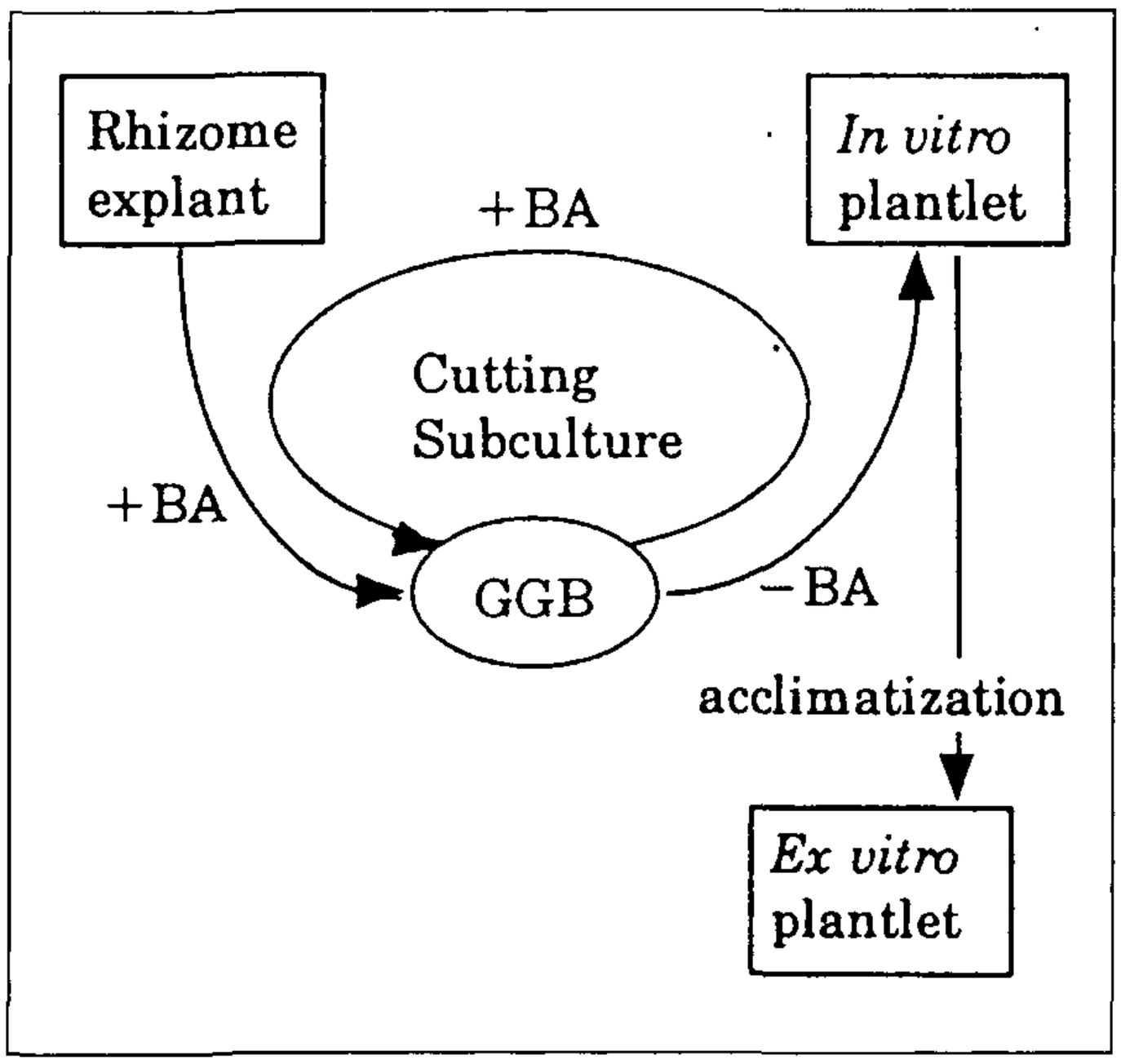

Figure 1. The scheme of a micropropagation system for ferns.

MATERIALS AND METHODS

Green globular body tissue of *P. ensiformis* 'Victoriae' was obtained by the method previously described, and multiplied on the multiplication medium [½ Murashige and Skoog (MS) medium] supplemented with 1 mg liter^{-1} BA, 20 g liter^{-1} sucrose, and 9 g liter^{-1} agar (pH 5.5). In the first experiment, GGB was divided into segments, 2.5 mm in diameter (ca. 8 mg FW) and subcultured in the multiplication medium

Table 1. Effect of subculture times on the rate of plantlet regeneration.

Times of subculture with BA	Days to leaf formation	No. of leaves produced within 8 weeks
1	22.0	72.2±5.1
3	25.0	98.8±9.5
5	38.0	65.1±5.5
7	42.0	27.2±7.8
9	50.0	13.0±2.3
11	51.5	4.9±1.3

Table 2. Effect of green globular body (GGB) transplanting to BA free medium on the rate of plantlet regeneration.

GGB (Times of subculture)	Transplant. to BA free medium	Days to leaf formation	No. of leaves produced within 8 weeks
8	-	50.0	13.0±2.3
8	+	24.5	41.6±6.3
9	-	51.5	2.4±0.7
9	+	26.5	42.2±5.7

Table 3. Benzyladine (BA) contents in green globular bodies (GGB).

Hydrolysis treatment (min)	BA content in GGB (μg/g FW)
0	0.46
30	0.50
90	0.25
180	ND

repeatedly at 4 weekly intervals for 1 year. At the time of each subculture, 10 segments of GGB were cultured on the regeneration medium (BA-free medium). After 8 weeks of culture on the BA-free medium, the number of leaves produced was recorded. In the second experiment, GGB subcultured on a medium containing BA, was divided 8 to 9 times and transplanted to a BA-free medium. After 30 days, the GGB was divided again and subcultured on the BA-free medium to estimate the capability of plantlet regeneration (leaf numbers after 8 weeks).

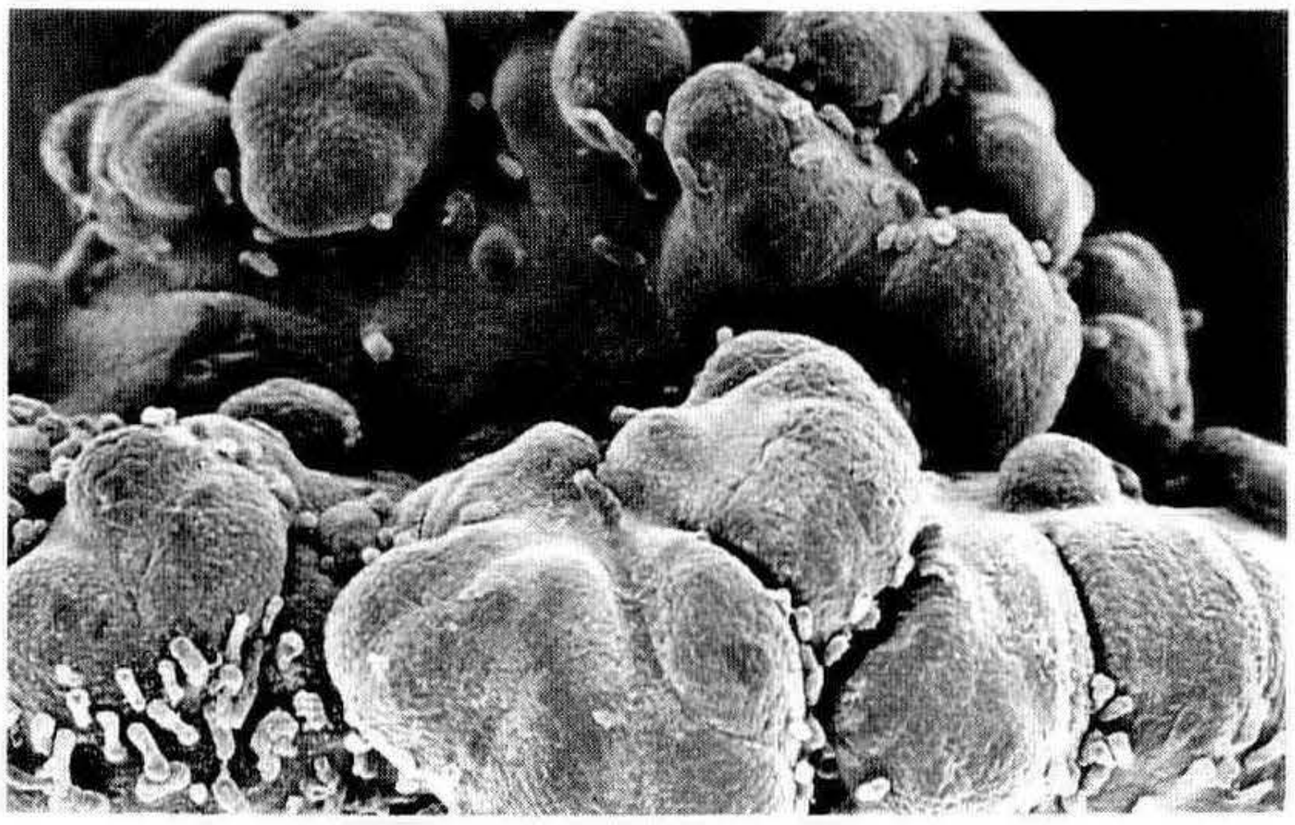

Figure 2. Surface structure of GGB.

Finally, the BA content in the GGB was determined. GGB was homogenated in 80% EtOH, and purified through an ion-exchange column, and finally the BA content was determined with HPLC. In addition, to measure the content of bound BA, the extracts of GGB were hydrolyzed with 2N HCl for 0 to 180 min at 80C.

RESULTS AND DISCUSSION

The time of leaf formation was gradually delayed with the increasing frequency of subculture (Table 1). After 8 to 9 subcultures on the medium containing BA, GGB produced no leaves within 50 days after subculture on the BA-free medium. On the other hand, leaf formation from GGB transplanted to the BA-free medium occurred within 30 days (Table 2). As the GGB, which was repeatedly subcultured on the medium with BA, continued multiplying for a while after transplanting to the BA-free medium, the BA concentration in the GGB might be gradually lowered with the increasing volume of GGB on the BA-free medium. In the GGB, BA was present in considerable amounts, mostly free-form (Table 3). These results indicate that the delay in plantlet regeneration after repeated subcultures of GGB on the medium containing BA was caused by an accumulation of BA in the GGB.

Figure 3. A regenerated plant of *Pteris ensiformis* after 2 months under ex vitro conditions.

The Propagation of Virus-free Sweet Potato Cuttings by Hydroponics in Miyazaki Prefecture

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It is well known that virus-free, sweet potato cuttings have advantages for crop production, although there has been no effective method to propagate a large quantity of cuttings in a short time. After several years of experiments, a hydroponic system has proved to be a successful method to propagate sweet potato cuttings; this system is a deep flow technique (DFT) hydroponic system. The system requires a clean culture bed, an automatic nutrient solution control system, and an air mixing device as shown in Figure 1. This system, as used by an agricultural cooperative and some growers in Miyazaki prefecture, is shown in Figure 2. In this process the cuttings are multiplied in a soil-less culture system through all stages, therefore, the cuttings are free of viruses, soil fungi, and nematodes. The plants propagated in this way are disease-free, better rooting, and produce higher yields. Because of these advantages, utilization of this hydroponic system to propagate virus-free sweet potato cuttings will be an effective method for future production elsewhere.

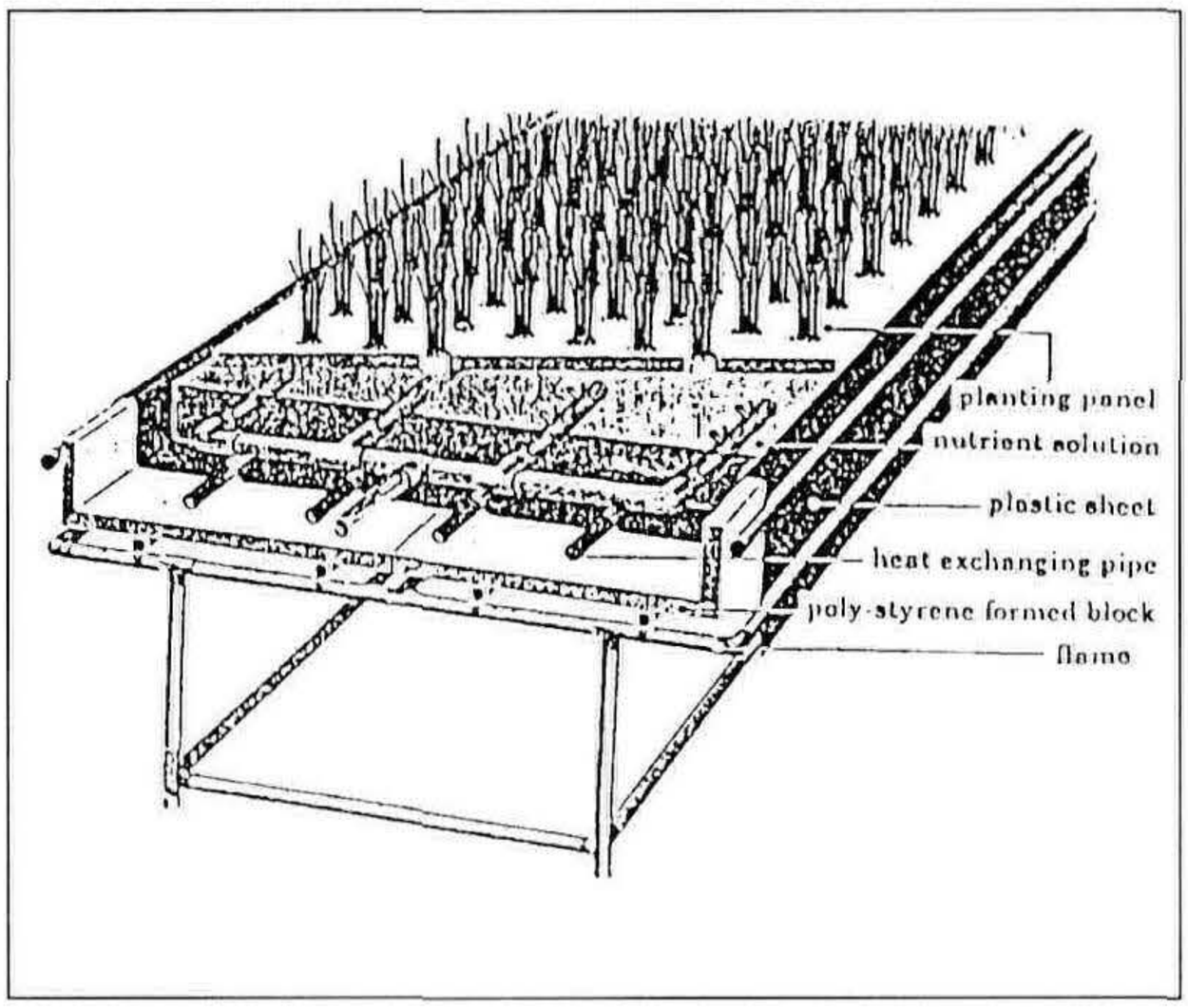

Figure 1. Schematic diagram of structure of the hydroponic system.

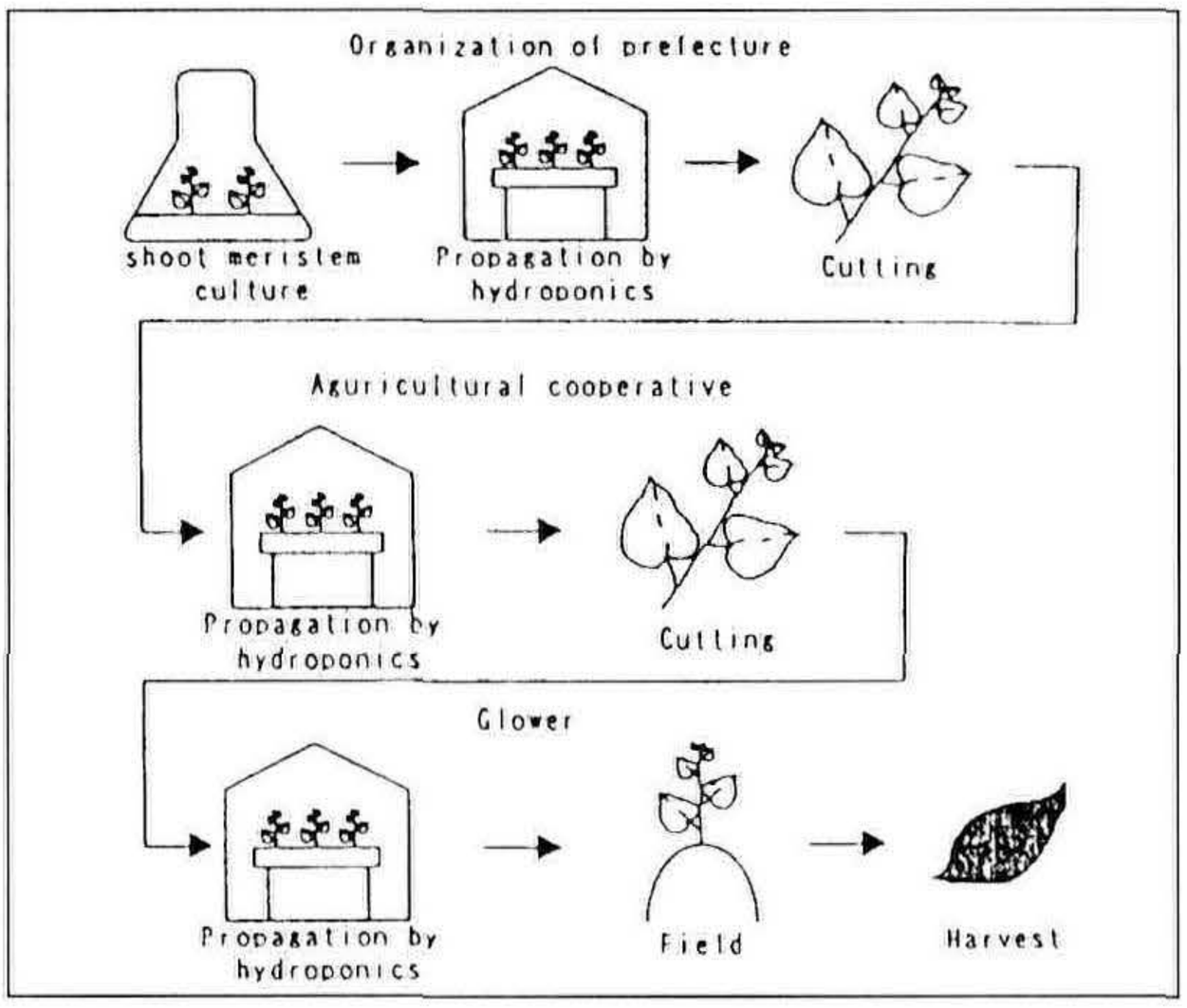

Figure 2. Schematic diagram of process of propagation.

Some Observations on the Breeding of Japanese Camellias

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In my garden, there grows a 20-year-old camellia with beautiful white flowers which I have named 'Kusano-Shiro'. This plant produces a lot of seed every year, and I have produced many young plants from it. I wish to report my observations on the segregation of flower colour and form in F1 crosses.

Flower Colour Segregation. Nearly half of the plants have white flowers (13/24) and about 20% have double or peony form. These plants are hybridised with a nearby camellia, cultivar Hagoromo, which has a lotus flower form and pale pink colour. A further 20% of these seedlings are bicoloured, suggesting an out-cross with the variegated-flowered cultivar Shibori-Shiratama.

Leaf Colour of Young Plants. The colour of the new leaves of the young plants indicate the flower colour of the adult plant. So, I can easily forecast the flower colour and variegation at seedling stage.

Variation in Fruit Size. I plan to breed oil-producing camellia cultivars. Therefore, I have begun to measure the size and weight of the fruits. The average weight of a fruit is 34.2 g, and they range from 5.0 to 87.5 g. The average total weight of seeds per fruit is 9.1 g, and they range from 1.0 to 20.2 g. The average percentage of seed weight to fruit weight is 27.8%, and ranges from 6.7% to 53.8%.

My most important criteria for breeding seed-oil-producing camellia cultivars in the future will be the selection of clones with a high percentage of seed weight and large heavy fruit.

Introducing Genes into *Zygopetalum* by the Use of a Particle Gun

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Protocorms and small seedlings of *Zygopetalum* grown aseptically were bombarded with accelerated gold particles coated with plasmids containing a ß-glucuronidase (GUS) gene as the reporter. Blue transformed cells were detected by the enzymatic GUS assay. Neomycin phosphotransferase II (NPT II) gene was used as the selectable marker. Two kinds of plasmid were used, namely pBI 121 and pBI 221. Gun parameters influencing DNA delivery such as the number of bombardments and helium gas pressure as the particle propulsion were investigated. The optimal conditions for introducing foreign genes were two bombardments at 1300 psi helium gas pressure. Although there was a possibility of the escape from kanamycin, several transgenic plants were obtained after a 4-week selection culture.

INTRODUCTION

The details of the molecular biology of natural gene transfer systems of *Agrobacterium tumefaciens* and *A. rhizogenes* have been reviewed by Morrish et al. (1992). In orchids, difficulties have been encountered both in whole plant regeneration from protoplasts and in the general insusceptibility of monocotyledons to *Agrobacterium*-mediated transformation. Therefore, microprojectile bombardment is now one of the most efficient methods to induce transgenic plants in orchids. The advantage of this method is that physical penetration of the plant cell wall allows species-independent transfer of DNA into a wide range of target tissues. This microprojectile bombardment by a particle gun was developed by Sanford et al. (1984).

Because of its fragrance and good cold tolerance, *Zygopetalum* has been introduced to Japan as a pot plant. The purpose of the present study is to try to introduce GUS and NPT II genes into protocorms and small seedlings of *Zygopetalum* by the use of a particle gun. Few studies have been carried out on gene transfer by particle gun treatments in orchids.

MATERIAL AND METHODS

Plant Material. *Zygopetalum blackii* was used as the plant material. A protocorm (actually a mass of 3 to 4 intact protocorms, 5 to 10 mm in diameter) and small seedlings (with two leaves 1 to 2 cm in height obtained from aseptic seed culture) were grown in vials (Φ 6 cm × 12 cm high) on 100 ml of half-strength Murashige and Skoog (Murashige and Skoog,1962) culture medium containing 20 g liter^{-1} sucrose, 3 g liter^{-1} Hyponex, and 2.5 g liter^{-1} gelan gum. The medium was adjusted

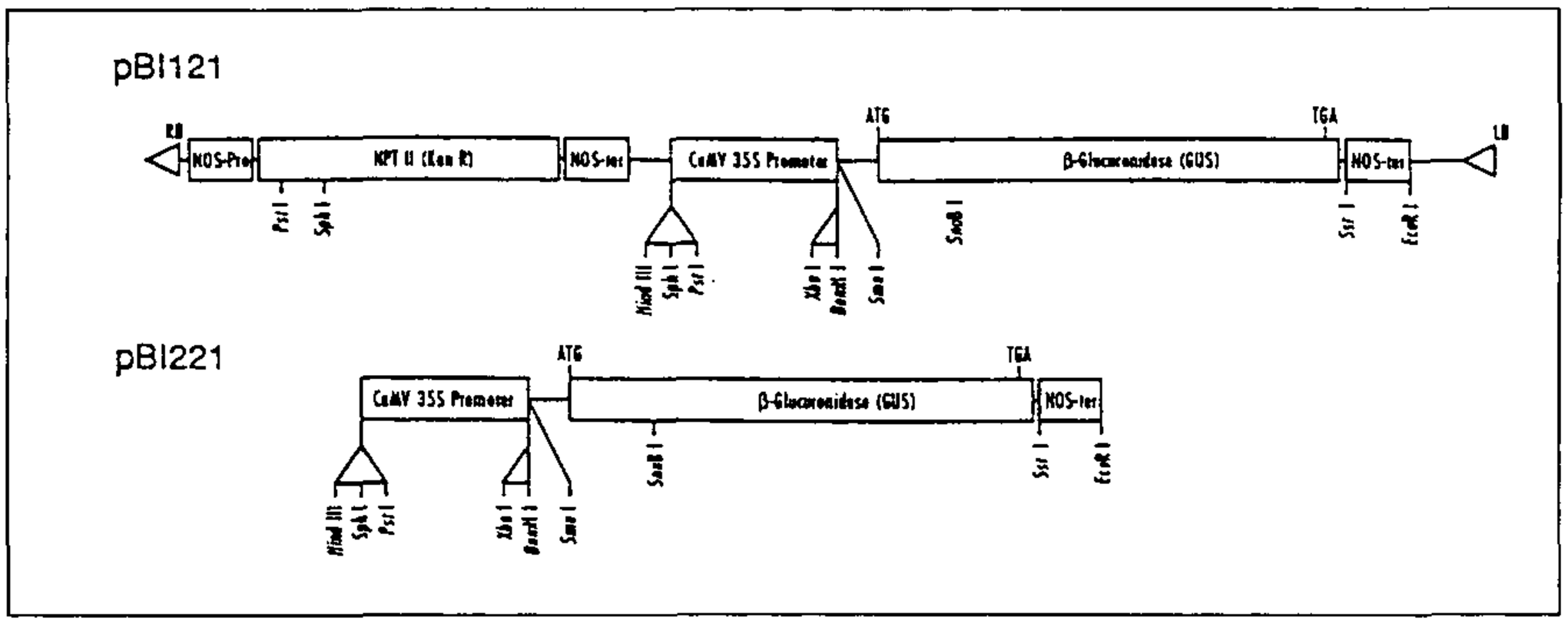

Figure 1. Two plasmids of pBI 121 and pBI 221 were used to introduce genes. Plasmid pBI 121 consists of NPTII (including kanamycin resistant gene) gene, GUS gene and CaMV 35S promoter. Plasmid pBI 221 contains GUS gene and CaMV 25S promoter.

to pH 5.8 before autoclaving. Cultures were incubated at 23C, under white fluorescent tubes for 16 h daily at 5000 lx. At 7 days before particle gun treatment, about 60 protocorms or 15 seedlings were transplanted in a petri dish (Φ 9 cm) containing 40 ml of the medium mentioned above.

Bombardment. Protocorms and seedlings of *Zygopetalum* were bombarded with accelerated gold particles (1 or 1.6μm) coated with pBI 121 plasmid or pBI 221 plasmid containing a GUS gene as the reporter with a CaMV 35S promoter. An NPT II gene with a nopaline synthase (nos) promoter, which was included in a pBI 121 plasmid, was used as the selectable marker. The two genes were bombarded by a BIORAD PDS-1000/He particle gun. Gun parameters influencing DNA delivery, such as the number of bombardments (1 or 2 shots), helium gas pressure as the particle propulsion, using 1100 psi or 1300 psi rupture disks, and the effectiveness of a 12-cm-target distance, were investigated, respectively. Two plasmids of pBI 121 and pBI 221 are shown in Figure 1.

GUS Transent Assay. Two days after bombardment blue transformed cells were detected by 5-bromo-4-chloro-3-indolyl glucuronide (X-Gluc) (Jefferson, 1988). All protocorms and seedlings bombarded with plasmid 221 were examined for the GUS transent assay.

Selection of Transgenic Plantlets. After 1 week of culture under dark conditions, all protocorms and seedlings bombarded with plasmid 121 were transplanted into vials (Φ 6 cm × 12 cm) and cultured under dark conditions. Each vial contained 100 ml of ½ MS medium with a 500 mg liter^{-1} kanamycin for selection. After a 4-week selection culture, the surviving plantlets were transplanted onto the selection media and cultured under white fluorescent tubes for 16 h daily at 5000 lx.

RESULTS AND DISCUSSION

Gene transfer techniques for many dicotyledonous crops have been successfully developed by using *A. tumefaciens*-mediated gene transfer (Klee et al., 1987). Because of the difficulties involved in transformation and regeneration of monocotyledons using protoplasts (Morrish et al., 1992), microprojectile bombardment was tested to introduce foreign DNA into intact plant cells (Sanford, 1988).

Table 1. Expression of GUS gene introduced by a particle gun in protocorms of *Zygopetalum*.

Rupture disk		Protocorms with blue spots (%)	Average number of blue spot/protocorn	
1100 psi	1 shot	0%	0	(0)
	2 shots	3.3%	1.5	(0.7)
1300 psi	1 shot	4.5%	6.5	(3.5)
	2 shots	28.8%	3.9	(3.4)

Plasmid 221; gold particle size 1.6 μm; (SD); X-Gluc GUS assay; total number of protocorms was 60

Table 2. Expression of GUS gene introduced by a particle gun in seedlings of *Zygopetalum*.

Rupture disk		(%) of protocorm with blue spots	Average number of blue spot/seedling	
1100 psi	1 shot	0%	0	(0)
	2 shots	0%	0	(0)
1300 psi	1 shot	0%	0	(0)
	2 shots	40.0%	14.8	(14.4)

Plasmid 221; gold particle size 1.6 μm; (SD); X-Gluc GUS assay; total number of seedlings: 15

Table 3. Percentage of survival protocorms and seedlings (including transgenic plants) after selection culture with kanamycin.

Rupture disk		Survival percentages of protocorms	seedlings
1100 psi	1 shot	0	0
	2 shots	3.3	0
1300 psi	1 shot	3.3	0
	2 shots	10.7	0.05
	Control	0	0

Plasmid 121; gold particle size 1.0 μm; modified (½ MS) medium containing 500 mg liter^{-1} kanamycin.

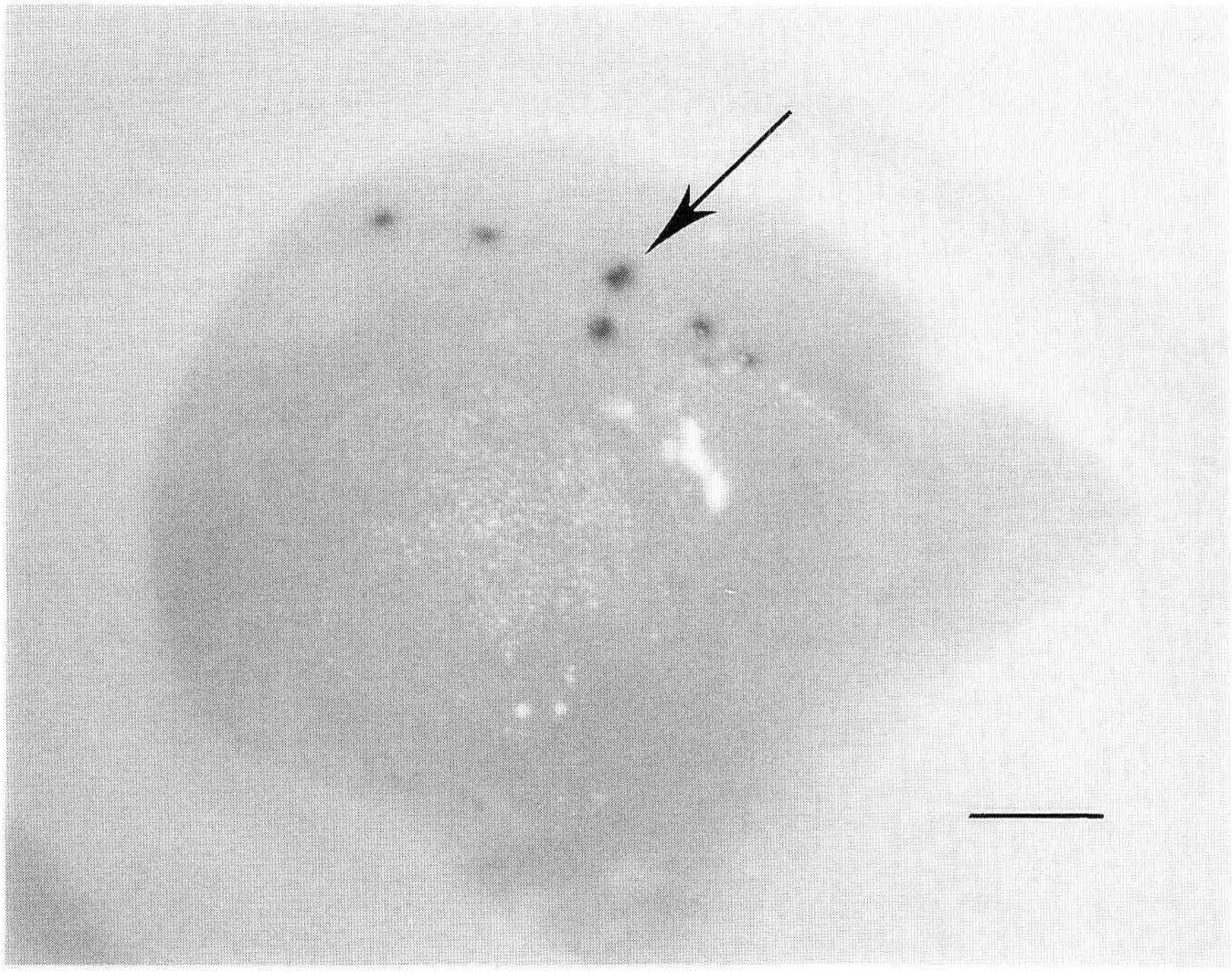

Figure 2. A protocorm with blue spots as the GUS gene expressions, which was treated with a 70% ethanol solution to remove chlorophyll. An arrow points to one of the blue spots. Scale bar = 1 mm.

GUS Transent Assay. In general, GUS (Jefferson, 1988), chloramphenicol acetyltransferase (CAT) (Fromm et al., 1985) and luciferase (Ow et al., 1987) have been used as reporter genes. Expression of the GUS gene introduced by particle gun into protocorms of *Zygopetalum* is shown in Table 1. After a one shot bombardment with 1100 psi rupture disks, no blue spot was observed, in other words, no GUS gene was expressed. However, after two shots, 1.5 blue spots on average were observed in 3.3% of protocorms. After one shot with 1300 psi rupture disks, 6.5 blue spots were observed in 4.5% of protocorms. In the case of 2 shots, 3.9 blue spots on average were observed in 28.8% of protocorms. GUS genes were expressed more when the bombardment was performed by using 1300 psi rupture disks rather than 1100 psi rupture disks, and by two shots rather than one shot, as indicated by the increase in blue spots. Therefore, it is best to bombard the protocorms twice with 1300 psi rupture disks. Figure 2 shows a protocorm with blue spots as the GUS gene expression. There is a possibility that a higher gas pressure than 1300 psi would result in better particle propulsion, because the number of blue spots was relatively small. The expression of the GUS gene introduced by a particle gun in seedlings of *Zygopetalum* is shown in Table 2. When seedlings were bombarded twice with 1300 psi rupture disks, 40% of seedlings exhibited 14.8 blue spots on average as the GUS gene expression. Therefore, it is also desirable to bombard seedlings twice with 1300 psi rupture disks. It seems that 1300 psi gas pressure at least is necessary

to introduce GUS genes into seedlings with a particle gun. It was shown that the target distance of 12 cm is enough to introduce foreign genes into protocorms and seedlings, because the damage to the materials was observed after both one and two shot bombardments. It was found possible to use both 1.6 μm and 1.0 μm diameter gold particles for introducing genes by bombardment.

Survival after selection culture. The survival percentages of both protocorms and seedlings, bombarded by the particle gun, after selection culture with Kanamycin for 3 weeks are shown in Table 3. Very few bombarded seedlings, and no protocorms or seedlings in the control survived after selection culture. If bombarded twice with 1100 psi rupture disks, 3.3% of protocorms survived and with 1300 psi, 10.7% of protocorms survived. Therefore, two shots of the bombardment with 1300 psi rupture disks might be the best way to introduce foreign genes into protocorms. The reason for the low seedling survival rate was because the cells were unable to recover and grow under a state of chimera introduced by a pBI 121 plasmid having NPT II- and kanamycin-resistant genes. On the other hand, 10.7% of bombarded protocorms survived, because if some parts of the cells in a protocorm obtained kanamycin-resistant genes, included in pBI 121 plasmids, by means of the bombardments, a protocorm could recover and grow even from a small surviving part of it in a selection medium containing Kanamycin. In general, a protocorm can grow and develop even from part of a divided protocorm.

Transgenic Plantlet. After 4 months of selection culture, seven plantlets were obtained, which might be transformants with GUS and NPT II genes. However, there is still a possibility that these plantlets escaped foreign gene introduction. It is therefore necessary to detect introduced GUS and NPT II genes by the PCR (polymerase chain reaction) method following the Southern analysis of transgenic plants. Although kanamycin selection using the NPT II gene has been widely used in the recovery of transformed dicotyledonous plants, monocotyledonous cells have been quite resistant (Morrish et al., 1992). It might be better to use geneticin instead of kanamycin for the selection medium. There is also the possibility of using a smaller plasmid in place of plasmid 121, because plasmid 121, containing the NPTII gene (0.8 kb) and the GUS gene (1.9 kb), is relatively large to introduce genes into the HB 101 host. The 35S promoter from cauliflower mosaic virus (CaMV) has been widely used in plant transformation studies including a study to get transgenic plants in maize (Fromm et al., 1990), but it is not regarded as the optimum promoter for use with all monocots, so T-DNA genes for opine synthase, nopaline synthase, or other promoters must be considered in order to increase transformation frequency.

CONCLUSIONS

It was found that GUS and NPT II genes could be introduced into protocorms and seedlings of *Zygopetalum* by microprojectile bombardment. The optimum conditions for introducing two genes were two shots of bombardment with 1300 psi of helium gas pressure. Although there was a possibility of escape from kanamycin, several transgenic plants were obtained after selection.

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Trial of Half-Cotyledon Selection Scheme Aided by Tissue Culture for the Acceleration of Tea Breeding

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NIVOT, Kanaya, MAFF, Kanaya-2769, Kanaya, Haibara, Shizuoka, 830

The breeding of tea plants is a time-consuming job because tea is a woody plant taking many years to grow from seed to maturity—the time of final evaluation of field performance. So, breeders have proposed various early selection procedures at the seedling stage.

In this paper we present a new method using divided halves of seed cotyledons for the early selection of tea. One half is for the maintenance and multiplication of the original stock, cultured on a solid medium (MS basic), and the remaining half

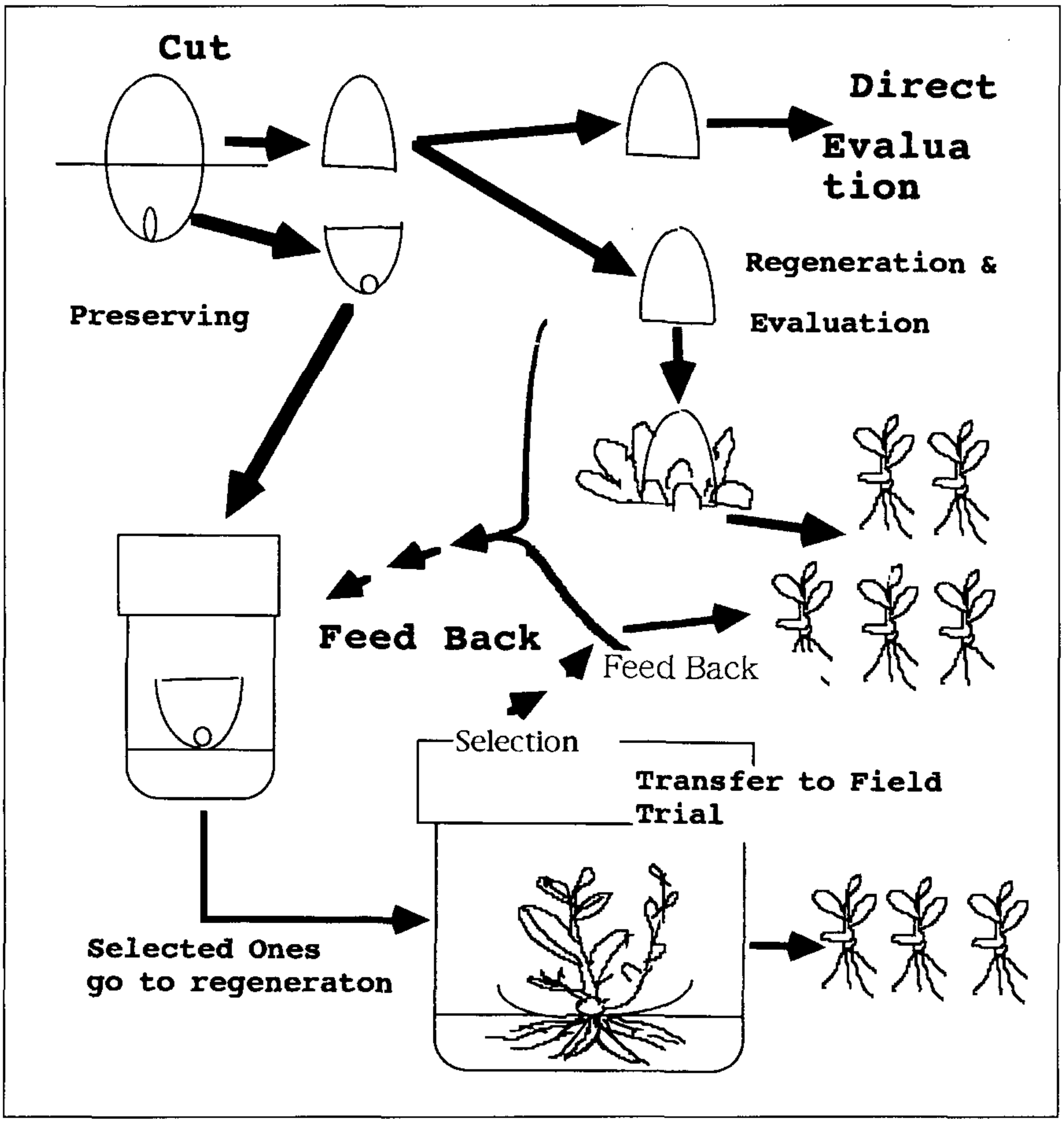

Figure 1. Brief protocol of half-cotyledon selection flow chart.

is used directly (or after multiplication in vitro) for several evaluations (chemical contents, disease resistance, DNA markers, etc.). Feedback seedlings (Fig. 1.) are selected and targeted for the next field trials. This procedure can save several years on the present breeding span (usually 15 to 25 years). A brief outline of our new protocol is illustrated in Figure 1.

Table 1. Results of inoculation trials of tea anthracnose disease resistance on the half-cotyledons of three cultivars of different degree of resistance.

Cultivar	No. cotyledons examined	No. diseased cotyledons	Diseased (%)
Yamatomidori	341	124	36
Sayamakaori	101	66	65
Miya-A—5	183	67	37

Effects of an Anti-Auxin-Like Substance Containing Fluorines and Chlorinated Indole Auxin on the Seed and Vegetative Propagation of Two Turf Species

H. Gemma and J-M. Du
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M. Takemura
Sana Co., Ltd. Exp. Lab. 5-10 Akitsu, Higashimurayama, Tokyo 189

The effects of 4,4,4-trifluoro-3-(indole-3-)butyric acid (TFIBA) and 4-chloroindole-3-acetic acid (4-Cl-IAA) on the seed and vegetative propagation of two turf species were investigated. As a result, TFIBA was seen to promote noticeable root growth on turf seedlings and sod.

INTRODUCTION

Turf is often utilized for the creation of green amenity areas and the prevention of soil erosion (Eguchi, 1988). It is also utilized as a ground cover in parks and sports facilities. Among turf species, bentgrass is multiplied by seed, whereas the multiplication of manilagrass *(Zoysia matrella)* is usually by vegetative propagation (Crockett, 1975). In this study, a number of treatments including a new chemical, an anti-auxin-like substance containing fluorines and chlorinated indole auxin, were applied to both turf taxa at the propagation stage, to find a more efficient method of multiplication.

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MATERIALS AND METHODS

'Penncross' bentgrass seeds were sown in a petri dish containing 0.01, 0.1, 1, and 10 ppm aqueous solution of each chemical: indolebutyric acid (IBA), 4,4,4-trifluoro-3-(indole-3-)butyric acid (TFIBA) (Fig. 1), 4-chloro-indole-3-acetic acid and its methyl ester (4-Cl-IAA and 4-Cl-IAA-Me), and water as the control. Treated seeds were subsequently incubated under 25±1C, 4000 lx and 16-h day length with various germination and growth responses observed.

In the case of Manilagrass, 10 cm × 20 cm sod pieces were submerged in the IBA, TFIBA, and 4-Cl-IAA solutions at concentrations of 0.1, 1, and 10

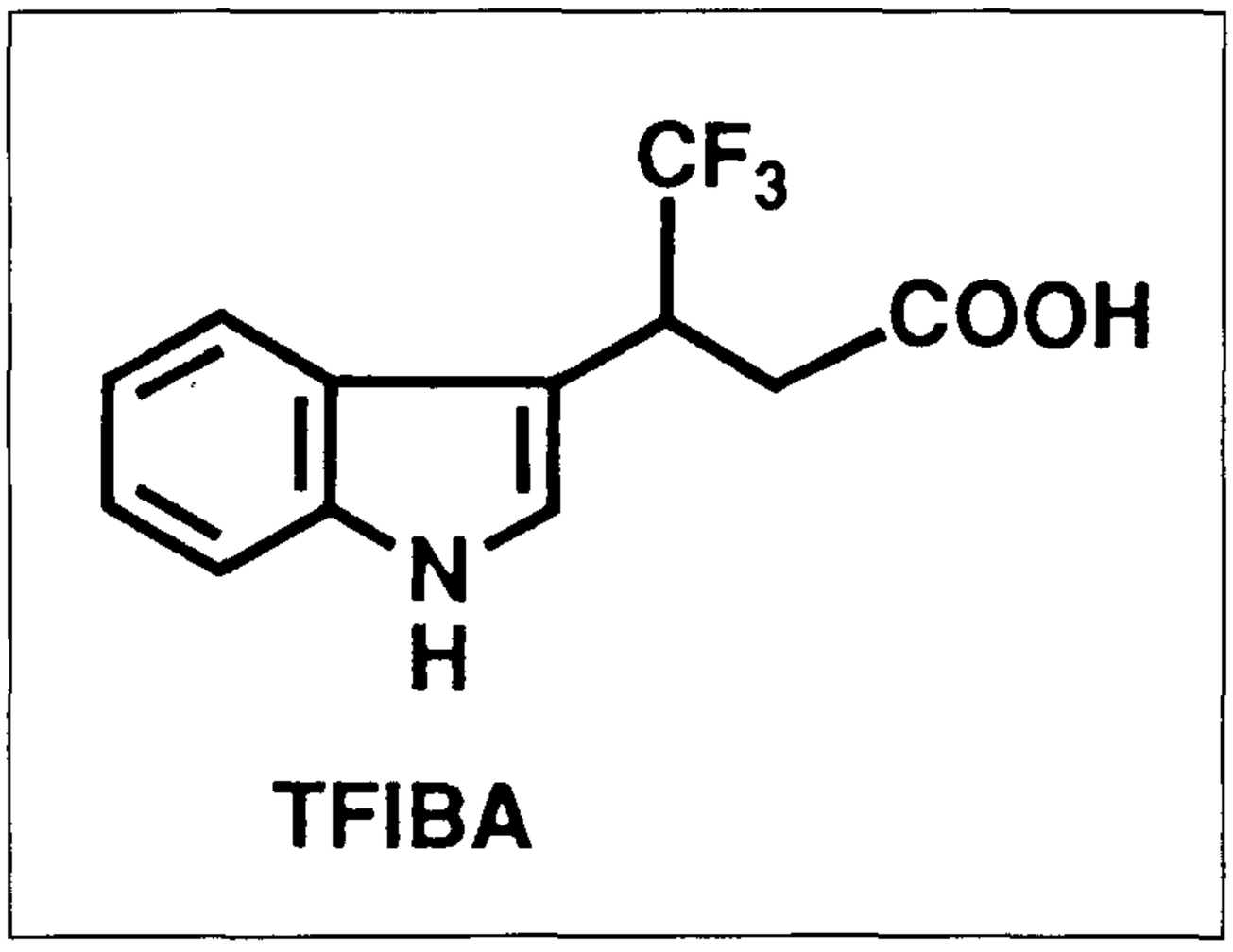

Figure 1. Structure of 4,4,4-triflouoro-3-(indole-3-) butyric acid (TFIBA).

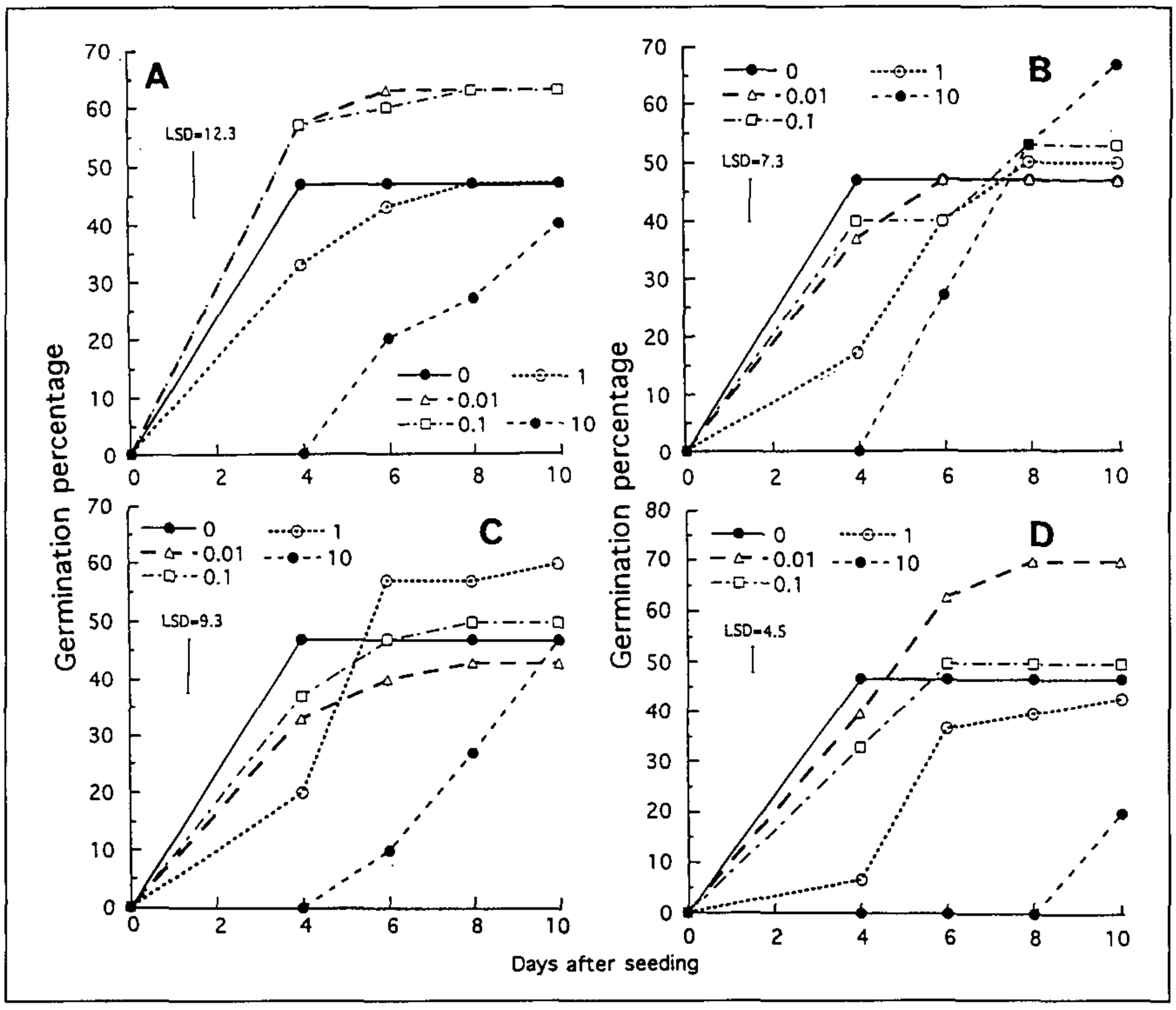

Figure 2. Effects of IBA (A), TFIBA (4,4,4-triflouoro-3-(indole-3-)butyric acid) (B), 4-Cl-IAA (4-chloroindole-3-acetic acid) (C), and 4-Cl-IAA-Me (D) treatment (ppm) on germination rate of turf.

ppm each for 1 h, and then grown in a plastic house from 22 March for 1 month.

RESULTS AND DISCUSSION

Low concentrations (0.01 and 0.1 ppm) of IBA promoted germination but high concentrations (1 and 10 ppm) inhibited it. On the other hand, TFIBA, 4-Cl-IAA, and 4-Cl-IAA-Me increased the ratio of germination 10 days after the seed was sown at the concentrations of 10, 1, and 0.01 ppm, respectively, although the TFIBA showed a tendency to delay germination (Fig. 2). Also, root growth was promoted by the low concentration treatments of IBA and TFIBA (Table 1).

Table 1. Effect of chemical treatments on growth of bentgrass.

Treatments	ppm	Stem length (mm)	Root length (mm)	Ratio of S/R
Control (H_2O)	-	20.2 ab[Z]	35.7 abcd	0.57
IBA[Y]	0.01	19.0 abc	38.8 ab	0.49
	0.1	17.5 cd	40.2 a	0.44
	1	14.3 ef	39.6 ab	0.36
	10	10.9 g	8.3 gh	1.31
TFIBA	0.01	20.4 a	37.3 abc	0.55
	0.1	19.3 abc	38.8 ab	0.50
	1	16.7 cde	32.1 cd	0.52
	10	15.5 de	20.3 f	0.76
4-Cl-IAA	0.01	21.2 a	35.6 abcd	0.60
	0.1	17.8 bcd	30.9 de	0.58
	1	15.8 de	11.3 g	1.40
	10	10.8 g	2.8 i	3.86
4-Cl-IAA-Me	0.01	19.0 abc	33.8 bcd	0.56
	0.1	18.8 abc	26.5 e	0.71
	1	12.3 fg	3.9 hi	3.15
	10	3.0 g	0.4 i	7.50

[Z] Mean separation within columns by Duncan's multiple range test at 5% level.
[Y] Abbreviations: IBA, indole-3-butyric acid; TFIBA, 4,4,4-triflouoro-3-(indol-3-) butyric acid; 4-Cl-IAA, 4-chloroindole-3-acetic acid; 4-Cl-IAA-Me, methyl ester of 4-Cl-IAA.

The results in Table 2 show that root number was enhanced markedly by IBA and TFIBA treatments, and their sods became much greener in colour, suggesting that the chlorophyll content of the leaves might have been increased as a result of these chemical treatments.

Table 2. Effect of chemical treatments on rooting, leaf growth, and viability of sod of manilagrass.

Treatments	ppm	No. of roots	Viability[Z]	Leaf growth[Z]	Greenish color of leaf[Y]
Control (H_2O)	-	66 cd[x]	4.3 ab	3.7 a	-7.5 b
IBA[W]	0.1	102 a	5.0 a	4.7 a	-9.6 a
	1	83 abc	4.1 bc	4.3 a	-8.2 b
	10	97 ab	3.3 c	4.7 a	-8.1 b
TFIBA	0.1	82 bc	3.7 bc	4.7 a	-8.1 b
	1	61 de	3.3 c	4.3 a	-8.2 b
	10	91 ab	3.3 c	4.1 a	-7.5 b
4-CI-IAA	0.1	45 ef	1.7 d	2.3 b	-5.3 c
	1	38 f	1.3 d	2.7 b	-5.4 c
	10	35 f	1.3 d	2.7 b	-5.7 c

[Z] Rating of the degree of each item; from 5 (excellent) to 1 (poor).
[Y] Severity as expressed by Hunter value (a).
[X] Mean separation within columns by Duncan's multiple range test at 5% level.
[W] Abbreviations: IBA, indole-3-butyric acid; TFIBA, 4,4,4-triflouoro-3-(indol-3-)butyric acid; 4-Cl-IAA, 4-chloroindole-3-acetic acid.

The positive effect of TFIBA on root growth in this study agrees with the findings of Katayama et al. (1995) and Kato et al. (1993). They observed that this anti-auxin-like substance promoted the root growth of rice, Chinese cabbage, and lettuce after the treatment of seeds or germinated seeds. Enhanced effect on root growth was not shown with 4-Cl-IAA whereas Ahmad et al. (1987) indicated root promotion on pea cuttings with an application of 10^{-3} M of 4-Cl-IAA compared to the control. The contrary result in this study is possibly attributable to the different concentrations used—Ahmad et al. used about 20 times the concentration used in this study.

Acknowledgement. We thank Dr. M. Katayama, National Industrial Research Institute of Nagoya, for kindly providing the newly produced chemical.

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Flower Production by Japanese in Brazil

Masanobu Arai
Sunami Kaen, 485 Shigesato, Sunami-cho, Motosu-gun, Gifu 501-03

Brazil is 8,500,000 km^2 in area, 23 times as large as Japan, and the population is 146,000,000. Although the capital is Brasilia, the biggest city is Sao Paulo which has a population the same as Tokyo.

Japanese people are involved in agriculture in Brazil, especially wheat farming, and fruit and flower production. Ninety percent of the flower growers are Japanese, and they live around Sao Paulo. Sao Paulo has the same climate as the highlands of Taiwan—it is a subtropical zone. The quality of potted flowers in Brazil, e.g. poinsettia, dendrobium, and ferns, is very high in spite of unheated production systems, because the climate is good for flower production with low humidity and a large difference between day and night temperatures. The growers also use a lot of insulation.

The price of agricultural land is: $10 m^{-2}.
The cost of a glasshouse: $2 to 3 m^{-2} - wooden glasshouse
$6 to 7 m^{-2} - pipe-frame glasshouse
$12 m^{-2} - glasshouse.

Gardening in New Zealand

Jo Dawkins
Dawkins Nursery, Quarry Road, Te Puna, R.D.6, Tauranga, New Zealand

Since the beginning of civilisation, gardens have been mentioned in history—the Garden of Eden, the Hanging Gardens of Babylon, and no doubt Japanese history has important gardens too. Throughout history mankind has used Nature for peace and meditation. The olive branch is a symbol of peace and every country has a national flower.

New Zealand is approximately the same size as Japan and lies in geographically similar degrees of latitude, north and south of the Equator. Tokyo is 36° North, Auckland City 36° South.

The first English settlers arrived in New Zealand 160 years ago. Although the natural vegetation was lush, green, and different, they brought with them reminders of their country—trees, shrubs, flowers, fruit trees, and English birds. Most of the plants grew well and some have become weeds. From this beginning an informal style of gardening has developed using plants from all parts of the world. A flowering *Prunus* can be planted beside a tropical hibiscus, a camellia beside a grevillia, a lapageria from Chile beside an English rose. There are no rules.

Native plants from New Zealand mix well with imported species. Cottage style gardens are very popular using a mixture of flowering shrubs, perennials, and annuals.

Gardening is the number one leisure activity in New Zealand. Every house has its own area of lawn and flowers and some people grow vegetables. Some country homes have large private gardens that are open to the public.

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Garden centres have a big range of plants available throughout the year. Spring is the busiest time for buying and planting. Some garden centres have a restaurant to attract customers and gardening classes are held to help people to learn more about plants and garden design.

In the Bay of Plenty where I live we enjoy a temperate to subtropical climate. Summer temperatures average 25 C, winter 12 C. Annual rainfall is 1310 mm. The soil is fertile. All these factors help to make good growing conditions. The Bay of Plenty is the major kiwifruit growing area, also avocados and citrus are grown and produce good crops.

Propagation of Roses and Transition of Nursery Management

Takashi Onishi
Central Rose Nursery, 772-4 Ichinotubo, Itonuki-cho, Gifu 501-03

INTRODUCTION

Nowadays, people in Japan love to have plants and flowers as a part of their lives and living areas. The consumption of potted miniature roses is increasing because they are cheap, attractive, and have many different coloured flowers. Production is also increasing as it is possible to produce them all year round by means of a short growing period and cutting propagation. We are involved in potted miniature rose production.

HISTORY

1973, April:	The start of rose nursery plant production (100,000 plants per year). Two-year-old plants for garden roses and one-year-old plants for cut roses, propagated by veneer-grafting and bud grafting.
1977, August:	The start of potted floribunda rose production. Construction of pipe-frame glasshouse 600 m^2 (150,000 potted-rose production per year)
1987, September:	Introduction of potted miniature roses (100,000 potted-rose production per year). Introduction of miniature rose cultivars from Meilland (France) and Deluiter (Holland). Propagation by cutting (first grower of year-round production). Use of peat moss (pH 5.5) for propagation bed.
1989, September:	Establishment of Central Rose Nursery Ltd.
1990, April:	Construction of glasshouse (1540 m^2) and office (108 m^2). Three hundred thousand potted miniature roses produced per year. Contract with Kirin Brewery Co. Ltd. and introduction of miniature rose cultivars from Polesen (Denmark).

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1992, April:	Construction of glasshouse (1000 m^2), pipe-frame glasshouse (1320 m^2), and shipping yard (250 m^2) . No.1 grower of potted miniature roses.
1993, September:	Construction of glasshouse (1000 m^2) and automatic irrigation (open field). 500,000 potted miniature roses produced per year. Start of potted conifer production (*Juniperus* 'Gold Crest', 'Gold Star', and 'Silver Star')
1994, February:	Potted miniature roses received a Gold prize from a Floral Exposition in Japan.
1995:	Setting up lighting system in glasshouse for cutting production (3000 lx, 18-h photoperiod). Selling of "Happy Dome"; dried flower miniature roses.

FUTURE

Our future goals are to increase the efficiency of cutting production, decrease the costs of production, and supply goods which meet the demands of the consumer.

Ornamental Horticulture in Australia, the Propagators Role

E. J. Bunker

Redlands Greenhouse Holdings Pty Ltd., 191 Gordon Road, Redland Bay, Qld 4165, Australia

Australia was initially settled by people of European background. The English and European influence in gardens and public spaces is outlined.

A brief resume of early nurseries and their role in a changing society is shown. Australian society changed, so nurseries grew and specialist staff were needed. A propagator who looks after crop scheduling, cutting production on mother stock, and the actual propagation unit is central to every successful nursery.

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Export and its potential in cut flowers, tissue-cultured plant material, and in young green plants is a growing business, expanding at about 12% per year.

A brief review illustrated with slides of the authors business was shown.

1992, April:	Construction of glasshouse (1000 m^2), pipe-frame glasshouse (1320 m^2), and shipping yard (250 m^2) . No.1 grower of potted miniature roses.
1993, September:	Construction of glasshouse (1000 m^2) and automatic irrigation (open field). 500,000 potted miniature roses produced per year. Start of potted conifer production (*Juniperus* 'Gold Crest', 'Gold Star', and 'Silver Star')
1994, February:	Potted miniature roses received a Gold prize from a Floral Exposition in Japan.
1995:	Setting up lighting system in glasshouse for cutting production (3000 lx, 18-h photoperiod). Selling of "Happy Dome"; dried flower miniature roses.

FUTURE

Our future goals are to increase the efficiency of cutting production, decrease the costs of production, and supply goods which meet the demands of the consumer.

Ornamental Horticulture in Australia, the Propagators Role

E. J. Bunker

Redlands Greenhouse Holdings Pty Ltd., 191 Gordon Road, Redland Bay, Qld 4165, Australia

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Setting up a Plant Tissue Culture Laboratory

Lynley Watson
Plant Microculture Laboratories, Auckland, New Zealand

Plant Microculture Laboratories was established in April 1992, with an initial goal to propagate calla lilies (*Zantedeschia*) for local nurseries to grow on to export bulbs and the longer term aim of becoming a contract tissue culture laboratory, undertaking the development and propagation of a wide range of crops, cut flowers, and ornamentals.

The laboratory was set up in an existing building which left some compromises in the design. The available space was allocated to two incubation rooms, a supervisors office and a transfer area to accommodate 12 laminar-flow hoods. The kitchen and development laboratory were established in a separate area.

It soon became apparent that the process of tissue culturing large volumes of plants requires an encompassing quality system and a decision was made to implement the ISO 9002 system which is internationally recognised and well suited to such an operation. We expect to gain accreditation to this standard in October this year (1994).

Calla lilies were the first crop produced in the laboratory and in our first season in excess of 1 million tissue cultured plantlets were shipped to local growers. The callas are initiated from mother bulbs which are virus tested by ELISA prior to entering the laboratory. Appropriate secondary buds are selected for tissue culture and the mother bulb is then grown on to flowering to check for high health and true colour. Once initiated, each meristem is checked for sterility prior to transfer to a media containing high cytokinin to promote bud multiplication. In the latter stages the cytokinin in the media is reduced to promote bud extension and finally rooting, and the plantlets are shipped from the laboratory as a well-rooted, healthy, young plant approximately 5 cm high.

After 2 years we are producing a wide range of plants and putting considerable emphasis on new product development and the application of methodology which will reduce the labour content of our business. In the future we plan to become involved in gene transfer technology, through collaboration with university and government department research facilities. Our commitment is to produce a quality product through an innovative and service-oriented approach, backed up by an ongoing development programme.

Propagation and Production of *Zantedeschia* Tubers for Export

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B. L. McKenzie
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The floriculture industry in New Zealand is gaining a reputation for the supply of novelty flowers to world markets. *Zantedeschia* (calla) has been one of the bulbous crops gaining in importance for exports of both cut flowers and dormant tubers. This paper will outline the various techniques used for propagation and provide detail on production of flowering-size tubers from a propagule.

Seed propagation has been a common means for reproduction of true species or open-pollinated selections. However, the diversity of colour type and growth habit are greatly limited from seed-true lines. The hybrid selections which make up the mainstream of the New Zealand export industry are clonally propagated by tissue culture. Natural division of established tubers is sometimes used as a means of increasing flowering stock, however, divided tubers are likely to carry over disease and they are not recommended as export quality stock.

Zantedeschia propagules require two growing cycles to become a natural flowering-grade tuber (4- to 6-cm diameter). In the first growing cycle explants are removed from the flask with roots developed and one leaf unfurled. Agar is removed and plants are established in a pine-bark soilless growing substrate contained within plastic or polystyrene open trays. Density in the first growing cycle is 400 per m^2 or 5 cm apart. Newly established plants are treated with fungicide and placed in an acclimatisation environment with reduced light levels and high humidity for 10 days.

During the cycle, irrigation is applied overhead and nutrition is achieved by a combination of controlled-release and foliar application. The main pest to protect against is aphids (vectors for Dasheen Mosaic Virus). Fungal disease organisms include *Rhizoctonia, Pythium,* and *Phytophthora* which are readily controlled by soil drenches. The duration of the growing cycle is 6 months from establishment. Dormancy is brought about by withholding irrigation.

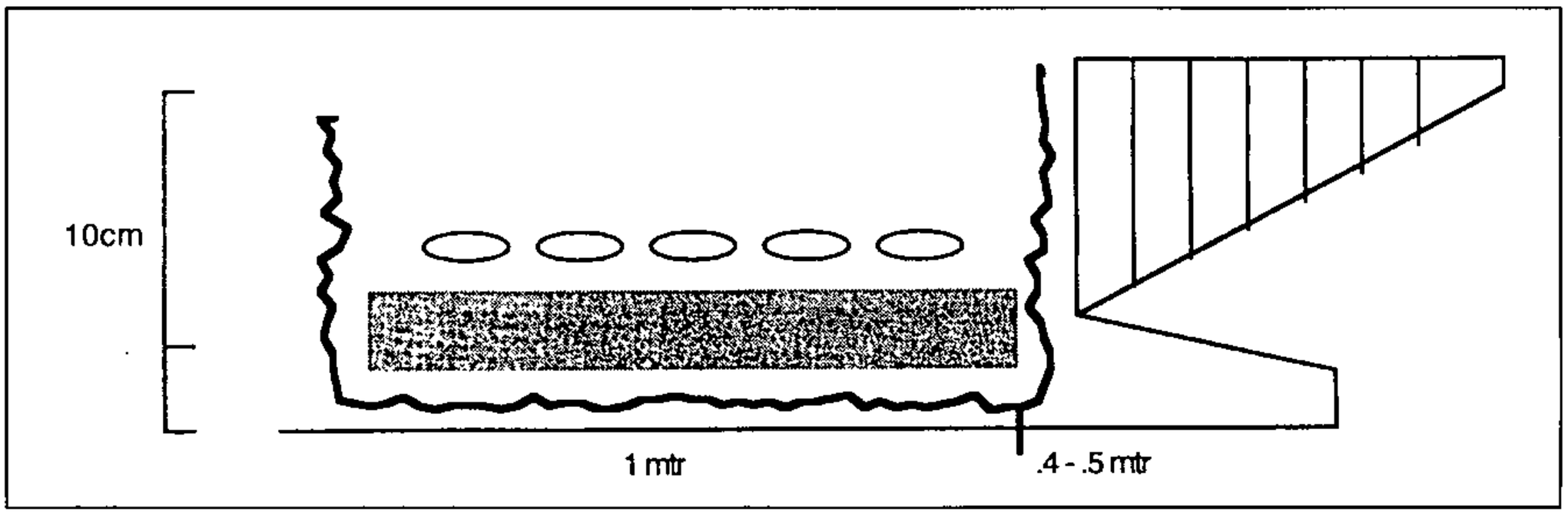

Figure 1. A diagram from a cross section of strata culture beds.

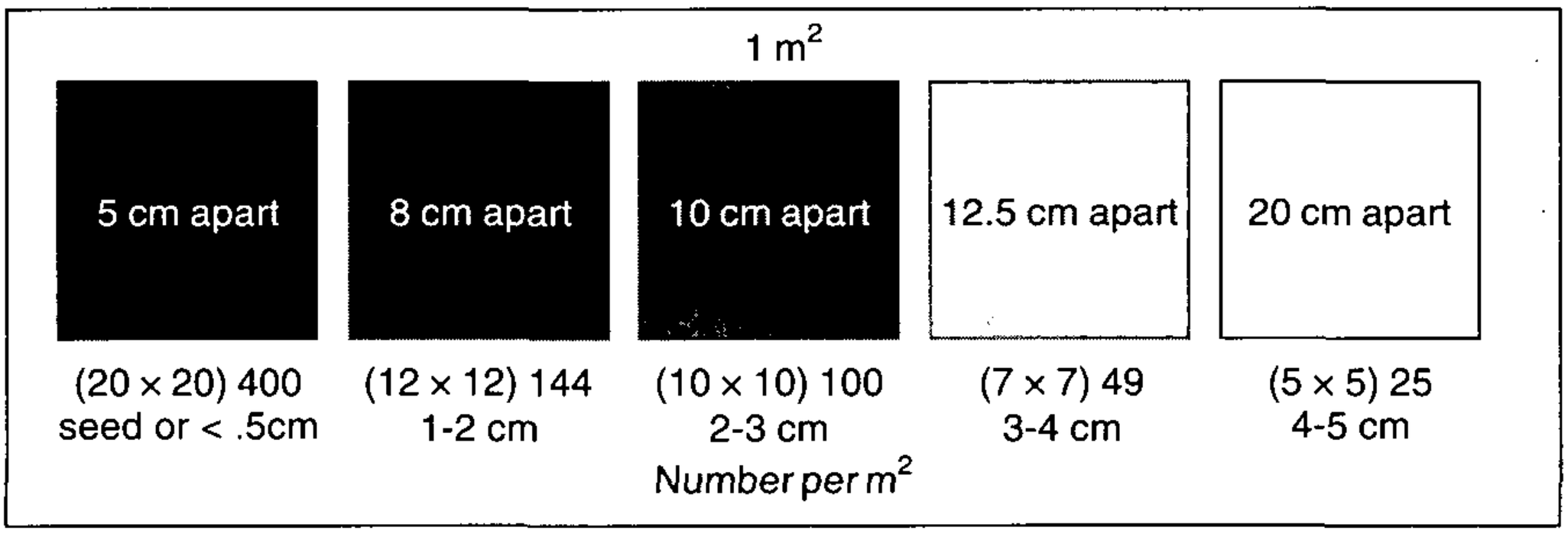

Figure 2. Planting densities for various tuber sizes.

At the conclusion of the growing cycle, the tubers are removed from the trays, cured, cleaned, and graded for size. Tubers are cured under ambient air temperatures away from full sun when lifted in late summer and autumn. If lifting occurs in winter, curing takes place at 20 to 30C with forced air movement for a period of 3 to 5 days. Desiccated roots and shoots are removed and clean tubers are placed in wire mesh trays apical side up for storage. Storage temperatures are kept between 15 to 20C for immediate replanting after 6 to 8 weeks. If long-term storage is required (up to 6 months) tubers should be held at 8C and packed in dry material, such as sawdust or rice hulls, to avoid over-dehydration. Tuber size will range between 1 to 3 cm in diameter.

A flower may be obtained from tubers 2-cm diameter and larger. However, flower length will be short (20 to 30 cm) and it is generally advised to grow on marble size tubers for another cycle. The second growing cycle is often carried out in open fields, however, protected cultivation as described in this paper is gaining in popularity. Protected cropping of tubers during the second growing cycle gives reduced losses from disease and tubers ready for dispatch at times more favourable to Northern Hemisphere demands.

A growing system titled "strata culture" is employed for protected cropping in the second cycle. Strata culture provides for efficient use of labour in planting and harvesting. Tubers are harvested clean and do not require washing. Density in the second cycle is dependant on starting size: 1 cm at 144 m^{-2}, 2 cm at 100 m^{-2},and 3 cm at 64 m^{-2}.

To set up strata beds, soil is prepared in the usual manner with controlled-release fertilisers incorporated. Woven shadecloth at 70% to 80% mesh is placed over the cultivated bed in sections no longer than 2 m. A layer of untreated sawdust is placed to the depth of 25 mm and tubers are set on top at the desired density. A minimum of 75 mm of sawdust is placed over the tubers. Frequent overhead irrigation is required until roots have emerged and penetrated through the mats into the soil substrate. The mulch effect of the sawdust will keep roots moist and cool. Weeds will also be kept at bay as there will not be sufficient light for germination.

At the end of the growing cycle water is withheld for 4 weeks prior to lifting. Mats are easily lifted by hand and workers can lift and sift out 1350 tubers per person per hour. Once lifted, tubers are cured identically to those harvested after cycle one. Cleaning and storage is also the same after each growing cycle. Tuber size will range between 4 to 6 cm at the conclusion of the second growing cycle.

Protected cropping will greatly reduce *Erwinia* soft-rot infection if growing cycles are scheduled to commence or conclude during the warm months of summer. In New Zealand, early planting in June/July under heated glasshouse conditions (16C minimum) gives finished tubers ready to lift in January. After an 8-week rest period tubers are ready for dispatch and planting in March. *Zantedeschia* are day-length neutral and scheduling for year-round production of tubers and cut flowers is possible.

Propagation of *Camellia japonica* in Horticultural Rockwool

Ralph Scott
Spencer Scott & Sons, Kurrajong Heights, New South Wales, 2758 Australia

Our Nursery grows 225,000 camellias annually and is situated at Kurrajong Heights which is 80 km west of Sydney in the Lower Blue Mountains at approximately 500 m above sea level. The climate is mild with minimum temperatures of 0C in the early mornings during winter, to a maximum of 40C during mid summer.

Propagation commences in mid December, which is early summer in Australia.

Our Nursery began using rockwool 10 years ago, when we were researching different propagation materials. The rockwool is delivered to the nursery in sheets, each of these consisting of 21 smaller blocks measuring 38 mm × 38 mm × 57 mm

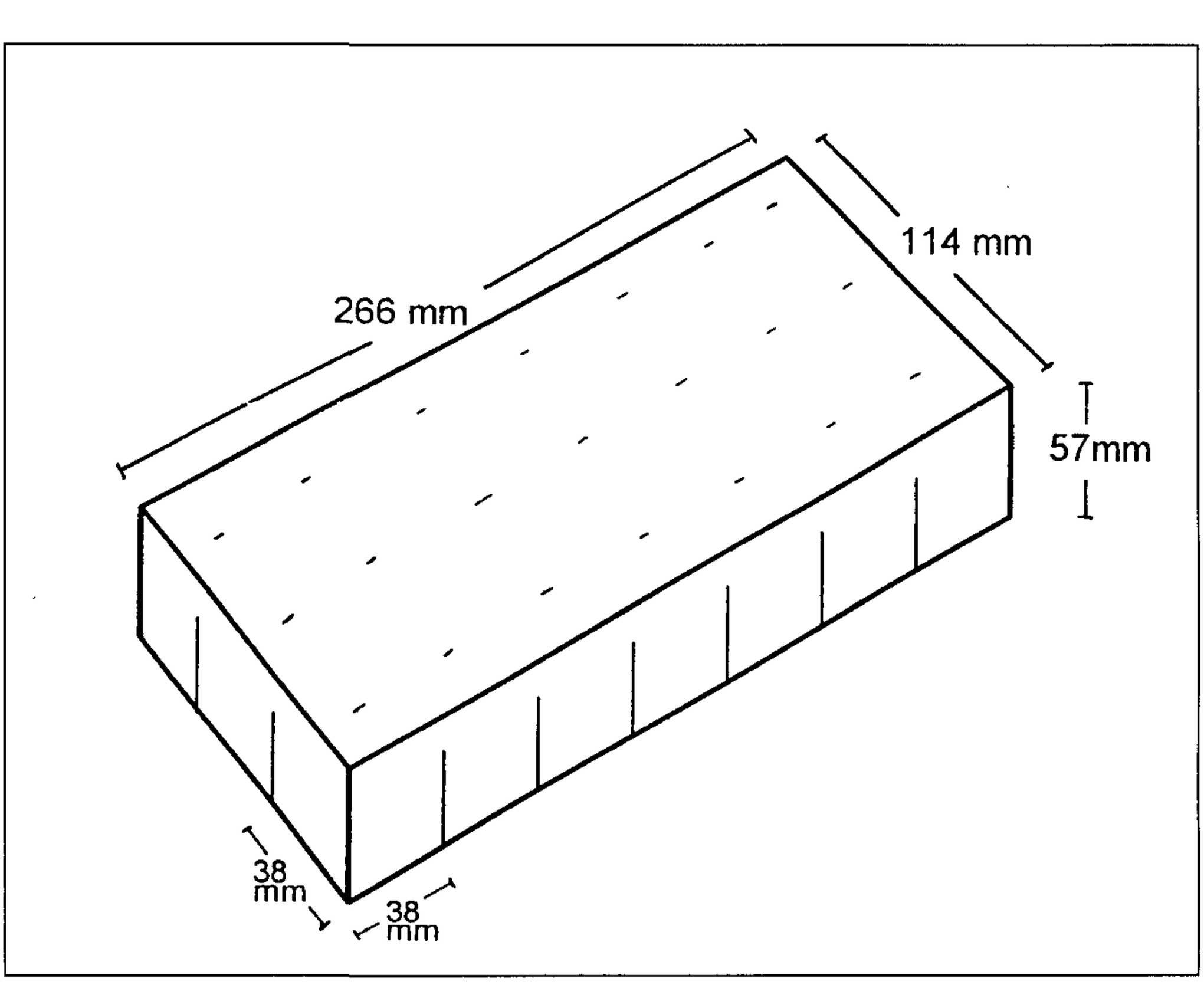

Figure 1. Rockwool sheet not to scale.

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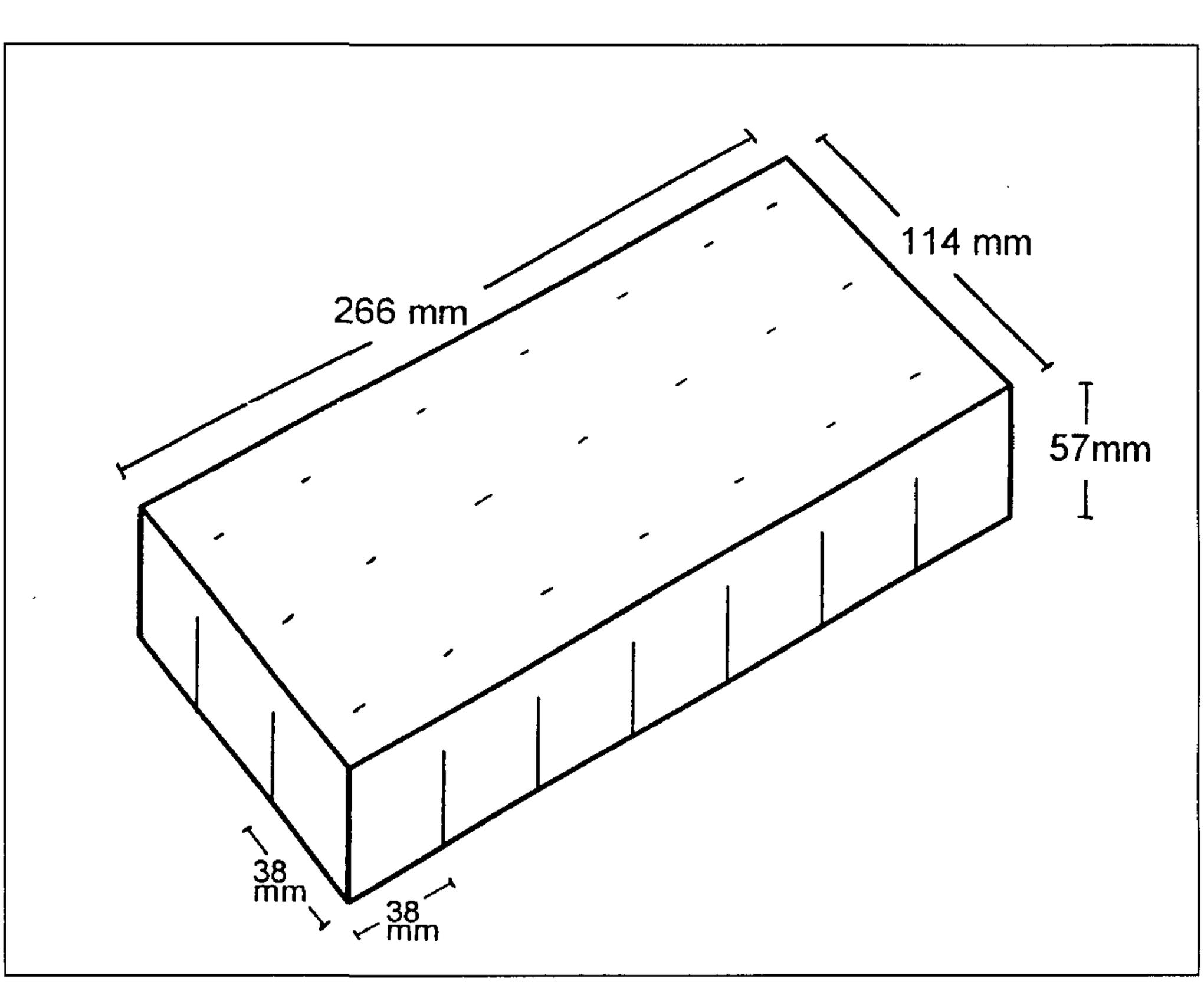

Figure 1. Rockwool sheet not to scale.

with the sheet measuring 266 mm × 114 mm × 57 mm (Fig. 1).

The sheets of rockwool are placed on sand beds on glasshouse benches, where the beds are heated by electrical cables controlled by a thermostat to maintain a temperature of around 25C. Blocks are placed on the bench in numbers that can be used during that day, as leaving blocks overnight results in a greater chance of material contamination and makes them more difficult to work with.

The rockwool is watered thoroughly at this stage to ensure the material is saturated through to the base of the blocks.

The sticking of cuttings begins immediately after watering. The cuttings we work with are those of semi-hard new-season growth measuring 100 to 150 mm in length, with a minimum number of base leaves removed to enable sticking to take place in the medium. The base of the cuttings are lightly wounded and dipped in a talc striking powder, the active ingredient being 16 g of indolebutyric acid per kilogram of talc.

The cuttings are inserted into the rockwool and watered immediately, the remainder of the watering is carried out via intermittent mists of 10 sec every 10 min during daylight hours, unless the weather is very hot when misting occurs every 8 min. Fungicide is used only if necessary.

Callus is noted about 2 weeks after sticking with roots appearing after about 5 weeks. Potting can be commenced after about 8 to 10 weeks.

As a propagation material, rockwool is of great benefit to us as the material is sterile and easy to handle. We grow no other crops so the use of rockwool is no problem. If used in multiple crops some problems could be encountered from different plant requirements.

Juvenility and Rooting Potential on the Stem Cuttings of *Pyrus betulaefolia*

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To establish a method for cutting propagation of *Pyrus betulaefolia*, an attempt to understand the biochemical mechanism of juvenility which increases the rooting potential was made by analyzing the endogenous polyamines in cuttings taken at different stages during the rooting process. As expected, cuttings taken from the juvenile phase showed higher rooting potential than those from the mature phase. When treated with 30 ppm IBA, endogenous putrescine (Put) increased in parallel with increased rooting. In contrast to juvenile cuttings, changes in Put, spermidine (Spd), and spermine (Spm) in mature cuttings were less even with IBA treatment.

INTRODUCTION

Pyrus betulaefolia is a superior rootstock for Japanese pear because of its well developed root system which helps prevent certain physiological disorders of the fruit, e.g. yuzuhada (rough skin). Because of these advantages, it is desirable that the seedling rootstocks currently used be replaced by clonal rootstocks in order to avoid the wide variation in characteristics found in seed-propagated rootstocks.

Many factors are important in the rooting of cuttings, however, juvenility is one of the most important. In general, the rooting potential of cuttings from the basal part of a plant (juvenile region) is higher than from the apical part of a mature plant (adult region). The differences in the biochemical and physiological status between different growth phases is not known. The objectives of this study were: (1) to determine the difference in rooting capability on the cutting of juvenile and mature *P. betulaefolia,* (2) to investigate the biochemical significance in both types of cuttings of endogenous polyamines which have a role in senescence of plants (Galston and Sawhney, 1987) and possibly rooting, and eventually (3) to establish the methodology for cutting propagation of *P. betulaefolia.*

MATERIALS AND METHODS

Cuttings were prepared from current shoots arising from basal and terminal parts of a 20-year-old *P. betulaefolia* plant—the basal portion with thorny growth and round leaves (characteristics associated with the juvenile phase) and the apical portion from the mature phase. Green stem cuttings, approximately 12 cm long with 3 to 4 leaves were taken. After submerging the base of the cutting in 30 ppm IBA solution for 24 h, they were transferred to the propagation bench in a glasshouse equipped with a mist propagation system.

Polyamine extraction and analyses were carried out on the stems and leaves of both cutting types—with or without IBA treatment—as follows. Tissue samples were homogenized and extracted with 5% $HClO_4$ at 4C. After centrifugation at

20,000 g for 20 min, the supernatant was benzolated by a reaction of NaOH and benzoyl chloride, and then subjected to HPLC analysis. The HPLC conditions were: mobile phase, acetonitrile and water (1:1, v/v); column, C 8 reverse phase; detection, UV at 254 nm (McDonald and Kushad, 1986).

RESULTS AND DISCUSSION

Rooting was significantly faster and higher in basal cutting than from apical cuttings, although percent rooting in both was relatively low which was probably an inherited quality from the mother plant (Fig. 1). Since the apical part of the mother plant was already mature ontogenically, it was expected that the rooting potential would show a difficult-to-root character (Heuser, 1976; Smith, 1985).

Table 1. Changes in endogenous putrescine level in stems of *Pyrus betulaefolia* cuttings taken from basal portion of mother plant (referred to as juvenile phase) during rooting process.

Days after planting	IBA	Control
	nmol g^{-1} FW	
0	28.63	
10	4.663	9.697
20	9.411	7.301
30	15.028	6.001
40	20.027	7.832
50	20.950	11.822

The polyamines were separable under reverse phase HPLC (Fig. 2) and putrescine (Put), spermidine (Spd), and spermine (Spm) were identified as the major polyamine by comparing retention times with benzoyl standards. Changes in Put contents in IBA-treated and non-treated cuttings from juvenile phase cuttings during the rooting process are shown in Table. 1. Put decreased after sticking and then increased with time; the content of which was greater in IBA-treated than in non-treated cutting 20 days after sticking. This increase coincided with root initiation in the cuttings. These results are similar to those shown by Jarvis et al. (1983), who observed, using stem cuttings of mung bean, enhanced levels of polyamines in the hypocotyl prior to primordium formation when IBA was applied. They implied this response might be associated with the changes in RNA metabolism leading to the initiation of adventitious root primordia. The changes in polyamine contents expressed as nmol per g fresh weight showed different tendencies between juvenile phase and mature phase cuttings during the rooting process (Fig.3). Put in leaves and stems gradually increased at the later period in juvenile cuttings. Despite IBA-treatment Put in mature cutting did not increase. In contrast, Spd tended toward a decrease on both cutting types with an exception of a conspicuous increase in leaves of cuttings from juvenile phase 30 days after planting. These changes was similar to that of Spm, however, Spm in leaves and stems of mature cutting and in stems of juvenile cutting was mostly stable until

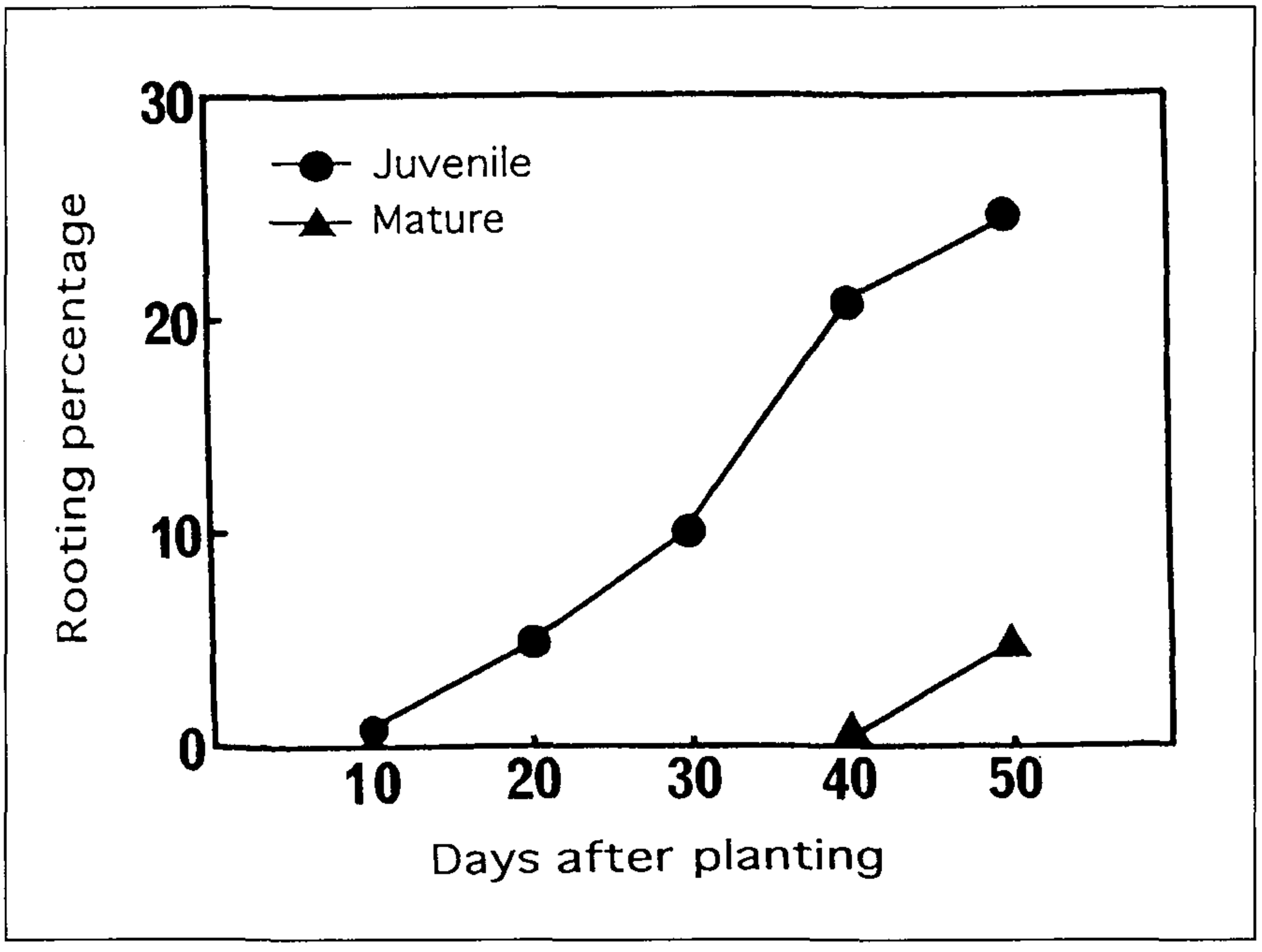

Figure 1. Rooting response of juvenile and mature *Pyrus betulaefolia* cuttings.

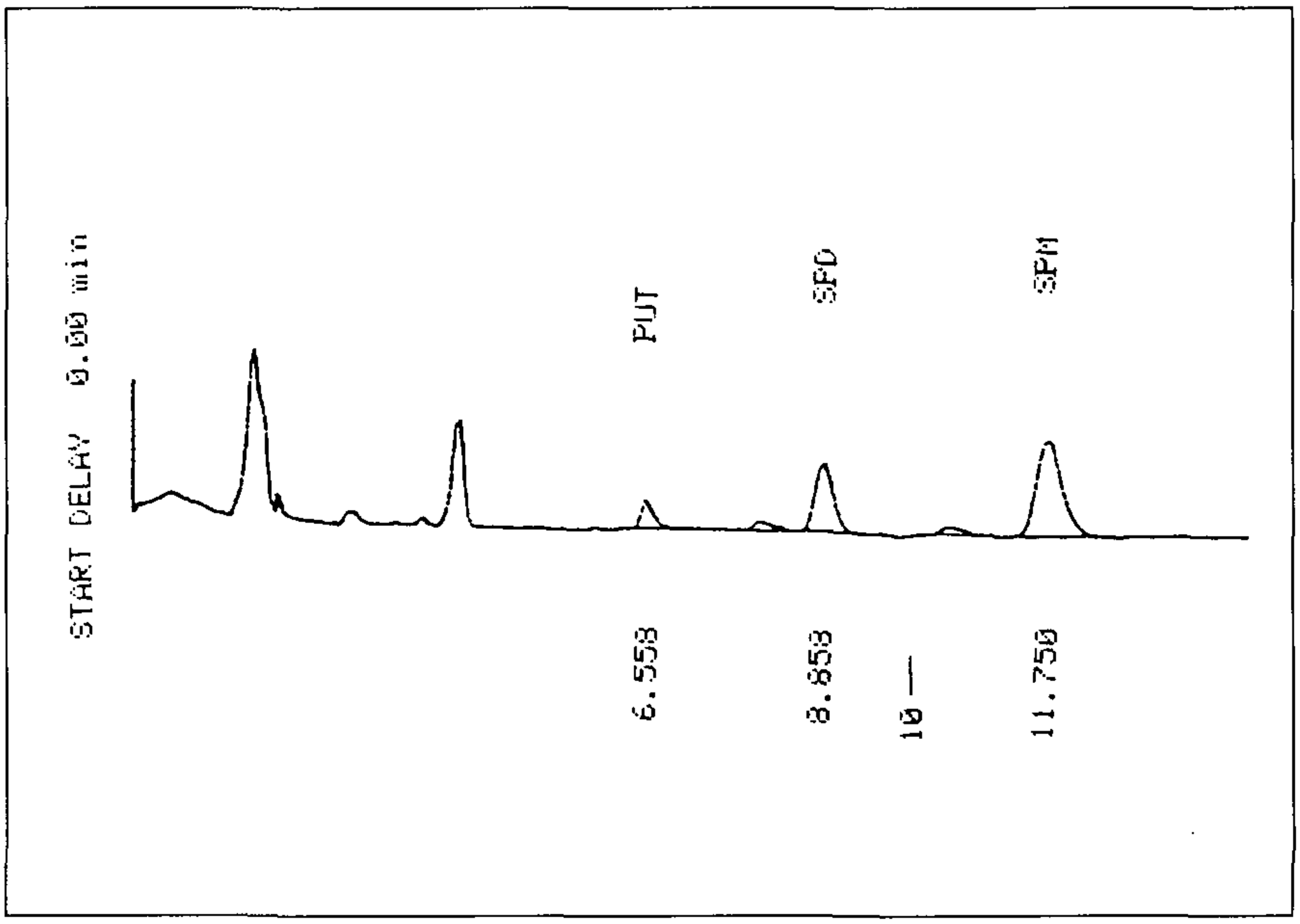

Figure 2. HPLC chromatogram showing the extracted sample containing putrescine (Put), spermidine (Spd), and spermine (Spm) identified as major polyamines.

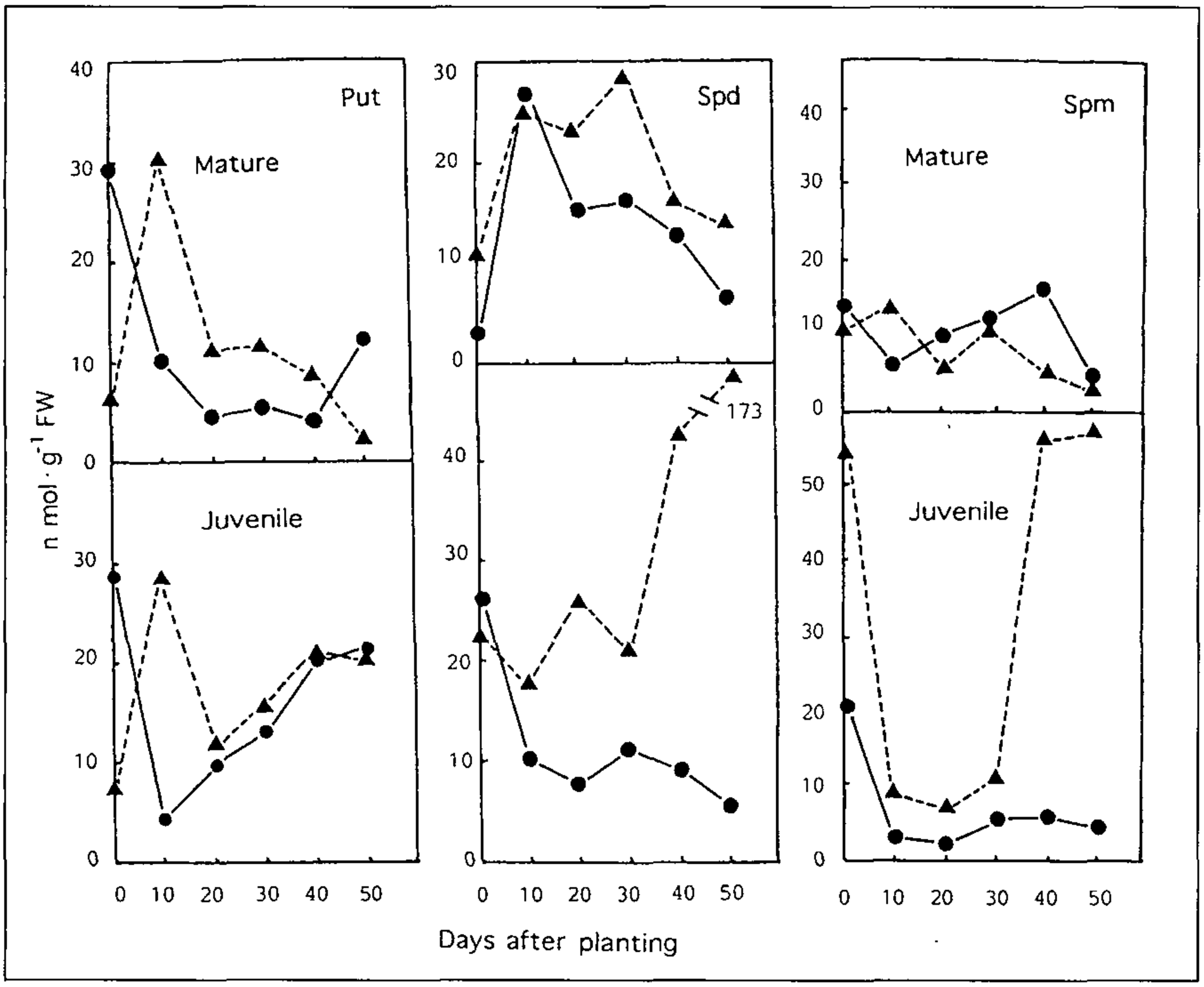

Figure 3. Changes in polyamine levels in stem (-●-) and leaves (--▲--) of *Pyrus betulaefolia* cuttings from juvenile (bottom) and mature phase (top) during rooting process.

termination of the rooting period.

As to differences in rooting potential between cuttings taken from different growth phases (juvenile and mature phases), it has been postulated to result from significant difference in rooting cofactor (Heuser, 1976) or endogenous ethylene level (Geneve et al., 1990). However, it also could be polyamine level is associated with juvenility in relation to rooting potential.

Polyamine levels have been reported to increase considerably in parallel with root formation of apple seedlings (Wang and Faust, 1986) and adventitious root formation in sweet cherry shoot cultures (Biondi et al., 1990). The result of this study was mostly in agreement with their data. Particularly, Biondi et al. (1990) emphasized the involvement of polyamines in root initiation which could be accompanied by action of ethylene based on the competitive relation in both biosythetic pathways (Galston and Sawhney, 1987). Nevertheless the role of ethylene in adventitious root formation is still unknown. The pattern of ethylene production stimulated by exogenous auxin application was significantly different in juvenile and mature debladed petioles of English ivy suggesting reduced ethylene level might be a prerequisite for root initial out-growth (Geneve et al., 1990). As shown in this study, Spd and Spm contents in leaves of juvenile cuttings, which show a good-rooting potential, increased markedly at the later rooting period. This seemed to be in accord with hypothetical ethylene function in the rooting process

on the basis of polyamine-ethylene competition in their synthesis pathway. In addition, it could also be considered that higher Put levels in juvenile cuttings involve easy- or different-to-root potential as mediated by RNA metabolism. For better understanding of juvenility and rooting potential further studies concerning auxin, ethylene, and polyamine relations are necessary.

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