Stimulating Natural Plant Defences for Disease Control

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There are problems associated with repeated pesticide use including the build up of toxic residues, the development of pathogen resistance, and adverse effects on nontarget beneficial organisms. The withdrawal of some very effective fungicides and a global trend towards lower pesticide inputs has generated greater interest in the development of disease control strategies that are safer and more environmentally acceptable. One possible alternative, induced resistance, involves the use of treatments which increase disease resistance in plants by stimulating their natural defence mechanisms. Induced resistance has been demonstrated to be effective in controlling disease development in several economically important crops. The integration of induced resistance with other biological control approaches such as the use of antagonistic microorganisms and antimicrobial natural products may offer practical methods for controlling plant diseases and reducing our dependency on synthetic pesticides.

INTRODUCTION

Plants defend themselves against pathogens using a combination of chemical and physical resistance mechanisms, some of which are preformed and others which are induced after infection (Dixon et al., 1994). Recent advances in our understanding of plant/pathogen interactions indicates that disease often occurs because of a delay in the defence response rather than because of the absence or inactivation of any particular defence mechanism. Indeed, many of the defence responses observed in resistant plants are also observed in susceptible plants, although usually later and to a lesser extent.

Plant defences can also be activated in the absence of infection by compounds called elicitors. Several elicitors have been identified, including extracts of microbial and plant origin, as well as several organic and inorganic compounds (Kuc, 1987; Lyon et al., 1995a). The use of elicitors to activate defence mechanisms in susceptible plants and thereby increase their resistance to pathogens has been suggested as an alternative approach for crop disease control (Kuc, 1987; Lyon et al., 1995a). This has sometimes been called "induced resistance" and it is proposed that elicitor treatment accelerates and intensifies the plants defence response to subsequent infection. Induced resistance against fungal, bacterial, and viral pathogens has been demonstrated in several important crops worldwide, including cereals, legumes, solanaceous plants, trees, and small fruits (Tuzun and Kuc, 1991). This paper presents an overview of different methods which have been shown to induce plant resistance and discusses the practical integration of induced resistance into disease management strategies.

MICROBIAL ELICITORS

Previous inoculation of plants with either avirulent strains of a pathogen or with non-pathogens have been shown to induce resistance to subsequent infections. This phenomenon was first documented nearly 100 years ago (Ray, 1901; Beauverie,

1901) when attenuated strains of *Botrytis cinerea* were shown to induce resistance in *Begonia*. Plants previously injected with the attenuated strain or grown in soil inoculated with the attenuated strain were shown to be resistant to subsequent inoculation with highly virulent strains of *Botrytis*. Interest in this approach to plant protection continued in the early part of this century and in 1933 Chester published a review in which he documented several examples where the "vaccination" of plants, whether with attenuated strains or with extracts of pathogens, resulted in increased resistance towards subsequent infection.

The first detailed laboratory analysis of induced resistance was published by Ross in 1961 who demonstrated systemic induction of resistance against tobacco mosaic virus (TMV) in tobacco plants following inoculation of lower leaves with TMV. More recently stem injection of tobacco with spores of the blue mould fungus (*Peronospora tabacina*) was shown to induce systemic resistance to blue mould under glasshouse and field conditions (Tuzun and Kuc, 1991). Resistance was elicited by a single injection and was reported to persist throughout the growing season. Induced resistance was shown to coincide with the accumulation of pathogenesis-related (PR) proteins including beta-1,3-glucanase and chitinase. A single elicitor application has been shown to protect plants against a broad range of pathogens. For example, resistance against fungi, bacteria, and viruses (Tuzun and Kuc, 1991) as well as some insects (McIntyre et al., 1981) was induced in cucumber following inoculation of the first true leaves with a necrosis-forming organism. Gregersen and Smedegaard-Petersen (1989) demonstrated that not only pathogens and nonhost pathogens but also saprophytes are capable of inducing resistance in barley. There are numerous other examples of induced resistance in response to pathogens and nonpathogens, however, it has been suggested that the use of such organisms in the field may be problematic if handled carelessly (Tuzun and Kloepper, 1995) .

FUNGAL EXTRACTS

Carbohydrate components from fungal cell walls are amongst some of the most potent elicitors of plant defence. Yeast cell-wall extracts (YE) have been shown to induce resistance against important diseases such as barley powdery mildew, grey mould and stem rot on lettuce, and chocolate spot on beans (Reglinski et al., 1994a,b; 1995; Lyon et al., 1995b). Yeast cell-wall extracts induced a rapid stimulation of phenylalanine ammonia-lyase activity in barley and accelerated papilla formation leading to a 90% reduction in powdery mildew infection (Reglinski et al., 1994a,b).

Chitosan is a structural component of fungal cell walls and has received a lot of attention as a potential agent for controlling postharvest diseases (Wilson et al., 1994; El Ghaouth, 1997). Application of chitosan to stem scars in tomato, strawberry, and bell pepper fruit was shown to induce defence-related enzymes including peroxidase and beta-1,3-glucanase. Chitosan is also directly antimicrobial and was shown to inhibit the radial growth of a range of postharvest pathogens. The combination of antifungal and resistance-eliciting properties is potentially very useful for crop protection.

MICROBIAL METABOLITES

Metabolites produced by some saprophytic bacteria and fungi were shown to induce resistance in a number of hosts against fungal pathogens, without any direct antagonistic effect on the pathogen (Schonbeck et al., 1986). The metabolites gave

a high degree of disease control in the field against powdery mildew of cucumber and, in particular, wheat where mildew was reduced by over 90%, but were less effective against mildew on grape. The induction of resistance with microbial metabolites was associated with a reduction in the number and size of mildew colonies and a reduced sporulation rate (Steiner et al., 1988).

Some fungi that have been used for the biological control of plant pathogens have been shown to produce extracellular enzymes and metabolites that induce the plant hypersensitive response. This defence response is characterised by a rapid collapse and desiccation of host tissues adjacent to the site of attempted infection. A commercially available cellulase preparation from *Trichoderma viride* (Onozuka R-10) has been shown to stimulate production of antimicrobial compounds and the hypersensitive response in grape cell cultures (Calderon et al., 1993).

COMPOSTS

The benefits of using composts to maintain soil fertility and plant health have been known for centuries. In addition to providing essential nutrients compost-amended soils have been shown to reduce the severity of root rots, vascular wilts, and nematode diseases. Composts are believed to control disease through direct antifungal activity and also indirectly through the induction of host plant defences. In cucumber and arabidopsis plants grown on a compost mix, antifungal hydrolytic enzymes were only induced following pathogen infection so indicating that the compost-induced resistance involved priming of the host defences rather than direct activation (Zhang et al., 1998). Aqueous extracts of composts, from both animal sources and plant sources, have been used to control botrytis, downy mildew, and powdery mildew (Elad et al., 1996). The active component(s) in these sprays have not yet been identified.

Resistance induced by different composts against anthracnose in cucumber (Zhang et al., 1996) and *Xanthomonas* in radish, tomato, and lettuce was highly variable (Miller et al., 1997). This may be partly explained by the highly complex nature of composts which contain a variety of chemical and microbial components. Many of these individual components have been shown to induce systemic resistance in plants. Little is known about the interactions which occur between these components in a compost and how they influence the ability of compost to induce disease resistance. However, sterilization of composts resulted in a loss in their ability to induce plant resistance and so microbial populations appear to play a crucial role (Hoitink et al., 1997). The variability of composts as elicitors of resistance is likely to prove the biggest problem for their practical implementation at present.

PLANT GROWTH-PROMOTING RHIZOBACTERIA

Some soil and root colonising bacteria promote plant growth either directly, by producing plant growth regulators, or by stimulating nutrient uptake, or indirectly by suppressing pathogens. These bacteria are often referred to as plant growth-promoting rhizobacteria (PGPR). There is increasing evidence that selected PGPR (mainly *Pseudomonas* spp.) can also induce systemic protection against pathogens (Wei et al., 1991, 1996). Spatial separation of PGPR strains and pathogenic strains, using split root systems, demonstrated that disease control was not due to direct effects but rather due to the induction of plant resistance (van Peer et al., 1991). Plant growth-promoting rhizobacteria are effective as either a seed or as a soil treatment and have been shown to induce resistance in a number of plants against

fungi, bacteria, and viruses (Maurhofer et al., 1994; Hoffland et al., 1996). In recent field studies seed treatments with PGPR strains were shown to promote early season growth and to induce resistance against angular leaf spot (*Pseudomonas syringae*) and anthracnose (*Colletotrichum orbiculrae*) in cucumber (Wei et al., 1996).

Several studies have shown that PGPR-induced resistance is associated with the stimulation of host defence mechanisms. For example, induction of resistance by *P. fluorescens* was associated with an accumulation of phytoalexins in carnation (van Peer et al., 1991) and an increase in pathogenesis-related (PR) protein levels in tobacco (Maurhofer et al., 1994). However, the accumulation of PR proteins is not a prerequisite for the expression of resistance suggesting that different pathways of induction may be involved (Pieterse et al., 1996). Soluble chemicals produced by PGPR as well as structural components of the microorganism itself appear to play important roles in the induction of plant defences (Leeman et al., 1995; De Meyer and Hofte, 1997).

PLANT EXTRACTS

There are several reports indicating the potential of plant extracts as elicitors. Aqueous extracts from barley leaves stimulated papilla formation and induced resistance to powdery mildew in barley seedlings (Yokoyama et al., 1991). A number of products containing seaweed extracts are available which are reported to enhance plant health. Synermix (a seaweed extract plus $AlCl_2$ hexahydrate) was shown to elicit phytoalexins in grapes and reported to increase the efficacy of iprodione against *B. cinerea* (Jeandet et al., 1996).

Extracts of the perennial weed *Reynoutria sachalinensis* have been shown to control powdery mildew on apple, tomato, and begonia (Herger and Klingauf, 1990). Biochemical studies showed that the plants treated with the extract had increased levels of defence-related enzymes including peroxidase, glucanase, and chitinase (Herger and Klingauf, 1990) and rapidly accumulated antifungal phenolics (Daayf et al., 1995). In 1990, a wettable powder formulation of these extracts was commercialised (Milsana, Compo, Munste, Germany) and more recently an aqueous formulation (Milsana flussig, BASF) was developed. Applications of Milsana at a concentration of 2% have been shown to reduce the incidence of powdery mildew on cucumber (Daayf et al., 1995) and *Septoria tritici* in wheat (Metcalfe and Wale, 1997).

CHEMICAL INDUCERS

There are numerous chemicals that have been shown to induce plant resistance mechanisms (see reviews by Kessmann et al., 1994; Lyon et al., 1995a). Salicylic acid (SA) plays an important role in the establishment of both local- and systemic-induced resistance in plants and has been one of the most intensively studied elicitors over the last 20 years. White (1979) was the first to report that exogenously applied SA or acetylsalicylic acid induced resistance to tobacco mosaic virus in tobacco. Treatment with SA, or structurally related derivatives has been shown to induce resistance to viral, fungal, and bacterial pathogens in both dicotyledonous and monocotyledonous plants, including tobacco, parsley, wheat, kiwifruit, and radiata pine (Kauss et al., 1993; Gorlach et al., 1996; Reglinski et al., 1997, 1998). However, it has been suggested that field application of SA may be impractical because only a narrow margin separates the rates at which it is efficacious and the rate at which it is phytotoxic (Kessmann et al., 1994; Reglinski et al., 1997).

The synthetic compound 2,6-dichloroisonicotinic acid (INA) has been shown to

induce systemic resistance and to provide protection under field conditions against fungal and bacterial pathogens on pear, pepper, rice, and tobacco (Kessmann et al., 1994) and in green beans (Dann and Deverall, 1996). This compound is not antimicrobial and has been shown to induce the same set of gene families that are induced by either SA or pathogen infection. However, although INA showed early promise as a plant protection compound it was insufficiently tolerated by some crops to warrant practical use (Gorlach et al., 1996).

Benzo(1,2,3)thiadiazole-7-carbothioc acid *S*-methyl esther (*BTH*) is an elicitor that has been developed by Novartis Crop Protection AG. It shares structural and functional similarities with SA and INA but has been reported to be a more potent elicitor of plant defences (Gorlach et al., 1996). This compound is currently commercially available as Bion™ and is being marketed for use against wheat powdery mildew. Bion represents the first of a new generation of crop protectants developed specifically to operate through the induction of plant defence mechanisms. However, induced resistance is also thought to contribute to the efficacy of several pesticides that were not specifically developed as elicitors, including probenazole, metalaxyl, fosethyl-Al, and tricyclazole.

RESISTANT CULTIVARS

The most effective and practical method of disease control is to have naturally resistant plant species. Unfortunately many modern high-yielding crop varieties appear to lack much of the natural resistance of old cultivars or related wild species. It is possible that breeding for high yield and other desirable traits has failed to retain genes that are essential for effective resistance (Davis et al., 1990). However, recent advances in molecular biology has led to the identification of genes required for disease resistance. The technical feasibility of engineering broad-spectrum and stable disease resistance is growing fast and several transgenic plants exhibiting high levels of resistance to fungal and bacterial pathogens have been reported (Shah et al., 1995). Further, progress in the cloning of resistance genes and a greater understanding of plant/pathogen interactions has opened the door for the production of crops with agronomically useful levels of resistance. However, public acceptance of genetic engineering to produce transgenic plants is not widespread and very likely be the subject of debate for many years to come.

PRACTICAL INTEGRATION OF INDUCED RESISTANCE

Induced resistance has been demonstrated as an effective method of disease control in a variety of plants and against a broad range of pathogens. However, there must be a high probability that its implementation will be of economic benefit to growers before it will find widespread acceptance. In the short term the most practical way for implementing induced resistance for crop protection will be to integrate it with existing disease management programmes. Elicitors have already proven themselves to be compatible with commercially available fungicides. Mixtures containing yeast cell-wall extracts with reduced rate fungicide produced yields similar to those obtained with full rate fungicide (Reglinski et al., 1994a). Similarly, Bion™ can be used as a stand alone elicitor or in conjunction with fungicides for controlling wheat powdery mildew.

Induced resistance is also compatible with other natural control measures that promote plant health and reduce plant disease including the use of resistant

cultivars, cultural practise, and biological control. Inducer/cultivar interactions have been reported in field studies (Reglinski et al., 1994a; Steiner et al., 1988) suggesting that the selection of genotypes better able to respond to elicitors could be included in future breeding programmes. However, the development of crops with broad spectrum and stable disease resistance through breeding is a longer term strategy and not of immediate benefit to growers. The integrated use of elicitors with antagonistic biological control agents has recently shown promise for controlling bunch rot in grapes caused by *B. cinerea* (Reglinski and Elmer, unpublished data). Benhamou et al., (1998) also recently reported the combined use of PGPR and chitosan to induce resistance to fusarium wilt in tomato.

Possibly the most economic approach would be the development of PGPR seed treatments or composts specifically selected for their ability to stimulate natural disease resistance. These would offer additional benefits over foliar applied elicitors by protecting against seed decay and pre- and post-emergence damping-off. Seed treatment is particularly attractive because of the possible savings of labour, time, fuel, and machinery associated with foliar chemical application.

Are There any Problems That Are Likely to be Faced in the Application of Induced Resistance for Crop Protection? Induced resistance relies upon a physiological and biochemical response by the plant and so efficacy of any elicitor may be affected by different climatic and agronomic factors which influence general plant health.

Will Induced Resistance be Durable? The durability of any form of resistance depends on how easily random mutations in the pathogen population can produce some means of negating it. Induced resistance operates through stimulation of the plants multicomponent "immune system" and, therefore, is likely to be more durable than the use of chemical pesticides that target a single metabolic site. In addition induced resistance in crop plants appears to be relatively nonspecific and so is likely to offer broad spectrum disease control.

Will the Energetic Costs Associated with Induced Resistance Cause a Loss in Yield? Smedegaard-Petersen (1990) attributed loss in yield, following induction of host resistance mechanisms in cereals, to a redirection of plant metabolites. However, this appears to be an exception rather than the rule and most studies on induced resistance have reported either no effect on yield or have actually observed yield benefits (Steiner et al., 1988; Reglinski et al., 1994a).

Is Induced Resistance Safe? Fears have been expressed about safety of using elicitors on foods and the induction of high levels of plant defence compounds which themselves may be toxic. Induced resistance is likely to be as safe for health as disease resistant plants since the mechanisms activated in both are the same.

Exploitation of induced resistance in the field is not yet widespread and is still at a relatively early stage in its development. There are prospects for improving the efficacy of elicitor treatments through formulation optimisation. Frequency and timing are also critical components as elicitors need to be applied before a pathogen becomes established. Disease prediction models may provide useful information to achieve maximum benefit from elicitor treatment. Research into the practical implementation of induced resistance is likely to become an area of intense activity

over the next few years. However, there is already ample evidence to suggest that the integration of induced resistance, and other natural-based control methods, with more conventional control methods can offer an economic and environmentally safe crop protection strategy.

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A Legal Perspective of Plant Variety Rights

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INTRODUCTION

I am going to talk to you today about Plant Variety Rights (PVR) in New Zealand. I will first discuss the eligibility requirements for PVR, then look at who is eligible to apply for PVR. I will take you through an overview of the steps required to obtain PVR, what rights the grant of PVR provides to the grantee, exceptions to these rights, and finish by considering some scenarios which I think may be of interest to you.

ELIGIBILITY FOR PLANT VARIETY RIGHTS

Plant Variety Rights are governed by the Plant Variety Rights Act 1987. This Act sets out four basic requirements for eligibility for PVR protection in NewZealand:

1) The variety must be **new**. The variety must not have been sold in New Zealand for more than 1 year or sold overseas for more than 4 years (or more than 6 years for a woody plant) prior to filing the PVR application at the New Zealand Plant Variety Rights Office.
2) The variety must be **distinct**. The variety must be distinguishable in at least one characteristic from another variety of common knowledge.
3) The variety must be **uniform**. All of the members of a population of the variety must be substantially uniform and have the same characteristics, and the particular features of its sexual reproduction or vegetative propagation must be considered.
4) The variety must be **stable**. The variety must remain true to its description in its essential characteristics over a number of generations or propagations.

WHO IS ELIGIBLE TO APPLY FOR PVR

The applicant for PVR must be the owner of the variety. The owner is defined as "a person who bred or discovered the variety and includes a successor of that person", e.g., an assignment of rights to a third party makes the third party the owner of the variety. If a person considers that the applicant is not the true owner of the variety, the person concerned can object to the Plant Variety Rights Office either before or after grant.

What If Two People Independently Both Breed a New Variety? Under Section 11, the person who first files a PVR application for the variety shall be granted PVR protection.

HOW DO YOU GO ABOUT OBTAINING PVR PROTECTION FOR A NEW VARIETY?

1) File a PVR application at the Plant Variety Rights Office in Lincoln; such PVR application must consist of the following documentation: application form (including proposed denomination

for the variety), technical questionnaire (specific to each genus/species), photographs showing distinguishing features of the variety, supply of seeds (if applicable), and the official filing fee (there are three levels of fees).

2) The Plant Variety Rights Office acknowledges the application, checks that the minimum requirements have been complied with, and accords a filing date and application number. The filing date is important for two reasons. Firstly, because provisional protection commences at the filing date. Thus the PVR applicant can take action for infringement from the filing date. However, if PVR are not granted on the application in due course, then such right is withdrawn. For example, if an injunction is granted by a court to prevent alleged infringement prior to grant of PVR, and the grant of PVR is eventually refused, the aggrieved third party against whom the injunction was awarded, could claim damages for loss suffered from the injunction being imposed. In deciding whether to award a claim for action prior to grant of the PVR, the Court will apply the balance of convenience test and consider the status of the application at the time the action for alleged infringement is commenced. The court may grant an injunction in such circumstances, but is unlikely to grant a claim for damages as it may be preemptive of a valid grant of PVR. The second importance of the filing date, as mentioned previously, is that if the new variety is bred or discovered independently by more than one person, and both file PVR applications, then the PVR application with the earliest filing date is the only one that can proceed to grant.
3) Publication in Plant Variety Rights Journal of variety details, i.e., filing date, application number, proposed denomination, applicant.
4) Organise for objective testing of the variety to occur, e.g., testing of pip and stonefruit varieties at the National Cultivar Centre.
5) Results of the objective testing will be considered by the Examiner at the Plant Variety Rights Office who prepares a technical recommendation of the variety for the Commissioner of Plant Variety Rights. If the variety is shown to be distinct, uniform, and stable, then the Commissioner will advise the applicant that the variety is eligible for protection.
6) Pay issue of grant fee, then a Grant of Plant Variety Rights is issued and an advertisement of grant appears in the Plant Variety Rights Journal. The term of PVR is 20 years for nonwoody plants and 23 years for woody plants from date of grant.
7) During the term of grant, a grantee must ensure reference plants of the variety are supplied to the Plant Variety Rights Office or available upon request, depending on the genus.
8) Renewal fees are payable annually after grant to maintain the grant in force. If a renewal fee is not paid on time, then the grant expires and there is no proviso in the Plant Variety Rights Act for restoration of a grant.

9) After grant, any person who sells reproductive material of a protected variety (or a variety that is no longer protected because the term has expired) must use the denomination of the variety when such material is sold If not, it is an offence under Section 22 of the Plant Variety Rights Act

WHAT RIGHTS DOES A GRANT OF PLANT VARIETY RIGHTS PROVIDE TO THE GRANTEE?

As mentioned previously, from the filing date of a PVR application, an applicant has the same rights as if a grant has been made, although these rights are reversed if a grant of PVR is refused A grant of PVR gives to the grantee (and his/her licensee) the right to exclude others from.

1) Selling (including offer for sale) or producing for sale reproductive material of the protected variety
2) Propagating that variety for the purpose of commercial production of fruit, flowers, or other products of that variety if the variety is a vegetatively propagated fruit producing plant, ornamental plant, or vegetable producing plant
3) Propagating, selling, or using imported reproductive material of a protected variety as reproductive material
4) Importing plant material of a variety protected in New Zealand from a country where plant variety rights protection is not available for that variety.

If a third party performs any of the above acts without the authority of the grantee, or uses the denomination of a protected variety in connection with the sale of another variety, this is an act of infringement which can be actioned by the grantee The holder of a licence from a grantee shall have the same rights as the grantee to action infringement proceedings, if the actions of the alleged infringer affect the licensee's rights

WHAT ACTION CAN BE TAKEN BY A GRANTEE?

The grantee (or his/her licensee) can

1) Apply for an injunction to prevent further infringement,
2) Claim damages for infringement based on: loss suffered or likely to be suffered by the grantee as a result of the infringement, any profits or other benefits derived from the infringement, and the flagrancy of the infringement, and/or
3) Apply to Court for authority to seize infringing material of the variety If it is innocent infringement, i e., the infringer was not aware and had "no reasonable grounds for supposing" that his/her actions were an infringement of PVR, then damages cannot be awarded (but an account of profits may be) For example, there may have been test sales of a variety in the 1-year period before the filing of a PVR application In such a case it may be advisable to mark plant material of the variety with a warning that it is intended that PVR will be applied for in relation to this variety in

New Zealand. A grantee should also mark propagating material of the variety or make sure labelling of the variety contains a reference to the fact that the variety is protected under the Plant Variety Rights Act, e.g., "New Tree Variety Plant Variety Rights Grant No. X", otherwise any alleged infringement may be considered innocent infringement and it may not be possible to claim damages for the infringement.

Are There Any Exceptions to PVR Protection?

It is not an infringement to:

- Propagate, grow or use a protected variety for noncommercial purposes.
- Hybridise or produce a new variety from a protected variety and sell the same, as long as the production of such a hybrid or new variety does not require the repeated use of the protected variety. This is known as the breeders privilege.
- Use reproductive material from a protected variety for human consumption or other nonreproductive purposes.
- Collect and replant seeds on a farm to grow crops for consumption by animals. This is known as the farmer's privilege.

What Rights Do Individual Propagators Have to Use Plant Material of a Protected Variety? They can propagate the variety for non-commercial purposes, e.g. to propagate plants for their own gardens and they can breed new varieties from such material. They can propagate the variety to produce fruit/vegetables for their own consumption. However, they **cannot** sell reproductive material of the variety after they have propagated it, **and** if the variety is a vegetatively propagated fruit-producing plant, ornamental plant or vegetable-producing plant, they cannot propagate the variety for the commercial production of fruit, flowers, foliage, or other products of that variety.

A Local Body Propagates Plant Material of a Protected Variety for Use on Council Land — Is this Allowable? Yes, because the local body is not selling or producing for sale reproductive material of the variety, plus is not propagating for commercial production of flowers, fruit, or other products of that variety.

An Individual Propagates Material of a Protected Variety for Commercial Purposes in Ignorance of the PVR Protection. What Happens Then? This is still infringement. An injunction can be imposed to prevent further infringement, and a Court could order that the infringing material be seized. But in terms of damages, the grantee can only claim the profits derived from the infringement, not full damages.

What If a Propagator Started Propagating before PVR Protection Was Applied for? The propagator will only be liable for infringement from the filing date of the PVR application (i.e., when provisional protection is granted). If the PVR application does not proceed to grant, then any alleged infringement cannot be actioned and any action taken against the alleged infringer will be reversed. Plus, the propagator could potentially oppose the PVR application before the grant under Section 6(3) if plant material of the variety was sold in New Zealand more than 1 year before the filing date (i.e., by arguing that the variety is not new). After grant the propagator could object to the PVRO under Section 15.

An Individual Propagates Plant Material of a Variety to be Exported for Sale Outside New Zealand, Is this Infringement? Yes, because it is still producing reproductive material "for sale" under Section 17 Section 17 does not limit "sale" to sale within New Zealand (but there must be propagation for the sale of reproductive material or vegetative propagation under Section 17(1)(b)).

WHAT ARE THE CHANGES TO BE EXPECTED IN THE NEW PLANT VARIETY RIGHTS ACT?

The breeder's privilege will be removed, there will be a broader range of infringing activities, the removal of or restriction of compulsory licensing However, there is not enough time available in this forum to go into these changes in detail.

CONCLUSION

Plant Variety Rights is something that it is important for propagators such as yourselves to be aware of, to ensure you are not potentially infringing the PVR of a protected variety However, PVR protection is of limited scope in that it only lasts for a maximum 20 (or 23) years, is a right to exclude others form taking certain action rather than an exclusive right of the grantee, and is subject to all other legislation (such as the Commerce Act, the Fair Trading Act, etc)

Why have Growing Trials for Plant Variety Rights?

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The purpose of a Plant Variety Rights (PVR) growing trial is to establish whether or not a candidate variety meets the technical criteria of distinctness, uniformity, and stability (DUS) under local climatic conditions. The PVR Office must test these criteria and be satisfied that the variety is DUS before a grant of rights can be made. The growing trial may involve not only the candidate variety but also additional varieties for comparison and reference purposes. All plants are grown under the same cultural and environmental conditions. A growing trial may last from a few months to several years depending on the kind of plant. Growing trials are located in various sites around New Zealand depending on the species under test.

INTRODUCTION

Protected varieties feature prominently in present day commercial horticulture. It is noticeable that a high percentage of recent new variety releases are subject to a grant of PVR or under test for PVR. It is this term "under test", or the technical part of protecting varieties that is not understood. I would go further and suggest that many people in the nursery industry and the wider community have poor knowledge of how a variety becomes protected and the process involved. I stress the word process, because the general understanding of PVR has improved significantly in recent years.

DETERMINATION OF DISTINCTNESS, UNIFORMITY, AND STABILITY

The three technical criteria that must be determined before any owner can be granted a PVR for a variety are distinctness, uniformity, and stability. This is abbreviated to DUS. The PVR Office (PVRO) must satisfy itself that a variety is actually distinct from all other known varieties or what we term varieties of common knowledge. A variety of common knowledge is one that is commercially available or described in literature, journals, magazines, or in the public domain such as on display in a botanic garden. We also consider unnamed selected forms of a species maintained as clones in commerce. For PVR purposes these are considered as varieties. Many will be familiar with the widely advertised and promoted lavender 'Monet'. This was refused PVR because it could not be distinguished from an unnamed dark-flowered form of *Lavandula dentata* propagated vegetatively and commercially available in the South Island.

We first try to identify varieties of the genus or species in New Zealand. This information is available from published literature, nursery catalogues, trade magazines, plant collections, individuals with particular species, and variety knowledge and from existing protected varieties in that genus. In theory, we should take a global view and search for varieties of common knowledge internationally. With today's ease of communication and our networks through the International Union for the Protection of New Varieties of Plants (UPOV), keeping track of

varieties in say Europe is not that difficult. However, the problem arises when we actually find one and no plant material is in this country. Whether or not we actually include this variety in a New Zealand trial is another question. This decision is made case by case.

Once the varieties of common knowledge have been identified, we can single out the variety or varieties, if any, that are most similar to the candidate and include them in the growing trial.

A variety must also be uniform and stable. Uniformity is determined by looking at plants of the variety and checking for any sign of mutation, reversion, or other nontrueness-to-type characters. Stability is not tested. It can only be properly assessed over a period longer than that for a PVR trial. If a variety becomes unstable after PVR is granted then the right can be cancelled.

The cancellation of a right after PVR is granted can also occur if a candidate variety is later found to be indistinct from a similar variety which was not considered during testing. Similar varieties can be over looked or missed for a number of reasons. This situation happened recently for a variegated jasmine. Several years after PVR had been granted for this variety an apparently identical variety in Southland was brought to our attention. At the time of testing, the PVRO and others consulted had been completely unaware of this variety. The variety was trialed again and found to be indistinct from the Southland variety. As a result , Rights were cancelled.

GROWING TRIALS

Every variety is tested for DUS in a growing trial. Most varieties will require testing in New Zealand growing trials in order to establish whether or not they are DUS under local climatic conditions. A PVR growing trial is set up on a single site. The trial is exclusively for PVR purposes and cannot be combined with any other function. The trial could be used further for other purposes after PVR testing has concluded.

A PVR trial includes a set number of plants of the candidate variety or varieties plus plants of any other variety or varieties necessary for comparison or reference purposes. Every possible attempt to reduce variation between plants and varieties is made. If differences between varieties are observed, then we can say with greater certainty that the differences are genetically based and not caused by cultural practice or the environment. We minimise variation due to growing conditions and cultural practice by: all plants being propagated by the same method; all plants on the same site; all plants in the same pots, media, or area of ground; all plants managed the same way according to set trial requirements. When plants in the trial are sufficiently mature or have reached the appropriate growth stage the evaluation will begin. It may be years between the time a trial is established and when it is suitable for evaluation, depending on the species. The evaluation involves preparing a detailed morphological description of the candidate variety, written and photographic recording of differences between trial varieties, and the assessment of uniformity.

Many applications for PVR are for imported varieties, possibly already protected in several countries. You may ask why testing using a growing trial in this country is necessary when the variety has already been tested and approved overseas. Local testing is necessary because of several reasons. Experience has shown that a distinct variety overseas is not necessarily distinct in this country. There may be similar

varieties in this country not tested overseas. We cannot assume that the distinguishing character(s) will be expressed here or that the variety will be uniform. New Zealand has a unique climate and environment with the resulting effects on plants. A rose breeder from Meilland, the largest rose breeding company in the world, noted that some of his varieties growing in New Zealand had a higher petal number than the same variety grown in France. It is well known that some plant characters such as petal colour, plant height, and habit are strongly effected by environment and you would expect to see differences between countries. Petal number is not known to be influenced by growing conditions and is usually very consistent between countries.

Location of Growing Trials. Growing trials are located throughout the country, depending on the kind of plant. Pip and stonefruit are tested at the National Cultivar Centre. Roses are tested in a central trial in Palmerston North, lavender on a site near Lincoln, and marguerite daisies at the Auckland Regional Botanic Gardens. The majority of ornamental varieties are tested using growing trials on the applicant's property. The applicant is required to established and maintain the trial as requested and according to our "Guidelines for Plant Variety Rights Growing Trials". All evaluation and testing work is carried out by myself or one of our regional describers.

OVERSEAS TEST REPORTS

In the case of imported varieties used for indoor use, grown as greenhouse crops, and a few other special cases we will use test reports from trials outside New Zealand. We would be more likely to accept overseas test results from countries using official testing according to UPOV protocols. UPOV testing protocols or guidelines are developed at an international level for each genus or species. These protocols set out in detail how varieties in a particular genus or species are tested. This includes a list of morphological characters required for the description. A UPOV guideline exists for roses. The way roses are tested here is essentially the same as testing in other UPOV member states where the rose guideline is followed.

A relatively large number of PVR applications are for varieties imported from Australia. We have a lot in common with Australia, and it could be argued that Australian test results would be suitable and applicable here. There appear to be some climatic and environmental similarities between New Zealand and parts of Australia. This can be misleading. The PVRO has experience with at least one Australian-bred variety that when described here did not match the Australian description. It was not clear why the descriptions differed when you would perhaps expect them to very alike. It is for this reason that we exercise great caution in using overseas test results, even those from our nearest neighbour.

Towards an In Vitro Propagation System for *Astelia* Species

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INTRODUCTION

The genus, *Astelia*, which belongs to the Liliaceae family, comprises about 25 species confined mainly to the Pacific region. Thirteen of the species, including all species named in this research note, are endemic to New Zealand (Moore and Edgar, 1976). They are dioecious, mostly short-tufted terrestrial herbs without a significant stem, found from wet lowland to subalpine environments. *Astelia* taxa are generally untroubled by pests and diseases and do not have particular soil type requirements. Leaves mostly range in length from 10 to 80 cm, but some species have leaves up to 3 m long, e.g., *A. chathamica*, *A. fragrans,* and *A. grandis* have long and graceful arching leaves.

The horticultural potential of this genus is now beginning to be realised internationally and a few species, e.g., *A. chathamica* and *A. nervosa,* are being exported for their attractive foliage and for use as hardy amenity plants. Selections have been made from the two species, *A. nervosa* and *A. nivicola*, in which a range of leaf colours (e.g., red and/or bronze), naturally occur (Metcalf, 1993). Interspecific hybridization has also produced other forms with varied foliage colours.

With the exception of genera such as *Cordyline, Phormium,* and *Hebe*, New Zealand native flora has a minimal presence in international markets with only small volumes of other native genera exported as either flowering stems (e.g., *Leptospermum)*, or cut foliage (e.g., *Pittosporum* and *Astelia)*.

Astelia are currently propagated from seed extracted from the berries on female plants, or by plant division, although the latter is relatively slow. Depending on seed age, germination can be erratic. Dividing shoot clumps into single shoots often results in side shoots breaking-off without any stem tissue. Tissue culture offers an alternative means of propagation. There are no published studies on tissue culture of *Astelia* although some commercial laboratories in New Zealand have had limited success with two species. If superior *Astelia* forms, including new hybrid selections, are to be successfully commercialised a rapid clonal propagation system is required. In vitro propagation of New Zealand species has been limited, often undertaken only to conserve the species (Aitken-Christie et al., 1993; Hargreaves et al., 1997). The use of tissue culture to overcome the slowness of conventional propagation methods has had only moderate success (Oliphant, 1993). However, micropropagation techniques have been successfully developed for several native species with ornamental potential (Bicknell et al., 1996; Morgan et al., 1997). This research note reports on progress towards developing an in vitro propagation system for six *Astelia* species with commercial potential.

MATERIALS AND METHODS

Cultures were initiated from either seed or shoot tips. Seeds of *A. nervosa, A. fragrans* (New Zealand Tree Seeds, Rangiora, N.Z.) and *A. chathamica* (Crop & Food Research, Levin, N.Z.) were aseptically placed in culture following sterilisation in a sodium hypochloride solution (1% effective chlorine) for 40 min. It was often necessary to resterilise seeds two or three times during the first 10 days before clean cultures were obtained. Once the seeds were clean, nicking the ends with a scalpel was found to hasten germination. Plants of *A. fragrans, A.banksii, A. nervosa, A. grandis*, and *A. solandri* were obtained from local nurseries. Whole shoots were removed from these plants; where possible, outer leaves were removed and the remaining leaves cut back before sterilising stems as for the seeds. Shoot tips of the terminal shoot (1 to 2 mm in size) and axillary buds positioned in the axils of outer leaves were removed and put into culture.

The pH of all media was adjusted to 5.7 before autoclaving for 20 min at 121C and 103 kPa. The auxin, indoleacetic acid (IAA), when used, was filter sterilised and added to media after autoclaving. All cultures were maintained at 23C with a 16/8 h light/dark photoperiod at a light intensity of 32 μmol m^{-2} s^{-1} provided by cool white fluorescent tubes.

Seeds or shoot explants were placed on media with $^1/_8$ to full strength MS salts (Murashige and Skoog, 1962), LS vitamins, 0 to 0.1 mg $liter^{-1}$ indolebutyric acid (IBA), 0 to 0.3 mg $liter^{-1}$ benzylamino purine (BAP), 30 g $liter^{-1}$ sucrose, and 7.5 g $liter^{-1}$ agar.

To encourage shoot proliferation, individual in vitro shoots of *A. nervosa* were placed on MS media in a factorial experiment with 1.0, 3.0, or 6.0 mg $liter^{-1}$ IBA, IAA, or NAA, and either 3.0 mg $liter^{-1}$ BAP or 3.0 mg $liter^{-1}$ thidiazuron (TDZ). A similar experiment for adventitious shoot initiation compared 0, 0.3, 1.0, and 3.0 mg $liter^{-1}$ NAA with either 0 or 3.0 mg $liter^{-1}$ BAP. Individual shoots were placed on MS media containing 1 to 10 mg $liter^{-1}$ IAA to develop roots before being transferred to the greenhouse where the shoots were planted in a fine pumice mix and placed in a fog tent for 10 days. The shoots were then placed under intermittent mist for a further 2 to 3 weeks.

RESULTS AND DISCUSSION

Within 2 weeks, 60% of fresh seed germinated in vitro whereas seed over 3-months old, even following a 2-month chilling period, took up to 6 weeks to reach fresh seed germination rates. Similar growth rates of seedlings occurred on very dilute MS media ($^1/_8$-strength MS salts) compared to full-strength media. Fewer than 5% of seedlings formed two or more shoots on media with 0.3 mg $liter^{-1}$ BAP. Within a month, shoot tips generally developed into single shoots 1 cm tall. After 2 months in culture, *A. banksii* shoot tips developed clumps of 3 to 5 shoots on MS medium supplemented with 0.05 mg $liter^{-1}$ IBA and 0.3 mg $liter^{-1}$ BAP. These were divided into either single or double shoots and continued to proliferate when placed back onto similar media. While shoot tips of the other species developed into healthy green shoots on this medium, they rarely proliferated additional shoots. *Astelia nervosa* shoots, grown on MS media supplemented with NAA and either 3.0 mg $liter^{-1}$ BAP or TDZ, had smaller leaves and the base of the shoots was considerably swollen, although no additional shoots were visible. This response did not occur when NAA was replaced with either IAA or IBA.

Astelia fragrans shoots grown in the presence of 1.0 or 3.0 mg liter^{-1} NAA and BAP were greener and more vigorous (some had multiple shoots) than shoots grown on similar media with either 0 or 0.3 mg liter^{-1} NAA and BAP. In contrast, *A. nervosa* shoots had more basal swelling when exposed to the higher NAA rates although leaf growth was similar on all media. Minimal proliferation occurred on media with up to 3.0 mg liter^{-1} BAP in the absence of an auxin.

Removing the outer leaves from the swollen basal parts of *A. nervosa* shoots growing on media with NAA, and either BAP or TDZ, revealed meristematic tissue with various degrees of differentiation including distinctive shoot tips. Three to four weeks after placing this new tissue on MS media with 0.3 mg liter^{-1} BAP, clusters of up to 12 adventitious shoots developed with leaves up to 4 cm long.

A two-stage proliferation protocol is therefore being developed. In the first stage, an MS medium supplemented with 1.0 to 3.0 mg liter^{-1} NAA and 3.0 mg liter^{-1} of either BAP or TDZ is used for the initiation of adventitious buds. The second stage, a shoot-elongation medium, has little or no auxin and only low levels of BAP. Long exposure to media with TDZ has been reported to suppress shoot elongation (Seelye and Butcher, 1991). Pulsing tissue on media with TDZ followed by a period on media with no, or minimal, growth regulators has been effective for some shoot regeneration systems (Seelye et al., 1994).

In our studies to date, shoots of *A. nervosa* and *A. banksii* developed roots on an MS medium supplemented with up to 10.0 mg liter^{-1} IAA without loss of shoot quality. Roots also formed on growth-regulator-free media after 6 to 8 weeks. Plants transferred to a fine pumice potting medium and placed under high humidity greenhouse conditions developed a vigorous root system. Three to four weeks after removal from culture, acclimatized plants were being maintained on open benches under normal greenhouse conditions.

SUMMARY

We are successfully developing micropropagation techniques for a number of *Astelia* species which will enhance the commercial development of new selections and hybrids. Our preliminary studies, mainly with *A. nervosa,* found that adventitious buds were initiated on an MS medium with 1.0 to 3.0 mg liter^{-1} NAA plus 3.0 mg liter^{-1} BAP or TDZ. The shoots were then transferred to a shoot-elongation medium with little or no auxin and low levels of BAP. Shoot clusters developed with up to 12 adventitious shoots. Roots developed relatively quickly on a medium containing IAA and these were successfully acclimatized in a greenhouse. Following this promising start, studies are continuing to compare the effect of BAP and TDZ on the initiation of adventitious shoots for the six species of *Astelia*, and the subsequent ability of shoots derived from highly regenerative tissue to initiate and develop a good root system.

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A Botanical Visit to the Chatham Islands

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INTRODUCTION

Why am I talking to a group of plant propagators, more especially about the Chatham Islands? I thought that maybe because I too am interested in plants. Maybe also because the New Zealand Dendrology Group went over there to have their annual get-together and A.G.M. Who else goes there? Fishermen, perhaps bird lovers, and then there's that breed that want to be on Pitt Island to greet the new millennium. I will give you a very brief overview of the Chatham Islands and then talk about the plants.

AN OVERVIEW OF THE ISLANDS

The Chatham Islands are 800 km east of Christchurch, or 1h by Convair aircraft from Wellington. The population is about 700, mostly involved in fishing or farming. The main island, Chatham Island, is about 90,000 ha, and Pitt Island 6000 ha. There are another eight islands in the group, some just virtually rocky outcrops. Waitangi is the main settlement with three smaller fishing villages. Main accommodation is in or near Waitangi; a hotel, motel, lodge—where we were based; there are also farm-stays. There is also a shop, garage, church, Department of Conservation (DOC) Office, policeman, a courthouse; and that's it. At Kaiangaroa, one of the fishing villages, there is a cottage brewery which produces both light and dark ales which is appropriately called Black Robin Ale. They produce about 40% of the Islands beer requirements. Topography is easy rolling, with a couple of small volcanic type cones indicating the island's past. Much of this rock has been overlaid with limestone. There is a lot of gorse. There are possums, but no rabbits.

THE PLANTS

There are 37 plant taxa that are endemic to the Islands. That's a higher level of endemism than anywhere on mainland New Zealand. Many of these plants are under threat. We saw quite a few of these but certainly not all. There were three basic types of indigenous vegetation as we saw it: fenced forest that had survived; fenced land now allowing regeneration; steep cliffs where stock could not graze. This is where we saw *Astelia chathamica* growing which is a plant very much under threat in the wild.

Plants That the Islands Have in Common with Mainland New Zealand but with Unique Differences.

- Chatham's ake ake, *Olearia traversii*. Huge, wonderful shaped old trees, which we saw near the coast.
- Kopi, the Chatham's karaka. Older trees, unlike their mainland cousins, having buttressed roots. These were the trees with dendroglyphs or carvings on their trunks done by the Morioris.
- Tree-like coprosmas, *Coprosma chathamica*.

- And attractive long-leaved saplings of *Pseudopanax chathamicus*. These caused a lot of comment, as did the large unmarked leaves of kawakawa.
- Whitey-wood (*Melicytus ramiflourus*), easily identified with its blue berries up the stem but with fleshy leaves.
- Ribbonwood, also slight differences to its mainland cousin, *Plagianthus regius* var. *chathamicus* (syn. *P. betulinus* var. *chathamicus*).
- Myrsine with dark green leaves, *Myrsine coxii*.
- We saw a lot of flax. It was often seen being used as a base planting along hedge rows. Not an upright *Phormium tenax*, but a flax with a wider and more flaccid leaf. David Given called it *P. tenax* Chatham Island form.

Plants with Perhaps a Greater Interest to this Group.

- *Myosotidium hortensia* growing in a coastal situation amongst marram grass in sand and with giant kelp nearby.
- The Chatham Islands sow thistle was here, *Embergeria grandifolia*. It is, like the Chatham Islands forget-me-not, *Myosotidium hortensia*, not only endemic, but both are monotypic genera. The thistle is one of the Islands more vulnerable plants.
- *Geranium traversii* was scrambling about on the nearby rocks and easily identifiable with its tiny white flowers. We also saw it growing in a sand dune community.
- *Brachyglottis semidentata* with purple/blue flowers looked beautiful. It was much photographed and I would rate this shrub as the highlight plant of the trip for me. Its cousin *Brachyglottis* (or is it *Senecio huntii*?) was in the same area but not in flower.
- Others on this walk were the white-flowered gentian, *Gentiana chathamica*. There was only a hint of whiteness left on the short flower stalks. These were growing in the company of two *Aciphylla* species, *A. dieffenbachii* and *A. traversii*.
- There were two *Dracophyllum* species, *D. arboreum* and *D. paludosum*.
- The green-stemmed form of *Euphorbia glauca* was growing outside the DOC office. I believe that it is now extinct in the wild.
- We saw many other plants such as ferns, *Dicksonia* and *Cyathea*; a *Blechnum* species of the ground fern; nikau palms, *Rhopalostylis sapida*; and kowhai, *Sophora microphylla*.
- Then there were the sand dune communities with mingimingi dominant, *Cyathodes parviflora* and also *C. robusta*.

CONCLUSION

This is a very quick and brief overview of a fascinating few days. It was the off-season for crayfish although we did manage one meal of it. That, plus all the other home cooking, the Black Robin ale, and of course the good company, made for a great trip. I have to say that it was a great feeling flying back into Wellington and not having to face Ministry of Agriculture and Forestry officials with uncleaned seed, cuttings, and seedlings, which we were carrying.

A Review of Factors Influencing Organic Matter Decomposition and Nitrogen Immobilisation in Container Media

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INTRODUCTION

The organic fraction of a potting mix is subject to decomposition and, therefore, is important in relation to nitrogen (N) immobilisation. Immobilisation of N is the reduction in plant available N (i.e., nitrate or ammonium) as a result of microorganisms using this N as they decompose organic materials with a high carbon (C) content. The organic portion of potting mixes usually constitutes 50% or more of their volume and in New Zealand *Pinus radiata* bark and sphagnum peat are the most commonly used materials. *Pinus radiata* sawdust, tree fern fibre, composted mixed vegetation, and other sources of bark or sawdust are also used on a limited scale. Spent mushroom compost has also been successfully used in bark and peat container media overseas although there have been reports of problems with its use in New Zealand. It has good physical properties and is a useful source of nutrients except for N (Henny, 1979; Chong et al., 1991; Chong and Rinker, 1994; Stewart et al., 1998ab). Spent mushroom compost may cause temporary N immobilisation, after which N is slowly mineralised from it (Stewart et al., 1998a). Spent mushroom compost also has a high soluble salt content that can be ameliorated by leaching, and a pH of 6.5-8.1 (Henny, 1979; Chong et al., 1994; Chong and Rinker, 1994; Stewart et al., 1998b).

This paper seeks to review the factors causing decomposition of these organic materials and the implications of these processes on N immobilisation.

FACTORS INFLUENCING DECOMPOSITION RATES

Chemical Composition. Cellulose is a constituent of organic matter and is the key component of cell walls. Bunt (1988) states that cellulose plays a major role in N immobilisation since it breaks down very rapidly and has a high C : N ratio. The secondary thickening that occurs in growing wood, produces thicker cell walls and hence greater amounts of cellulose. Hardwood trees have denser cell walls and their bark contains up to 40% cellulose compared with softwoods which have low-density bark containing only about 5% cellulose (Bunt, 1988). Hardwood and softwood are plant classification terms and the wood of each type of tree may not be particularly hard or soft, e.g., balsa is a hardwood. Hardwoods are dicotyledonous flowering trees (e.g. *Eucalyptus*) while softwoods are conifers e.g., *Pinus radiata* (Raven et al., 1992).

Lignin is another component of organic matter and is closely associated with cellulose. Lignin is more resistant to decomposition than cellulose and may protect

cellulose, slowing its decomposition. Bragg and Whitely (1995) provided an example of the different rates of decomposition of constituents within one organic material. They showed readily decomposable carbon in rape straw incorporated into the soil can be broken down rapidly whereas the residual high-lignin straw fibre resisted further decomposition.

Polyphenols are plant tannins that are also relatively resistant to decomposition (Haynes, 1986). The polyphenol content of plant material decreases in response to additional N, and so may vary within a source of plant material (Haynes, 1986). The rate of decomposition of organic material is related to its cellulose, lignin, and polyphenol content (Mtambanengwe and Kirchmann, 1995; Tian et al., 1995). Rather than trying to predict decomposition from one of these components a useful approach has been to use a residue quality index which is a combination of C : N, lignin, and polyphenol concentrations (Tian et al., 1995). Another approach for predicting decomposition is to calculate the amount of C available for microbial decomposition (Mtambanengwe and Kirchmann, 1995).

Particle Size. This influences decomposition because it relates directly to the surface area exposed to the surrounding environment and microbial attack. The smaller the particle, the greater the surface area that is exposed and the greater the potential rate of decay. However, some materials (e.g., peat) are resistant to decomposition despite their fine particle size. The chemical composition is, therefore, a more important factor than particle size (Maas and Adamson, 1972).

Ease of Wetting. Allison et al. (1963) in comparative studies of wood decomposition from different species of trees concluded that wettability was a key factor. They reported a slower breakdown of wood from softwood species compared with hardwoods. The water insoluble resins in the wood of softwood species results in strong resistance to water, making their wood particles a poorer substrate for microbial growth. Similarly, peat contains wax and bark contains suberin, both of which are water repellent and hence the stability of peat and bark. Sawdust, which is more wettable than bark, decomposes much faster. Also, wood from hardwood species decomposed six times faster than that from softwoods (Allison et al., 1963). Straw has a slow rate of decomposition when cultivated into the soil because both its resistance to wetting and its high lignin content.

C : N Ratio. Early texts on N immobilisation tended to place a heavy emphasis on the C : N ratio. Bunt (1988) reported how two pine barks with the same C : N ratio (about 300 : 1) and under similar conditions had very different C decomposition rates (i.e., 24% and 4%). However, Bunt (1988) also stated that immobilisation is more likely in materials with a high C : N ratio as they are more deficient in N. Examples of C : N ratios of soil, sedge peat, and young sphagnum peat in the U.K. are 10 : 1, 20 : 1, and 40 : 1, respectively (Bunt, 1988). There are limitations with the C : N ratio as not all C is available to microorganisms and the available C : N ratio may be a more useful concept (Mtambanengwe and Kirchmann, 1995).

Fog (1988) described the interactions between the composition of materials and the microorganism population decomposing them. Where there is a large amount of cellulose in a substrate (i.e., high C : N ratio) then ascomycetes fungi will be the dominant decomposition agents. In contrast, wood decomposition is dominated by basidiomycetes fungi and although it may have a similar C : N ratio as a cellulose

substrate, it has a slower rate of decomposition because of its higher lignin content. The different microorganism populations can operate in succession as they change the nature of the substance they are decomposing. It can be concluded that the C : N ratio is not an appropriate indicator of decomposition for all types of media, but it is more useful for predicting N immobilisation.

Added N. Fog (1988) reviewed the influence of added N on organic matter decomposition and found that the effect was dependent on the composition of the material. Easily decomposable materials generally with a low C : N ratio and lignin content will decompose much more quickly if additional N is supplied. However, resistant materials generally with high C : N ratios and/or lignin contents often decompose more slowly following N addition (i.e., sawdust). This may result from the added N disturbing the balance of competition between specific microorganisms, blocking the production of ligninase enzymes, increasing the breakdown of easily available cellulose and the accumulation of recalcitrant ligno-cellulose, and stimulating the formation of toxic substances (Fog, 1988). This may partly explain why a substrate consisting of only *P. radiata* sawdust has proved a successful growing medium for liquid-fed container-grown tomatoes. Bark, however, contains little or no lignin (depending on its wood content) and shows a more variable response to added N. Addition of N to composting bark is important when the bark has a high cellulose content (Hoitink and Poole, 1980).

MEASUREMENT OF DECOMPOSITION RATE

The C : N ratio has been shown to be a poor indicator of the decomposition rate and it does not necessarily correlate well with the amount of carbon dioxide (CO_2) release (Handreck, 1991). It is generally inconvenient and complex to measure C release as CO_2. The N-Drawdown Index (NDI) was developed as a laboratory method to measure the N immobilisation potential of container media following incubation with 75 mg litre^{-1} KNO_3. Handreck (1992ab) recommends the NDI test as a means of predicting the N fertiliser requirements of mixes. Materials such as fresh sawdust (from both hardwood and softwood species) have a high N immobilisation potential, and NDI values of close to zero. They consume large amounts of N (about 300 mg N litre^{-1} week^{-1}) and are difficult to obtain adequate growth from. Composted pine barks typically have NDI values of 0.3 to 0.6. Peat-based media often have NDI values close to one and hence have a low rate of decomposition and N immobilisation (Bodman and Sharman, 1993).

There are situations where the NDI test can give misleading results. Firstly, if a material has poor wettability, such as dry fresh *P. radiata* sawdust, it could have an *NDI of 0.5 to 0.6 indicating that little or no decomposition has occurred.* Handreck (1991) recommends that all test materials should be maintained at potting moisture content for at least 8 days before testing. The second potential problem is with materials that have been composted with a source of mineral N. If the material still contains high levels of ammonium following composting it can also produce an inflated NDI reading. Bragg and Whitely (1995) concluded from their experiments using NDI tests on a range of decomposing materials, that this test provides a "snapshot" of the N immobilisation potential at one time. Successive NDI tests may be needed to determine the N needs of a decomposing substance which may vary with time. An alternative to the NDI test could be to

calculate the potential N immobilisation from the C available for decomposition (Mary et al., 1996), however this would require knowledge of the chemical analysis of the ingredients in the medium.

PLANT GROWTH RESPONSES

Richards (1981) outlined the problems of growing plants in pure *P. radiata* sawdust including the difficulty in providing sufficient N to overcome N immobilisation while avoiding osmotic stress from the salinity of the nutrients applied. Decreasing aeration was an additional problem. Thomas et al. (1980) found that seedling plants grown in peat/sand media were consistently superior to those grown in a similar mix but containing one third *P. radiata* sawdust. A range of fertiliser types and N levels did not significantly improve growth in the sawdust medium. The authors have measured strong *Ficus benjamina* growth response to increasing N levels in composted-bark-based and fresh-sawdust-based mixes (both from *P. radiata*), but at low N levels plants were superior in a peat-based mix (unpublished data). Plants growing in the sawdust-based mix generally showed greater leaf chlorosis indicative of N deficiency. Further unpublished work on container-grown liquid fed apple rootstocks found that Malling 9 rootstocks grew larger in a composted-bark-based mix compared with a 100% fresh sawdust medium (both from *P. radiata*). There was, however, no significant difference between media when MM106 rootstocks were used. Sharman and Bodman (1991) grew a range of woody ornamentals in media containing 50% composted *Eucalyptus* sawdust, other organic materials, and only 10% to 15% mineral materials. They applied controlled-release fertilisers at a range of rates and reported satisfactory growth particularly where leafy plants were grown at high N rates. Bragg and Whitely (1995) grew plants for 40 days in seven different organic media and also made sequential NDI tests and found that growth was correlated with the availability of N.

PRACTICAL RECOMMENDATIONS

Growers who suspect they have a N immobilisation problem or who wish to change the organic component in their container media can make sequential NDI tests over the duration of use of their media and/or have plant foliage samples analyzed for N. An N deficiency may be ameliorated in the short term by the use of additional inorganic N fertiliser, which may also reduce the rate of decomposition of the organic material. In the longer term the medium may need to be changed for example by using organic matter that is more resistant to decomposition.

The general recommendation is that media such as peat and composted pine bark, which have relatively low N immobilisation potential, are the preferred organic components for potting mixes. Additions of other organic materials such as fresh sawdust or SMC may appear economically attractive but it may be difficult to produce high quality plants using them. This is because of the difficulty of supplying sufficient inorganic N for plant growth to compensate for N immobilisation during the life of the media.

CONCLUSIONS

Nitrogen immobilisation, the temporary loss of available N to soil microorganisms, is associated with the decomposition of organic materials. The rate of decomposition, and hence N immobilisation, is related to factors including the chemical structure,

particle size, wettability, and C : N ratio of the organic material. The environment surrounding the material including pH, nutrient availability, moisture, temperature, and microbial populations can also affect the decomposition rate. The C : N ratio may provide a reasonable estimate of the potential N immobilisation. The NDI test actually measures inorganic N uptake by container media but it also has limitations particularly because the media may decompose and hence have a varying NDI with time. Plant tissue N content measured during crop growth is also a very useful tool.

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The Development of a Ginseng Industry in New Zealand

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INTRODUCTION

Ginseng, a perennial herb belonging to the Aralia family, is cultivated for its highly valued root although all parts of the plant can be used. In New Zealand, two economically important species are currently being established for commercial production: they are American ginseng (*Panax quinquefolius*) and Korean ginseng (*P. ginseng*). Both are commonly used as medicinal herbs and are marketed to the world through Hong Kong trading companies (But et al., 1995).

In the late 1980s, ginseng was identified as a potential new crop for New Zealand (Douglas, 1991). As a result a comprehensive research programme was established and ginseng was promoted to the primary industries as a possible new crop.

HISTORY

American ginseng was first evaluated in New Zealand in Canterbury in 1973 (Palmer and Hurndell, 1986). In July 1973 stratified seed was sown into seed boxes and left to germinate in a shaded unheated glasshouse. In 1975 the dormant seedlings were transplanted into a shade house where light levels had been reduced to less than 50% of ambient. In 1979 the roots were harvested, washed, and dried, and sent to Singapore for evaluation. The roots were considered too short with excessive branching of the tap root possibly caused by the ginseng being propagated in seed boxes then transplanted after 2 years. The hot dry föhn wind also caused some plants to drop their leaves possibly reducing growth rate and root size.

In the late 1970s a commercial evaluation of American ginseng was undertaken near Mosgiel (J. Wallis, pers. comm.). Seedlings were grown between two rows of black currant (*Ribes nigrum*) bushes. An evaluation of the 2-year-old roots by a Singapore buyer was favourable. However, subsequent commercial scale plantings failed probably because of insufficient knowledge of the crop's agronomic requirements.

At the same time the crop was also trialled by growers on the West Coast of the South Island in the natural shade of New Zealand native bush (H. Bezar, pers. comm.). The high rainfall of this region probably caused the severe disease problems that occurred in the trial.

Small scale plantings continued to be established throughout the country during the 1980s for both commercial evaluation and personal medicinal use (S. Hamilton, pers. comm.) but no commercial development followed.

RESEARCH

The current Public Good or Government-funded research programme on ginseng was established in 1989 in the Waikato, Rotorua, and Otago regions (Follett et al., 1995). Initially the programme was designed to evaluate production of American and Korean ginseng over a range of New Zealand climates. Results indicated that both species of ginseng would grow well in the colder drier regions of New Zealand such as Central Otago (Smallfield et. al., 1995). American ginseng was also found

to grow satisfactorily in the milder more humid regions of New Zealand provided adequate attention was paid to pest and disease control (Follett and Douglas, 1997). Ultimately the current research programme should be able to define the environmental and physiological constraints to ginseng production in a New Zealand maritime environment, and to develop production strategies to overcome those constraints.

STEPS TO ESTABLISH AN INDUSTRY

Crops for Southland. Crops for Southland (CfS) is an incorporated society (operating under the auspices of the Southland District Council) established to assist in the development of privately owned, market-based commercial horticulture to a significant scale in Southern New Zealand (Henderson and Hutchinson, 1996). Crops for Southland provides some funding and a strategic plan for the evaluation and possible development of a new crop. It aims to bring together all sectors (growers, processors, marketers, and researchers) of the industry. One of the first crops identified for evaluation and development was ginseng. In conjunction with the New Zealand Institute for Crop & Food Research (Crop & Food Research), CfS developed a Ginseng Starter Pack Programme to assist potential ginseng growers to establish a first trial planting. The hope is that as these trialists gain experience and confidence with the crop they will increase the area planted until production reaches the size of an economic unit. In 1996 all 21 trialists in the programme were in the South Island, with production in most cases under a forest canopy. Well attended seminars on ginseng have been held and CfS and Crop & Food Research have helped to establish the Ginseng New Zealand Association.

Ginseng New Zealand Association. The inaugural meeting of the Ginseng New Zealand Association was held on 30 Oct. 1996. The main objective of the association is to establish, foster, and develop the ginseng farming industry and the interests of all persons and companies engaged in the industry. To date the association has organised seminars and field days. Currently (1997) the association has 52 members. Several of the members have been growing ginseng for many years but most sowed their first seed in 1996.

INDUSTRY DEVELOPMENT

Accurate figures on the state of the ginseng industry are difficult to come by given the secretive nature of many growers. The industry is still in a development stage with product not yet available in sufficient quantities to make export economical. In addition to the starter pack trialists, forestry companies, and overseas investment companies are also trialling the crop. A number of independent growers successfully producing small quantities of ginseng are now looking to significantly increase production.

INDUSTRY PROSPECTS

Ginseng has a high price profile on the international market. While New Zealand growers are unlikely to grow intensively produced ginseng as economically as the large North American growers there is the possibility of producing ginseng for smaller but highly lucrative niche markets (Follett, 1997). These include forest-grown ginseng for the Asian market, and organically produced ginseng for the

American, European, and Asian markets. Ginseng is still a very new crop in New Zealand. Researchers and growers have still to discover how well this subcanopy herb, native to the deciduous forests and continental climate of North America and Asia, will cope with New Zealand's evergreen forests and maritime climate. Our initial results, while indicating many problems, has also provided a degree of quiet optimism.

CONCLUSIONS

The ginseng industry to date has developed through the combined efforts of the Southland District Council's active promotion of new crops, along with technical expertise from Crop & Food Research. Together these organisations have actively promoted ginseng to an audience already jaded by the number of new crops that have failed to live up to expectations. To counter this discouraging experience ginseng has been promoted as a crop with high risk and a long rotation time which requires a high level of commitment from the grower. Only time will determine whether it becomes a significant industry for New Zealand.

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Use of Beneficial Microorganisms for Improvement in Sustainable Monoculture of Plants

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INTRODUCTION

The introduction of bark- or peat-based soilless media in the commercial nursery industry has resulted in a more consistent medium for establishment, growth, and sale of most species of plants. Provided the medium has been supplemented with adequate nutrients and appropriate chemical pesticides are readily available, plant growth can be initiated and maintained economically. However, the microflora of the medium will seldom approach that of "healthy" soil in either magnitude or diversity of soil microorganisms. In many cases soilless media may be severely depleted of beneficial microorganisms extenuating the need for regular application of pesticides to control potentially harmful soil pathogens. In the past decade an increasing awareness has occurred of the important role beneficial microorganisms can play in commercial horticulture, provided sympathetic management practices are implemented for their establishment and maintenance. During this time the number of commercially available products based on soil-derived microbes has increased considerably. The identity, source, and use of some examples of these products will be summarised below together with selected case studies of their application in specific situations.

Table 1. Beneficial soil microorganisms.

Class	Activity			
	Symb.*	Bact.	Fung.	Insect.
Bacteria				
Rhizobium spp.	+			
Bacillus subtilis		+/-	+	
Pseudomonas spp.		+	+	
Streptomyces griseoviridis			+	
Agrobacterium radiobacter		+		
Serratia entomophila				+
Fungi				
Trichoderma harzianum	+/-		+	
Fusarium oxysporum			+	
Coniothyrium minitans			+	
Pythium oligandrum			+	
Candida oleophila			+	
Glomus spp.	+		+/-	
Bavaria bassiana				+
Metarhizium anisopilae				+
Nematodes				
Heterorhabditis spp.				+
Steinernema feltiae				+
Steinernema carpocapsae				+

* Symbiotic, bactericidal, fungicidal, insecticidal

TYPES OF BENEFICIAL MICROORGANISMS

Soil-derived microorganisms with well documented beneficial properties towards plants can be simply classified into three groups with individuals belonging to bacteria, fungi, and nematodes. Some examples within these groups are shown in Table 1.

All the examples depicted in the table have been used as bioactive ingredients in various commercial product formulations (Fravel, 1997). Most organisms have a single beneficial activity although *Pseudomonas* spp. show both bactericidal and fungicidal activity while *Trichoderma harzianum* and *Bacillus subtilis*, which are primarily fungicidal, and *Glomus* vesicular arbuscular (VA) mycorrhiza, which are primarily symbiotic, have been reported to have other activities (Samuels, 1996; Linderman, 1994).

COMMERCIAL PRODUCTS

An excellent summary of commercially available products for biocontrol of plant pathogens has been assembled by Fravel (1997) and is accessible on the Internet. Some examples of these products, their activity and details of the manufacturer are outlined in Table 2.

Most products are available as wettable powders to be watered or sprayed on to the soil, or as pellets or prills to be mixed with soil or media. The exception is Trichoject which is a liquid suspension of *Trichoderma* for injection into trees and vines.

Table 2. Commercial biocontrol products.

Product[1]	Manufacturer[2]	Agent	Activity
Epic	Gustafson	*B. subtilis*	*Alternaria, Rhizoctonia, Fusarium, Aspergillus* spp.
Intercept	Soil Technologies	*P. cepacia*	*Rhizoctonia, Fusarium, Pythium* spp.
Mycostop	Kemira	*S. griseoviridis*	*Alternaria, Rhizoctonia, Fusarium, Aspergillus* spp.
Polygandron	Plant Production Institute	*P. oligandrum*	*Pythium ultimum*
Soilgard	Thermo Trilogy	*G. virens*	*Rhizoctonia solani, Pythium* spp.
T-22G	Bioworks Inc.	*T. harzianum*	*Rhizoctonia solani, Fusarium, Pythium, Sclerotinia* spp.
Trichopel	Agrimm Technologies	*T. harzianum, T. viride*	*Phytophthora, Rhizoctonia Pythium, Fusarium, Sclerotinia* spp.
Vaminoc	MicroBio	*Glomus* spp.	*Fusarium, Pythium, Phytophthora* spp.
Trichoject	Agrimm Technologies	*T. harzianum, T. viride*	*Armillaria mellea, Eutypa lata, Chondrostereum purpureum, Phytophthora*

[1] Manufacturer's trademaks.

[2] For addresses see Fravel, 1997.

CASE STUDIES

Three case studies will be considered, two based on *Trichoderma* products as a biopesticide and a growth enhancer and one based on a *Glomus* VA mycorrhiza as a root inoculant. *Trichoderma* spp. are ubiquitous in origin and while generally saprophytic in activity, they occupy an ecological niche within the layer of decaying plant matter in both forest and agricultural soils where they assist in the formation of humus. They also demonstrate antagonistic and/or mycoparasitic activity towards a wide range of other soil-resident and wood-invading fungi from which they may derive an alternative source of nutrients. It is this property which has led to extensive investigation for many decades into their potential use as biological control agents (Samuels, 1996; Papavizas, 1985; Chet, 1993). *Trichoderma* was first registered for use as a biopesticide in the early 1980s and is now approved for commercial use in many countries including, Israel, USA, France, Belgium, Sweden, U.K., Australia, and New Zealand (Samuels, 1996).

Mycorrhizal fungal associations are also very common in nature with some 90% of higher plants interacting in a beneficial way with this group of fungi (Hunter, 1998). The term mycorrhiza is derived from the Greek for fungus root and describes the mutually beneficial relationship between fungus and plant where the plant's root system is extended by intimate interaction with the fungal mycelium. *Glomus* spp. are a group of endomycorrhizal fungi found naturally associated with many species of plants grown commercially where they assist with phosphorus uptake while also conveying improved resistance to water and disease stress (Linderman, 1994).

1) *Trichoderma* Biopesticide. Trichoject is described as a high-dose liquid injectable formulation of *T. harzianum* and *T. viride* which is registered in New Zealand for control of *C. purpureum* causing silver leaf of orchard fruit trees and protection against *A. mellea* root rot of kiwifruit vines. Trichoject has been administered to mature kiwifruit vines by injection of 20-ml dose into a 6-mm-diameter hole drilled in the trunk at ground level using a hydraulic injector for application. Results from field trials performed in orchards showing high disease pressure and deaths from *Armillaria* when followed for a number of seasons (Hunt, 1998) have shown significant improvement in the survival of treated vines compared with untreated controls (Fig. 1). Survival of untreated control vines show a death rate of up to eight times that of treated vines ($p < 0.005$). Contract injection of vines at risk in orchards throughout the Bay of Plenty region of the North Island of New Zealand has resulted in excess of 20,000 vines being treated since product registration in 1996.

Trichoderma has been isolated from vines 5 years after injection suggesting protective effects could last for extended periods (Hunt, 1998).

2) *Trichoderma* Soil Conditioner. Trichopel is described as a nutritive kernel pellet formulation with multiple strains of *T. harzianum* which is sold in New Zealand and Australia as a soil and media inoculant and conditioner. It has been evaluated as a plant growth enhancer (McPherson and Hunt, 1995) and in trials with commercially grown glasshouse tomatoes planted in sawdust-filled bags supplied with nutrients by liquid fertigation. Treated plants received 5 g per bag Trichopel G well mixed into the surface layer to a depth of 100 mm.

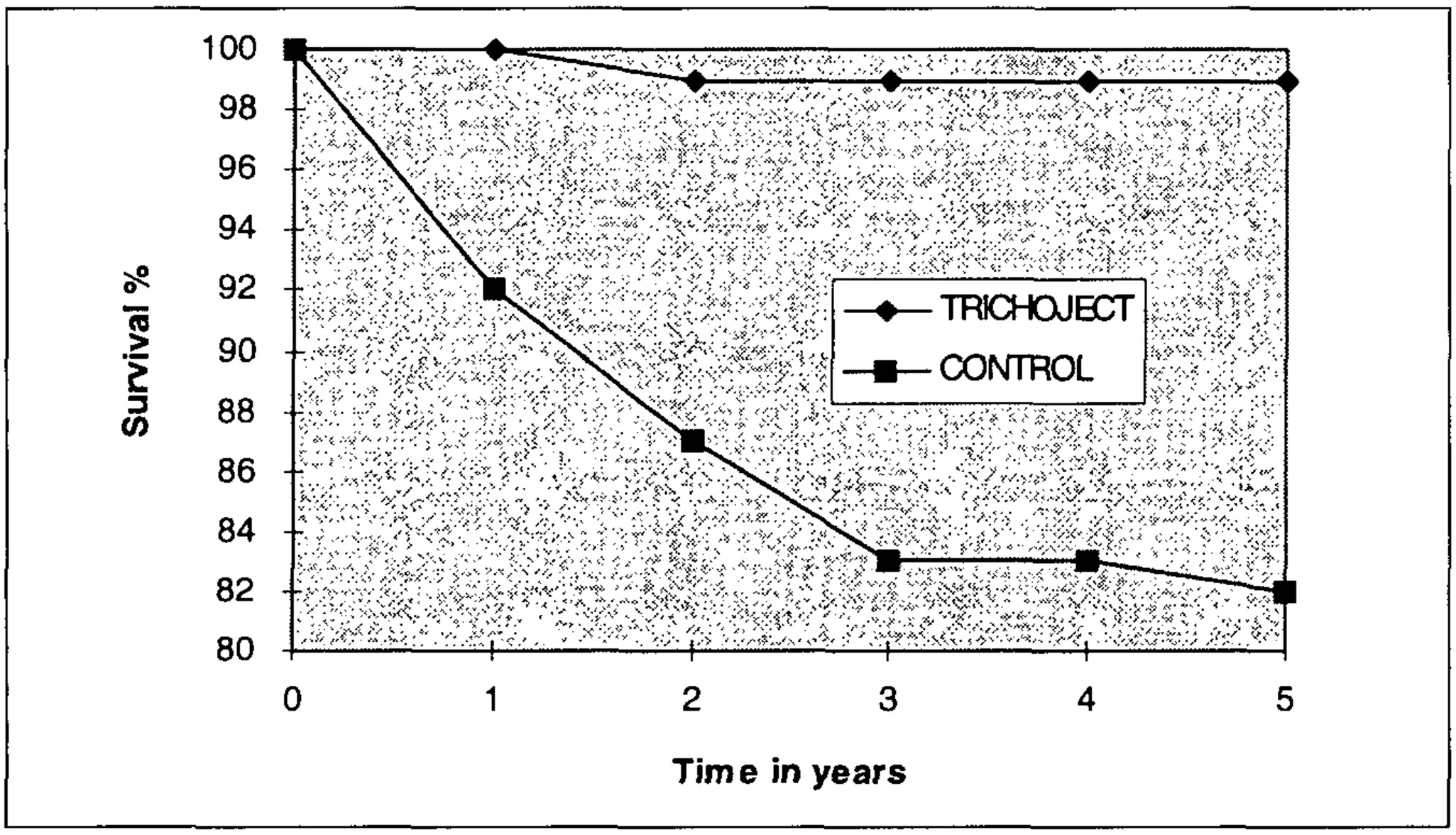

Figure 1. Survival of kiwifruit vines treated with Trichoject.

Results showed a significant increase in stem diameter measured at first truss on two varieties of tomatoes treated with Trichopel (Table 3). Although the mean crop weight for one of the varieties measured was not significant, total crop weight increased by 6.3% with treatment.

Table 3. Glasshouse tomatoes (*Lycopersicon*) treated with Trichopel.

Measurement	Trichopel mean ± s.d.	Control mean ± s.d.	Statistics p value
Stem diameter [1]			
'Taupo'	12.69 ± 1.56	11.69 ± 0.91	0.002 s.
'Evita'	9.33 ± 1.07	8.59 ± 0.66	0.014 s.
Crop weight [2]			
'Taupo'	34.30 ± 6.36	32.26 ± 5.16	0.189 n.s.
Total Crop Weight [3]	445.94	419.43	6.32%⇧

[1] Mean stem diameter (mm) from 10 replicates measured at the first truss.
[2] Mean weight (kg) per week harvested Monday, Wednesday, and Friday over a 4-week period.
[3] Total crop (kg) harvested from 240 plants sampled in each treatment.
Abrev: s.d. = Standard deviation; s. or n.s. = significant difference of the two means by Students t test; ⇧= increase in Trichopel treatment weight over control.

3) Glomus Root Inoculant. Vaminoc is described as VA mycorrhizae stabilised on an inert clay matrix which is sold in U.K., New Zealand, and Australia as a root inoculant to improve plant growth. It has been evaluated as a root inoculant to enhance plant growth in trials with vegetables, fine turf grasses, and forestry tree species. Six species of trees grown commercially in forest nurseries were evaluated

for VAM infection after 5 to 6 weeks growth from germination in pots containing Vaminoc inoculant and compared with sorghum as a positive control. Microscopic examination of seedling roots showed five of six species to contain either mycelial infection or inclusion bodies (vesicles) after 6 weeks (Table 4).

The sorghum-positive controls all showed clear evidence of mycelial infection as well as the presence of numerous inclusion bodies. *Acacia melanoxylon* was the only species not to show any evidence of infection.

Table 4. Reaction of tree seedling roots to growth in Vaminoc.

Plant	Mycelial infection[1]	Inclusion bodies[2]
Sorghum bicolor	+	+++
Pseudotsuga menziesii	-	+
Eucalyptus nitens	-	+++
Pinus radiata	-	+++
Cupressus macrocarpa	+	+++
C. lusitanica	+	++
Acacia melanoxylon	-	-

[1] + Glomus mycelium present, - no mycelium.
[2] +++ Numerous, ++ moderate, + scattered inclusion bodies, - no inclusion bodies.

CONCLUSIONS

There is a considerable range of commercial products currently available which are based on beneficial microorganisms derived from both bacteria and fungi. Many of these products offer the commercial nursery opportunities to introduce these organisms into new management techniques for sustainable improvement in plant growth and disease protection.

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Hastening and Controlling Flowering in *Metrosideros*

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When cultivars of *Metrosideros* are micropropagated, plants typically revert to the juvenile phase, becoming bushy and hard to handle in the nursery, and bearing leaves similar to those of young seedlings. Critically, this rejuvenation also causes micropropagated plants to lose the ability to flower. We are exploring the potential of the traditional techniques of restricting roots, and training and restricting the shoots to hasten maturation in rejuvenated plants. Shoot restriction was more effective than root restriction in returning plants to the adult leaf morphology. We are also monitoring shoot growth and floral development in mature *M. excelsus* plants growing in the field to determine how the timing of apical shoot abscission affects the ability of buds to be receptive to signals that will initiate floral development.

INTRODUCTION

Understanding the course of vegetative and floral development in mature plants growing in the field is an important foundation to the study of plants in the production setting. Although the timing of shoot growth and its characteristics have been broadly described for *Metrosideros* (Dawson, 1968), we do not know when flowers are initiated, why some shoots are floral and others vegetative, and why some flowering shoots bear more flowers than others. Detailed studies, similar to those made by Snowball et al. (1995) for kiwifruit, are being carried out for shoot growth and development in mature *M. excelsus* plants growing in the field.

A goal for horticulturists for many centuries has been to cause woody plants to flower earlier than they would normally. Not surprisingly, many techniques have been used to cause precocious flowering, including root restriction, training regimes, and (more recently) chemical plant growth regulators. Woody crop plants studied intensively in New Zealand include *Citrus* (Snowball et al., 1994) and kiwifruit (*Actinidia*) (Davies, 1991; Snowball, 1995). These workers described the annual changes taking place in the architecture, leaves, and flowering shoots of their plants. They also showed that flowering can be accelerated by training long, unbranched shoots of their plants. Plant growth regulators that inhibit vigorous vegetative growth, e.g., paclobutrazol, can also be beneficial for flowering (Snowball et al., 1994). Resuming our earlier work (Oliphant et al., 1992), we are using these techniques to accelerate and enhance flowering in the ornamental woody genus *Metrosideros*, paying particular attention to micropropagated cultivars.

MATERIALS AND METHODS

Monitoring Mature Plants. Mature plants of *M. excelsus* were monitored for 12 months in the field to establish the timing of shoot growth and floral initiation. Shoots were tagged on three trees in midwinter, and the diameter of overwintering buds measured. Buds were classified into seven size classes based on bud diameter, ranging

from 1.5 to 3.0 mm (size class 1) to 5.6 to 6.0 mm (size class 7). Buds were examined in the field every 2 to 4 weeks through bud break and flowering.

Root and Shoot Restriction. Micropropagated plants of *M. excelsus* 'Scarlet Pimpernel' were grown in containers of five differing volumes (0.2 to 1.8 litre) to apply different levels of root restriction. The containers were made from lengths of water conduit of differing diameter, which were cut into 110-mm sections. Woven fabric that would allow water penetration while restricting root growth was attached to the "base" of each section. Plants were transplanted into the pots using a growing medium that could be readily washed from roots at harvest, and containing controlled-release fertilisers. Over the following 9 months shoot growth in half the plants was restricted by removing all axillary shoots to give single-stemmed plants. Shoots were unrestricted in the other half which were allowed to branch freely. Shoot growth was monitored regularly before a single destructive harvest in which detailed measurements were made of the changes taking place in the leaves as the plants grew and matured, and the dry weights of plant parts determined.

RESULTS AND DISCUSSION

Monitoring Mature Plants. The majority of overwintering buds on mature trees in the field broke in September-October. If they were vegetative buds, they grew out into leafy shoots. Subsequently, the elongating shoot tips typically abscised, leaving leafy shoots with 2 to 5 nodes. Buds that were floral developed slowly until late December, when the individual flowers opened.

Many of the smallest overwintering buds (size class 1) did not break. Those that did break were predominantly vegetative, indicating that they had not been receptive to conditions suitable for floral induction in the previous months. Progressively larger overwintering buds were more likely to break, and the proportion of these that were floral increased up to bud size class 5 (Fig. 1). Larger floral buds contained more flowers than the smaller floral buds.

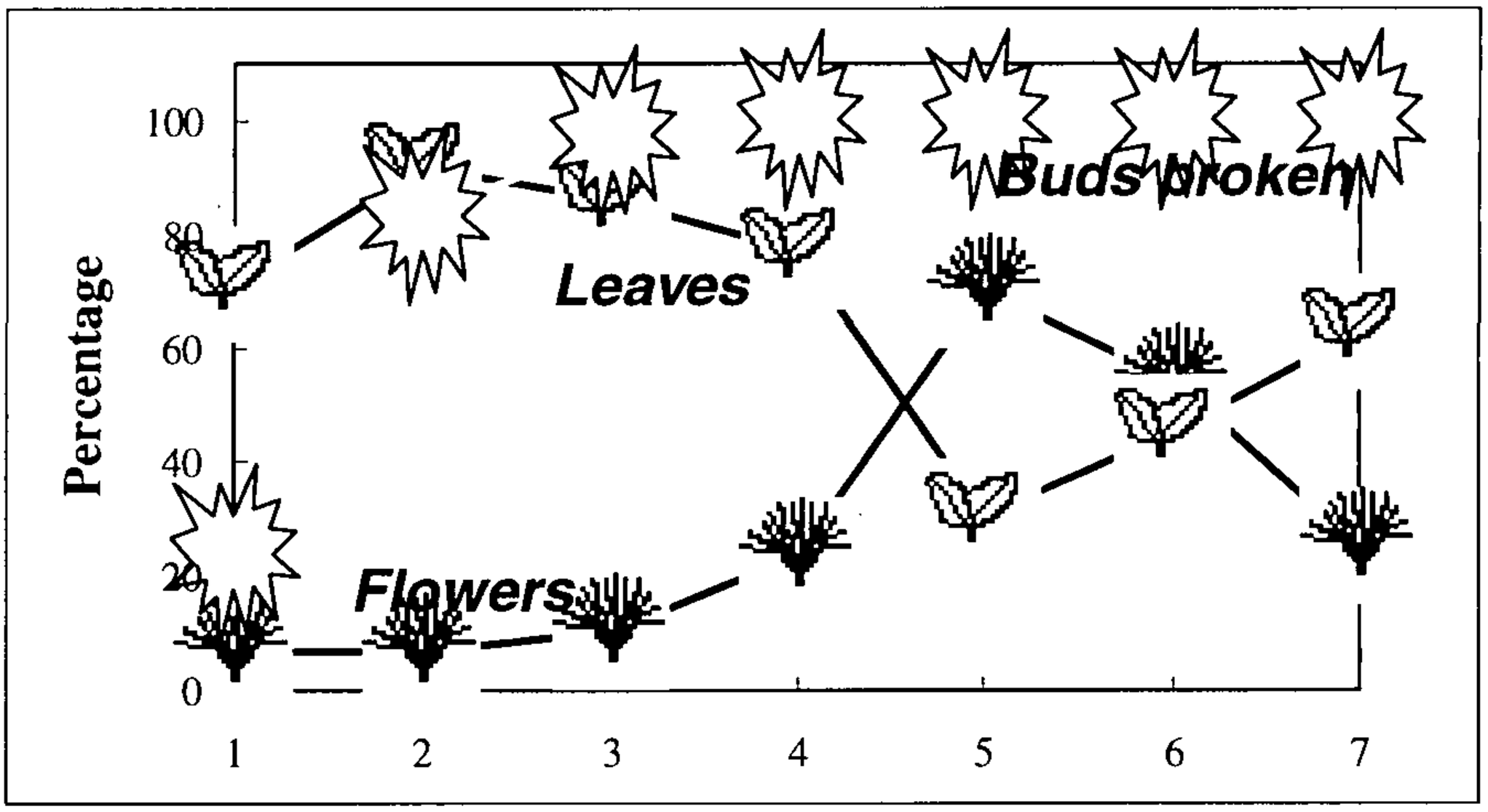

Figure 1. The percentage of overwintering buds in seven different size classes that broke in spring ("buds broken"), and the percentages of breaking buds that developed as vegetative shoots ("leaves") and floral shoots ("flowers"). Means are for 30 buds within each size class.

Surprisingly, the largest overwintering buds were more likely to be vegetative than floral, indicating again that these, like the smallest buds, had not experienced floral inductive conditions (Fig. 1). Abscission of the apex of the elongating vegetative shoot is a characteristic feature of *M. excelsus* and related species (Dawson, 1968). We believe that the ability of buds to initiate flowers may depend on the timing of apical shoot abscission in relation to temperature and photoperiodic signals inductive for flowering, and are testing this hypothesis in the coming season.

Root and Shoot Restriction. Micropropagated plants of *M.* 'Scarlet Pimpernel' responded to both root and shoot restriction treatments. Judging from the changes taking place in leaf shape, size, and spectral qualities, plants grown as single-stemmed plants matured much more rapidly than those allowed to grow branched. Bushy plants bore leaves that resembled those on the original rejuvenated liners (pointed and glossy green), whereas leaves on the single-stemmed plants were similar to those in adult plants (rounded and grey on the under-surface).

Branched plants weighed 2 to 3 times more than unbranched plants because branched plants developed many branches whereas single-stemmed plants were allowed to bear only one pair of leaves at each node with no axillary shoots. Branched plants also experienced greater root restriction in the smaller pots than the unbranched plants, root dry weight being significantly reduced. Unbranched plants had smaller roots than the branched plants, and were not restricted by the smaller pot sizes.

Preliminary results suggest that the root restriction experienced by the branched plants growing in the smaller pots did not accelerate the return of micropropagated plants to mature leaf morphology. Reversing the rejuvenating effect of micropropagation is, therefore, more likely to be successful by training rapidly growing single-stemmed plants, similar to the way Snowball et al. (1994) treated container-grown citrus, than by restricting root growth.

Temperature and day length treatments have been used successfully to bring about flowering in New Zealand woody ornamentals, e.g., *Hebe* (Noack et al., 1996) and *Leptospermum* (Zieslin and Gottesman, 1986). We are also using temperature and day length to manipulate flowering time in plants of *Metrosideros* that have been brought to the stage of being able to flower. The progress of shoot growth, floral initiation, and flowering in these plants will be tracked over the coming year. These growth studies are being complemented by analysis of the expression of genes associated with flowering and changes taking place in endogenous plant hormone (gibberellin) concentrations.

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In Pursuit of The Great New Zealand Garden

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INTRODUCTION

It was while recently enjoying the company of Ian and Barbara Duncalf, two worthy members of your Society, at a certain hostelry just North of Tauranga, that the conversation drifted onto the topic of The Great New Zealand Garden. Does such a thing exist? If not, why not, and if so, what characteristics qualified it for such lofty consideration? The discussion that followed was inconclusive but we did agree that a paper entitled something like "In Pursuit of The Great New Zealand Garden" or "Would The Real New Zealand Garden Please Stand Up?" could make an interesting topic for this conference.

I've been designing gardens, among other things, for a little over 20 years. Over that period I've probably designed on average, about 20 gardens a year. By virtue of a simple calculation, that means I've probably designed approximately 400 gardens, give or take a courtyard or two. I can confidently say that, as a result, there are about 400 landscapes that are more presentable than they were before we started and there are around about 400 clients who are reasonably satisfied with what has been achieved. However, without wishing to appear unduly self-deprecating, I have to concede that none of those 400 gardens could realistically be described as The Great New Zealand Garden, much as I hate to admit it.

All is not lost though, because although I haven't had the opportunity to personally inspect all the gardens of New Zealand, I doubt that anyone else has created The Great New Zealand Garden either!

WHAT IS THE GREAT NEW ZEALAND GARDEN?

It's worth considering for a moment what qualities a garden would have to have to be described as The Great New Zealand Garden. As a start point, maybe it would be helpful to firstly dismantle and define the words. The use of the definite article suggests that there is but one Great New Zealand Garden, unless one were to use the word in a generic sense, in which case there would be one Great type of garden. All the examples of which exhibited distinctively Great characteristics which enabled them all to be lumped together. For the purposes of this discussion, let's assume we are talking about one Great New Zealand Garden.

The Word "Great." This implies superlativeness, significantly better than that which is merely excellent. In the context of gardens, greatness implies comparability with other gardens of the world that are recognised as great. The New Zealand cricketer, Martin Crowe, who was by far the most prolific scorer of test cricket runs New Zealand has produced, became obsessed towards the end of his career with concerns as to whether history would judge him to be a Great Cricketer. Criteria like the number of test centuries he scored, his highest test score, the manner in which he scored his runs, against whom, and how these achievements compared with those of other past players who are acknowledged as having achieved Greatness, were put forward as yardsticks against which his performance and ability could be judged. For

a New Zealand garden to be considered Great it would need to compare favourably with the great gardens of the world, such as the Isola Bella on Lake Maggiore in Italy, Le Notre's Vaux-le-Vicomte in France, Stowe or Stourhead in England, or the Ryoan-ji of Japan. All these gardens have in common the following characteristics :

They successfully blended, built, and planted elements with landform, water, and space, if not literally, then, as in the case of the Ryoan-ji, metaphorically; they reflect the social, economic, philosophical, and spiritual conditions and attitudes of their respective place and time; they are the result of considerable refinement of a particular style—they epitomise the climax of a creative movement; they are made up mostly, if not entirely, of distinctively local materials; they exploit an emotional or intellectual response which is in turn connected with the fundamental senses of sight, sound, smell, taste, and touch; they respect and enhance the "genius loci" of the place in which they are situated; they all exhibit a sense of timelessness—an enduring quality and a meaning which appeals to, and is appreciated by, the intellect of the person experiencing it. These then, perhaps, are the yardsticks against which we must measure New Zealand gardens.

Defining New Zealand. Which brings us to the next words—New Zealand. We all know what those words mean....or do we? Which New Zealand are we talking about? The heavily bush clad archipelago that existed before human beings first set foot on it? (Now that must have been a Great Garden). Or is it the Aotearoa of pre-European colonisation? Or the New Zealand that I grew up in in the second half of the 20th Century, or is it the Aotearoa-New Zealand of the new millennium?

As we all know, the landscape of New Zealand has been, and continues to be, heavily modified by all of us and the plants and animals we brought with us. Our social and economic circumstances have been evolving continually and new paradigms are being established and disestablished—the most recent being over the last 15 years.

So What Are the Essential Qualities of "New Zealandness" That We Might Look for in a Distinctively New Zealand Garden? The most obvious item is plant material. While many of our native plants have look-alike cousins which originated in other parts of Gondwanaland, many of our native plants are endemic to New Zealand alone. Our botanical palate has been irreversibly extended through the introduction of a vast range of exotic plant material from virtually all corners of the globe. This process, of course, parallels the broadening of the human gene pool through the influx of immigrants from all parts of the planet—a process that is equally irreversible.

Some sort of botanical mix which reflects this reality is, therefore, probably inevitable in any garden that purports to represent the New Zealand of the late 20th Century, let alone the next millennium.

Our culture and lifestyles also help to define us. We have only to observe the antics of newly arrived immigrants to realise that we actually do things a little differently here.

We are generally an informal people. We tend to rebel against officiousness and officialdom. We have an aversion to pomp and ceremony ourselves, although we find such behaviour fascinating in others. We are generally hospitable and generous, although we don't like having our generosity taken for granted. We have an ability to laugh at ourselves, but we can't abide being laughed at by others. We are generally

resilient and resourceful and are used to making do with the materials available. Necessity has literally been the mother of many of our inventions. We tend to be skeptical about prettiness and good design unless such design can be shown to be clever, useful, or appreciated by overseas experts. We value our independence and privacy but we resent not being given the opportunity to be involved. We are deeply suspicious of anyone who gets ahead especially if that progress is at our expense. We exert a moderating influence on our innovators, our tall poppies. This is the curse of designers everywhere but seems particularly so in New Zealand where new ideas are frequently scorned, or even worse, ignored. Our innately conservative attitudes drive the most talented of us overseas and dilutes the remaining poppies into bland and ubiquitous buttercups.

It is interesting to ponder the thought that maybe it is our very egalitarian heritage of the sharing of resources and opportunities and our approach to welfare that has worked against the development of greatness in our gardens. I believe it is no coincidence that all of the great gardens that I mentioned at the beginning of this talk were created at the climax of a period of great power and influence and were thus an expression of that power.

The increasing stratification of New Zealand society and the accompanying redistribution of wealth is creating a clientele for designers who are willing to humour the design gifts of our most able and innovative designers. Many a half-baked pie has also emerged as a result our vulnerability to the forces of fashion, our scanty garden design heritage, and the invasion of the designing niche by an assortment of well meaning, partially qualified amateurs. It never ceases to amaze me how little training some people reckon is necessary to equip them adequately for spending other people's money!

Defining Garden. None of the meanings in my copy of the Concise Oxford Dictionary do justice to the way we perceive gardens today. Gardens for us have become much more than "a place where fruits, vegetables, and flowers are cultivated" or "a public place for the display of plants of various kinds". The establishment of a relatively affluent middle class in New Zealand has increased the extent to which gardening is undertaken here as a leisure activity. In contrast to the "deep and meaningful" approach of traditional Asian garden designers and the grandiose creations of the Europeans, the New Zealand version reflects partly the Kiwi "she'll be right" attitude, partly the constraints of size, space and limited resources and partly our unwillingness to look a gift horse in the mouth. Our willingness to compromise a carefully composed planting combination with "just a few bits and pieces from Aunt Margaret's lovely garden" is one of our more charming tendencies. It's little wonder greatness eludes us! Our gardens suffer generally from a lack of attention to detail, particularly with respect to the "hard landscape". This may be because, unlike the Australians, we haven't had the benefit of a large Italian migrant population, many of whom brought with them skills in masonry and stone-working.

Nevertheless, gardens and gardening have become a major growth industry as we all know. Along with the memoirs of our sporting heroes, books about gardens have become our best sellers. The perception that "doing up the garden" is probably going to be a better investment than overhauling the dwelling is now firmly established in the Kiwi psyche. The fun and satisfaction element of creating a garden is also a big part of why we are switching on to gardens.

For us, a lot of the value of the garden is in the making. Our gardens have become places to be in, as against places primarily designed to be looked at. We think of the garden as an outdoor area associated with a building of some sort—usually a dwelling. We have moved on a long way from the version of the garden displayed on the cover of the old Edmond's "Sure To Rise" Cookbook.

CONCLUSION

So, where does that leave us? Is there any chance that a Great New Zealand Garden will happen? My guess is, dare I say it, probably not, though I would be delighted to be proved wrong. I believe the globalisation of world fashion militates against such distinguishable excellence in gardens evolving here. While it is tempting to suggest we should ignore such influences in pursuit of a pure expression in Aotearoa New Zealand, these pressures are remarkably strong. Gardening books, magazines, television programmes, and the visiting of existing gardens all perpetuate images and consolidate expectations, particularly on the part of our clients (our modern-day patrons), of the need to re-create a little bit of Kent or Kyoto or Tuscany.

Even the deliberate and exclusive use of our native plants doesn't necessarily relieve us of the constraints of the picturesque or gardenesque landscapes of abroad — the so-called "pidgin picturesque" is alive and well in Aotearoa.

It would probably require a life-long, single-minded quest on the part of a group of skilled and dedicated designers to achieve the goal of a Great New Zealand Garden. The group best equipped to conduct such a quest, landscape architects, have, by and large, bigger fish to fry. A few make garden design their primary focus, but there tends to be a progression towards broader scale projects, where their impact will be greater and their rewards enhanced.

Home-grown or semiqualified exponents of the art of garden design, while responsible for some flashes of brilliance, generally lack the breadth of skills necessary to achieve greatness. Despite the commonly espoused ethic that "anyone can do it" there is a good deal more to the design of outdoor spaces than meets the eye. Which is not to say that the goal itself is not a worth pursuing. Yet The Great New Zealand Garden, if there ever is to be such a thing, will probably occur more by chance, than as the result of a drive towards perfection. It will be a place that owes its existence to a love of this land of ours and an understanding of, and sensitivity to the mauri, or essence of the place in which it stands. It will reflect the rich and youthful geology that underlies it. It will exhibit subtle understatement combined with diversity of form, colour, and texture. It will almost certainly **not** contain palm trees—at least not exotic ones. It will have places for all people of all ages. Its conception will have been the result of willing and generous cooperation of many people. It will combine landform, plants, water, structures, and spaces into an harmonious whole that will, like a great wine, improve with age. Let the pursuit continue!

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Novel Developments for the New Zealand Floriculture Industry into the Next Century

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Pioneering New Zealand growers and researchers have successfully developed exotic crops such as summer-flowering *Zantedeschia* and *Sandersonia.* The New Zealand floriculture industry requires an ongoing supply of new products that can command premium prices on international markets. This will require the ongoing introduction of new germplasm and the development of new crops, as well as breeding existing crops to introduce new forms and colours. Most new flower cultivars in New Zealand have been produced by conventional breeding techniques. In future, in vitro breeding techniques will increasingly support conventional breeding approaches. Many of the cultivars produced will need to be vegetatively propagated and so improved tissue culture techniques will be required to ensure that New Zealand's floriculture industry remains competitive.

INTRODUCTION

The value of New Zealand's floriculture exports (flowers, tubers, and bulbs) has grown dramatically over the last 18 years from $1.3 million in 1980 to $60-70 million per annum. Although this value is small in relation to the $50 billion of floriculture products traded annually worldwide, it is significant on a national scale.

International trade is dominated by a few standard crops (e.g. roses, carnations) that are high volume, low value, and very price sensitive. The New Zealand industry is not well placed to compete for a market share of these crops due to our high labour and transport costs compared to countries such as Colombia and Kenya. Most New Zealand exports are "exotic" crops or crops produced for niche markets in which we can receive premium prices (e.g., *Zantedeschia, Sandersonia*). The growth in New Zealand exports has been in cut flowers and foliage (now $50 million) and tubers and bulbs ($10 to 20 million). Bulb/tuber exports are expanding rapidly due to increased demand for *Zantedeschia* tubers and the production of tulip bulbs for Northern Hemisphere markets.

NEW PRODUCTS

Pioneering New Zealand growers and researchers have developed summer-flowering *Zantedeschia, Sandersonia aurantiaca*, and *Nerine sarniensis* as cut flower crops. Tuber storage systems have been developed along with dormancy breaking treatments and methods to extend the production season and reduce tuber disorders (Clark, 1995; Clark and Burge, 1997a,b; Dennis et al., 1994; Funnell, 1993). Our understanding of crop environmental and nutritional requirements has also improved (Brooking et al., 1997; Warrington et al., 1989). New crops under development in New Zealand (e.g., *Cyrtanthus elatus*) also require the development of production systems for high quality stems and to extend the production season. The

New Zealand industry requires an ongoing supply of new products so that premium export prices can be received. New cut flower products can be developed by:

- Developing crops from wild flora;
- Developing postharvest techniques to extend the postharvest life of possible new crops to an acceptable level;
- Developing production systems for potential crops;
- Breeding new cultivars.

BREEDING

Conventional breeding techniques have been used in New Zealand to produce a wide range of *Cymbidium* orchid and *Zantedeschia* cultivars (Funnell, 1993). Currently a breeding programme is developing *Leptospermum* cultivars with longer vase life. The native species, *L. scoparium*, has a short vase life but good flower characteristics and so this species was hybridised with two other species to introduce the long-vase-life characteristic (Bicknell, 1995).

Large increases in flower colour range, time of flowering, and quality have been achieved using conventional breeding techniques. However, a major limitation of these techniques is that the pool of genetic variation available within a species is limited. Often characteristics that are perceived as being valuable are seen in other species but it is not possible to transfer these characteristics into the crop of interest by conventional means.

In recent years a range of novel breeding technologies has been developed. These novel breeding technologies can complement conventional breeding programmes by extending the range of genetic material that can be used in breeding programmes as well as determining more rapidly whether the characteristic has been incorporated. The techniques available for enhancing conventional breeding programmes include mutation breeding, wide crosses using sexual or somatic methods, and transformation. Mutation breeding provides a tool for increasing the observed variation within a population. Selection of plants with desirable characteristics can then be carried out. Wide crosses involve combining the characteristics of plant species, which may or may not be related. Progeny can be expected to exhibit traits characteristic of both parent species. Transformation is the process of inserting new genes into plant cells. Wide crosses and transformation rely on inserting new genetic material into the species of interest, whereas mutation simply changes the expression of characteristics that are already present.

Mutation Breeding. Mutations occur naturally and horticulturalists have selected mutants with commercially valuable traits (e.g., new flower colours, dwarf, or prostrate forms). Mutagenic agents, either physical or chemical, can be applied to plant material to increase the frequency at which mutations occur. A range of chemicals is known to have more direct and specific effects on DNA, for example, ethyl methanesulphonate (EMS) is thought to cause random mutations at individual nucleotides. However, these chemicals can also be dangerous to handle and so we use gamma irradiation in our mutation breeding research because it is cleaner and there are no residual chemicals to dispose of. The physical mutagens cause breakages and deletions in the chromosomes. Reported phenotypic changes observed after irradiation of plant material include colour changes and dwarfing.

Spindle toxins (e.g., colchicine) block cell division and produce tetraploids. Tetraploid *Zantedeschia* plants have been produced with this technique (Cohen and Yao, 1996). Triploids can be produced by crossing tetraploids with diploids. Triploids have several potential advantages including enhanced vigor and sterility. Sterility is common in triploids and can be used as part of a breeding strategy to prevent other breeders from quickly producing new cultivars from our cultivar releases.

Wide Crosses. The genetic improvement of crop plants is achieved conventionally by hybridisation and selection within the gene pool of the crop species. New cultivars can be developed by producing interspecific and intergeneric hybrids. A greater understanding of the barriers to producing wide crosses is being gained and techniques are being developed to overcome them. These include pollination and post-zygotic barriers (van Tuyl, 1997). A common postzygotic barrier is abortion of the embryo due to poor development of the endosperm. A number of in vitro techniques are used to rescue the abortive embryo (e.g., ovule culture and embryo culture).

Sandersonia is the third most important export flower crop from New Zealand. However, until recently there were few opportunities to breed new cultivars as little variation occurs in this monospecific genus. Application of wide crossing technology has allowed the development of intergeneric hybrids between *Sandersonia, Gloriosa,* and *Littonia*. These hybrids (taxonomically *Sandersonia* spp.) have new flower colours and forms. Similarly, techniques have been developed that bypass the barriers to the production of *Limonium* hybrids. Two new interspecific *Limonium* hybrids have consequently been developed (Morgan et al., 1994). Many of the existing *Zantedeschia* cultivars are natural hybrids between the summer flowering species. Hybrids have been produced between the summer- and winter-flowering species but only with great difficulty as there are a number of incompatibility problems that mean the hybrids are difficult to grow (Yao et al., 1995).

An alternative approach to bypassing breeding barriers involves protoplast fusion where plant cells from different species are induced to fuse in vitro. Protoplasts are plant cells without their cell walls, the cell walls having been removed by enzymatic degradation using a "cocktail" containing enzymes such as cellulase, pectinase, and often macerozyme. Protoplast fusion has been applied successfully to a small range of plants that are in commercial use but the technique has not yet been widely utilised by plant breeders, despite the fact that it is applicable to a wide range of plant species. Over recent years we have developed protoplast regeneration protocols for a number of species including *Cyclamen*, some members of the Gentianaceae, and a number of *Solanum* species (Morgan and Burge, 1995). Present protoplast work in the lab involves further developing regeneration skills, developing electroporation techniques, and learning electro-fusion techniques.

Transformation. Molecular breeding techniques are being used to introduce new characteristics into crops. This technology enables us to insert known DNA sequences (genes) into plant cells. The genes carry codes for the production of specific enzymes that can catalyse reactions that would otherwise not occur in the plant. As DNA has the same basic structure in all plants, genes can be transferred across species barriers.

Molecular breeding techniques are very specific but can introduce only 1 to 3 genes and, therefore, can only be used to introduce characteristics that are controlled by

a few genes (e.g., flower colour, dwarfism). The Plant Pigments Group at Levin has been studying the use of molecular breeding techniques to produce new flower colours in a number of flower crops. This research includes an understanding of the plant pigments (flavonoids and carotenoids) present in the petals of these crops, the development of strategies to produce new flower colours, and transformation techniques to introduce genes (Davies and Schwinn, 1997).

The most commonly used and most efficient techniques for genetic transformation of cells of dicotyledon plants have been based on *Agrobacterium tumefaciens*. "Foreign" genes are hitched onto this natural plant gene vector and are transferred into the plant cell where they become integrated into the plant chromosomal DNA. However, the success of *Agrobacterium*-mediated DNA uptake by monocotyledon cells (e.g., *Zantedeschia, Sandersonia*) has been limited. This stimulated the development of direct DNA transfer methods which include microprojectile bombardment or so-called "biolistic transformation". The principles of microprojectile bombardment are quite simple. Literally, small particles (approx. 1 μm diameter) of gold or tungsten, onto which DNA has been precipitated, are accelerated to high speed and fused into plant cells or tissues. In some cells the DNA may be stably incorporated into the nuclear DNA. The presence of the introduced DNA can be demonstrated by testing for expression of the appropriate marker genes some weeks or months after the shooting event.

The Plant Pigments Group at Levin has successfully introduced flavonoid genes from species such as *Antirrhinum* to produce new flower or foliage colours in petunia and lisianthus. Scientists have also used antisense techniques to "turn-off" genes and produce white lisianthus and patterned flower colours.

TISSUE CULTURE

Two large commercial tissue culture laboratories in New Zealand each produce several million plantlets per year and a number of smaller laboratories produce smaller quantities. These laboratories produce about 2 million *Zantedeschia* plantlets per year plus a wide range of ornamental, berryfruit, forestry, and vegetable crops. They face competition from overseas laboratories with cheaper labour costs, especially for plants produced in large quantities (e.g., *Zantedeschia*). New Zealand laboratories export tissue culture plantlets to Australia, North America, and Europe. New Zealand laboratories retain their business by (1) supplying a wide range of species, (2) producing high quality plantlets, and (3) introducing new technologies. An example of a new technology is the development of in vitro tuberisation techniques for some crops. Other new technologies include somatic embryogenesis. Somatic embryogenesis systems are being developed internationally for important crops (e.g., conifer species, *Cyclamen*) as these systems have the potential to greatly reduce costs. Somatic embryogenesis systems have been developed in New Zealand for *Pinus radiata* (Aitken-Christie et al., 1994) and a system is currently being developed for asparagus. Research is required on the development of systems for crops relevant to the New Zealand ornamental industry.

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Plant and Environmental Factors Limiting Vegetative Propagation

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INTRODUCTION

Successful vegetative propagation of plants may occur by chance but it is more likely to occur consistently where there has been a systematic consideration of the factors that could be limiting root formation.

PLANT FACTORS

These are concerned with competence and preparation for root initiation.

Genotype. The genetic make up of a plant can have a marked influence on its capacity to form roots under ideal circumstances. This means it is worth propagators keeping records of propagation preplant procedures, propagation environment, and the rate of success. Big differences may occur between different species and cultivars within a species.

Stockplant Management. Plant material should be of the highest quality that can be obtained; where quality refers to the total quality of the plant, including freedom from known pests and diseases. Viruses and physiological disorders may reduce rooting potential. Plant thriftiness will also be influenced by nutritional status with the effect of deficiencies in some essential elements (N, Zn, B, Mn) being well documented. A high level of carbohydrate and nitrogen, as occurs in vigorous shoots producing firm cuttings, normally works well under intermittent mist whereas a lower nitrogen content would favour rooting of hardwood cuttings. Preharvest stem girdling and stem etiolation in low light both improve rooting of some more difficult-to-root species by altering the anatomy of the stem and increasing the sensitivity of the stem to applied auxin (Maynard, 1992).

In many plants there is a decline in rooting capacity as shoot material hardens-up. During a growing season, the plant material changes from softwood through half-ripe or semihardwood to fully lignified wood. These seasonal changes are often confused with the changes that occur during plant maturation as people often use similar names for quite distinct aspects of plant growth.

Juvenility may be an important factor influencing root formation in woody plants. The ability to form regular flowers in the adult stage is associated with decreased rooting potential in many species. Maturity and hence rooting may also be related to the position on the stockplant where the cuttings are collected. Lower shady branches generally provide better cutting material than material collected higher up the stockplant. The closer to the ground the stockplants can be maintained the more reliable they will normally be as a cutting source (Howard, 1991).

Timeliness of Setting Cuttings. For many easily rooted plants or those with preformed root initials the time of the year when they are propagated is really a matter of convenience. This allows the development of a market-driven propagation system as

described by Vallis (1991) For many woody plants there are marked seasonal fluctuations in the speed of root formation and in the number of cuttings rooted which does not permit the same flexibility, unless the environment can be controlled artificially to extend the growing season. Davies et al (1984) showed that shoot RNA content was related to bud activity and correlated with seasonal rooting activity Anticipating future bud activity may be a good indicator of the time when cuttings should be set as roots may be initiated shortly afterwards

ENVIRONMENTAL FACTORS

These are concerned with stress minimisation to allow root formation

Water. Cuttings should be fully charged with water at the time when they are collected or if they are stressed they will need additional water to make up for the water they have lost The driving force determining water loss from cuttings is related directly to the difference in the water vapour pressure in the leaves and the surrounding air As root initiation is particularly sensitive to water stress, leaf water deficits in leafy cuttings should be minimised through use of humidification by overhead intermittent misting or a fogging system The type of system may be rather less important than its efficiency at keeping the leaves fully turgid. In misting systems the cooling effect of water evaporating from leaves is often cited as a desirable virtue but this is of rather less importance in humidification or fogging systems where the leaf temperature may be higher than the air temperature

Water in the growing medium should be readily available for plant use as water uptake by cuttings is directly proportional to the volumetric water content of the growing medium Evaporation from the medium surface also will contribute to the humidification of the air surrounding the cuttings.

Light. The most suitable irradiance level (which may vary between 10% to full sun according to the species) needs to be established by propagators in their own facilities This requires a light meter to make objective measurements as our eyes (being self compensating) cannot make a reliable estimate of the irradiance at the height of the set cuttings Greenhouse coverings will change the spectral balance and light intensity, especially if dirty It is difficult to separate out the effects of light and temperature More light can be admitted if the system for water control is effectively controlling the leaf water deficit This is especially evident where nonmisted propagation is attempted without adequate shading.

Outdoor propagation areas don't usually require any shading provided the supply of water can balance the water losses from cuttings Whereas in an unshaded greenhouse environment the balance between light and related heating effects on water requirements can be more critical The relatively small volume of air can heat up quickly creating a rapid increase in the vapour pressure deficit Cuttings are less likely to experience a lethal level of water stress if they can be shaded. The photoperiod and light quality can all be manipulated if the greenhouse is equipped with supplemental lighting to extend the propagation season. Growing rooms may have a use in some climates The New Zealand environment is usually not sufficiently limiting that it warrants supplying all the light and heating when we can get a considerable amount directly from the sun

Temperature. The optimum temperature for crop growth should be considered (Preece, 1993). While it may be difficult to schedule, there is some support for a higher temperature for root initiation and a lower temperature for root growth (Kester, 1970; Dykeman, 1976). The shoot temperature can be usefully maintained at slightly less than the root zone to conserve stored and current carbohydrate supplies.

Gas Exchange. The physical properties of the growing medium have a major influence on its water holding and gas exchange properties. Root formation on cuttings is promoted by rapid permeation of propagation medium by oxygen and release of carbon dioxide. All propagators should be able to measure the simple physical properties of their propagation medium. This will give an estimate of the air- and water-filled pores which is more critical to the success of any propagation medium than the presence of a few pathogens in the medium. Propagation media should contain more air (to cope with the metabolic processes occurring at the base of the cutting during root formation) than water. Water is normally going to be applied regularly, therefore shallow propagation containers (only a few cm deep) are going to favour saturation of a higher proportion of the growing medium than taller containers. This will reduce gas exchange in the medium, encouraging an accumulation of carbon dioxide and reduction in oxygen which will reduce potential root formation.

Microflora.The main pathogenic fungi of concern are the watermoulds; *Pythium* species and *Phytophthora* species. These are most problematic under cool moist conditions. When it is rather warmer *Rhizoctonia* species can be more of a problem. Beneficial organisms include mycorrhiza and *Trichoderma*. These are really only in their infancy in terms of our understanding and application to assist plant propagators produce better plants.

CONCLUSION

The more we understand the factors limiting plant growth and development, the more readily we can develop techniques to investigate and solve issues we now regard as insoluble problems.

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Will You or Won't You Propagate Genetically Engineered Plants?

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INTRODUCTION

Worldwide plants are now being genetically engineered to provide such characteristics as herbicide resistance, insect resistance, delayed ripening, and altered flower colour. While the question many people are asking themselves is whether they wish to **eat** genetically engineered plants, the question plant propagators worldwide must ask themselves is whether they will **propagate** genetically modified plants. In this short paper I have focused on three of the more common questions that are asked relating to genetic engineering:

1) What is the technology underpinning genetic engineering?
2) How do we genetically engineer a plant?
3) What are the risks associated with genetically engineered plants?

THE TECHNOLOGY

The technology is called recombinant DNA (rDNA) technology because two pieces of DNA (usually from different species) are combined. The first step in the procedure is to cut open a piece of DNA in a precise place using restriction enzymes This opens a gap into which another piece of DNA can be inserted The new DNA is referred to as rDNA and an organism with a new piece of DNA in it as a genetically modified organism (GMO)—the GMO has been "genetically engineered"

Currently we have genetically engineered microbes, plants, and animals. Genetically engineered microbes provide us with insulin, hepatitis C vaccine and, soon, interferon Further, much modern biological and medical research is based on rDNA technology If we said "no" to GMOs in New Zealand, apart from the medical setbacks, both biological and medical research would be seriously disadvantaged However, the use of rDNA and GMOs for research is one thing, the use of genetically engineered plants for agriculture, horticulture, and forestry is another

How Do We Genetically Modify a Plant? There are two predominant methods in use One uses *Agrobacterium tumefaciens* as a biological vector to place the DNA into the plant while the other, commonly referred to as "particle bombardment", essentially blasts DNA-coated gold or tungsten particles into the plant in the hope that some of the DNA will be incorporated into the plant DNA. With particle bombardment, the process is completely random, whereas *A tumefaciens* is often referred to as nature's own "genetic engineer" When this bacterium infects a plant a piece of its own DNA (the tDNA or transfer DNA) is transferred and incorporated into the plant's own DNA The bacterial DNA causes the plant to produce excess auxin and cytokinin which leads to the formation of a gall and the development of crown-gall disease. The genetic engineer discovered that pieces of the tDNA could be removed and other DNA put in instead The piece of DNA that is spliced in is then transferred naturally by the *Agrobacterium* into the plant The plant then produces the new products coded for by the new DNA These new products may lead to the

plant being resistant to insects, to slower ripening of fruit, or even to a plant with a modified growth habit. *Agrobacterium* does not infect most monocotyledonous plants, such as the cereals, and for these plants the particle bombardment process usually is used.

ASSESSMENT OF GENETICALLY ENGINEERED PLANTS

The first issue to determine here is the basis of the risk assessment. From what perspective(s) do we assess genetically engineered plants? Ideally, this would be from the perspective of a nonhungry world with a sustainable food supply. However, I believe we must assess these plants in the context of today's world where current agricultural methodology is nonsustainable, where arable land is declining, and where the predicted population will be 8 billion by the year 2025.

While sustainable land management must be a target, an instantaneous move to sustainable organic-style agriculture is completely out of the question if we are to continue to feed the world's population. However, genetically engineered plants could become part of an integrated programme that may help towards the establishment of a sustainable food supply. Genetic engineering alone is certainly not the miracle answer to the world's food problems, but it may help if used wisely.

So how do genetically engineered plants measure up? Can we use genetic engineering to improve on what we do now? For example, consider the following scenarios:

1) If we were to genetically engineer a plant to be resistant to a herbicide that has been shown to be less damaging to the environment than the current herbicide regime, surely that is a step forward. This is Monsanto's argument for the introduction of the Roundup Ready Soybean. Roundup is considered a more "environmentally friendly" herbicide than many others currently in use.
2) If we were to genetically engineer a plant to be resistant to a set of insect pests and no longer have to spray on insecticide that is toxic to both the insect and to mammals, surely that is also a step forward.
3) And if we can genetically engineer into cowpeas a protein that inhibits the digestion of an insect pest (but not of a human) and reduces the storage losses of that staple food, surely that is a step forward (over 30% of the world's food is lost postharvest!)
4) If we were to engineer resistance to a herbicide in blackberry (blackberrry is a rampant, noxious weed in New Zealand) in New Zealand, that would be nonsensical, and in fact, would not be allowed by the regulatory authorities.
5) If we could use plants as chemical factories to produce industrial oils, surely that would be replacing a nonrenewable resource with a renewable one.

Genetic engineering **can** be used to improve on what we do now.

Unknowns Are Also Associated with Classical Plant Breeding. Opponents to genetic engineering of plants often claim it is a very risky process, that we don't know where the new DNA is inserted, and that we must select the ideal plant. However, some of these concerns could equally be applied to plants derived from standard plant breeding programmes.

For instance, if a cultivated potato cultivar was to be crossed with a wild relative showing, for example, virus resistance, the first cross would dilute the genetic material of the cultivated cultivar by 50%, rendering it essentially useless. Up to 20 backcrosses and selections may be required to "regain" essentially the original cultivar along with the new genetic material containing the virus resistance trait. Along with the new trait will be a significant number of linked genes of unknown character.

Using genetic engineering, the single gene conferring virus resistance (along with a marker gene) can be inserted into the selected crop plant via *Agrobacterium*. Genetic engineering thus provides a faster route, the integrity of the genetic material of the crop plant is maintained and we know precisely what DNA has gone into the plant. Further, we can subsequently determine where the new DNA has inserted into the genome of the plant. There are obvious, significant advantages to genetic engineering in terms of time to produce a new culitvar and knowledge of the DNA inserted.

Can the Inserted Gene Escape into the Wild? This is indeed possible. However, it must be remembered that classical plant breeding is also aiming to derive, for example, virus-resistant, herbicide-resistant, and insect-resistant plants. **Management** of the new cultivars is the issue at question, less so the origin of the genetic material in the new cultivars. It is highly improbable that one genetic engineering event will turn a cultivated plant into a superweed, but an awareness of the relatedness of the new cultivar to the local weed and cultivated species, as well as to the indigenous flora is needed to determine the potential for escape and hybridisation. For instance, a genetically engineered plant should not be grown in the centre of origin of that particular crop plant.

Are There Health-related Risks? There are health-related risks associated with **both** classical plant breeding and genetic engineering: but both sets of plants must be and are subjected to testing. It was testing that picked up that an allergenic protein from brazil nut had been incorporated into soybean (this in an attempt to improve the nutritional quality of the soybean protein).

CONCLUSIONS

Traditional plant breeding is a well established and accepted practise but it is not without its own set of "risks". When evaluating the issues surrounding the propagation of genetically engineered plants, traditional plant breeding should be the key reference point.

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Developing New Australian Plants

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INTRODUCTION

The Australian flora is fascinating and diverse. It is estimated that there are some 25,000 plant species in Australia (Elliot and Jones, 1989) with over 12,000 species in Western Australia alone (Hopper, 1997). The development of the Australian flora for cut-flower production and amenity horticulture has primarily focused on those plants that are interesting and relatively easy to propagate from seed or vegetative cuttings.

The Australian export flower industry is small by world standards, but has grown gradually since the early 1980s. In 1981-82 the export of cut flowers and foliages was valued at $1.5 million, increasing to $27 million in 1996-97 (Australian Bureau of Statistics, 1997). The three main export lines are Geraldton wax (*Chamelaucium uncinatum*), kangaroo paw (*Anigozanthos*), and banksia (*Banksia*).

Since 1994-95, the growth rate of Australian cutflower exports has been slowing, with overall exports declining from $30 million in 1995-96 to $27 million in 1996-97. Reasons for this decline include a general world oversupply of cutflowers with a downward pressure on prices, a continuing recession in Japan—the main Australian export market (Anon, 1998)—and currency fluctuations. In addition, there has been a specific oversupply of some cut flowers from Australia such as traditional cultivars of Geraldton wax and kangaroo paw (Kim James, pers. commun.). This last factor has led to a search by the local industry for new lines, including selections and hybrids of the main export lines with variable flower colour and harvest times, and other plant species not yet commercially cultivated.

New and novel plants are the key to the continuing success of the floriculture industry worldwide. Generally, the appearance of a completely new plant species for commercial production is uncommon (Wilkins and Erwin, 1998), and most "new" plant introductions are hybrids or selections of traditional plants. However, there are exceptions to this rule, with many Australian plants unknown both within Australia and overseas and, therefore, potentially of interest to the market. Plants such as *Brachycome multifida* and *Scaevola saligna* have been successfully introduced into Germany (von Hentig, 1996) and Geraldton wax is a highly successful cut flower in Israel and the U.S.A., with production in Israel over ten times that of Australia (Shillo, 1996).

Generally, the domestication and marketing of Australian flora has been ad hoc and not well coordinated. The recent emergence of plant brokers and nursery cooperatives has seen a more coordinated approach, at least on domestic markets. The establishment of the Centre for Australian Plants in Western Australia (WA) has seen a more collaborative and coordinated approach by partner agencies and industry to new plant development and introduction.

CUTFLOWER PLANTS

Generally, the development of native cutflowers in WA has been through serendipitous activity. Plants were collected from the conservation estate because they had interesting floricultural features. The systematic survey and collection of target plants, and subsequent breeding of those plants, was first done for *Chamelaucium uncinatum* (Considine et al., 1994) in the early 1990s. This process has since been followed for a number of other WA plant species including *Boronia* (Plummer et al., 1998), selected *Conospermum* spp. (Seaton and Webb, 1997), and *Pimelea physodes* (Seaton, pers. commun.). A process for introducing and commercialising new taxa has been adopted by the Centre for Australian Plants following guidelines developed by other researchers (Armitage, 1998; Wilkins and Erwin, 1998).

Today, there are over 25 species being developed by the Centre for Australian Plants for the domestic and international cut-flower markets. These include *Boronia* spp., *Chamelaucium* spp., *Conospermum* spp., *Verticordia* spp., *Ptilotus* spp., *Pimelea physodes,* and *Corynanthera flava.*

A major cut-flower breeding program (Centre for Australian Plants) was started in 1995 and involves Agriculture Western Australia, the University of Western Australia, and Kings Park and Botanic Garden. Using Geraldton wax as the model, four genera are now included in an intraspecific, interspecific, and intergeneric hybridisation program. The first cultivars from this program, Esperance Pearl (*C. uncinatum* 5 *C. megalopetalum*) and Jurien Brook (a *C. uncinatum* selection) were released in 1997. At least two cut-flower releases will be made each year for the next 5 years through the Centre for Australian Plants.

POT PLANT, BEDDING PLANTS, AND AMENITY PLANTS

From 1995 to 1997, over 797 species from 1042 provenances were tested by Agriculture Western Australia for suitability as pot plants or amenity plants. These plants were germinated, grown, and initially assessed without any pinching, variations in fertiliser or watering, or the use of branching or growth retardant hormones. The first selections from this program are being commercially tested in WA in 1998.

INTERNATIONAL DEVELOPMENT

The national and international development of Australian native plants has generally been opportunistic and not well managed or coordinated (Anon, 1998). Prior to the introduction of the Australian Plant Variety Rights (PVR) legislation in 1987, any significant and ongoing financial reward to plant selectors or breeders was generally not realised. Plant Variety Rights and subsequent changes have provided the opportunity for plant breeders and selectors to receive an ongoing benefit for their activity. Nevertheless, the production of Australian native plants is greater internationally than in Australia.

It has been estimated that the domestic production of Australian native plants is $85 million, compared to world production of $400 million (Australian Horticultural Corporation, 1996). Furthermore, the rate of planting of WA native species for cut-flower production is greater in other Australian states and overseas than in WA (Anon, 1998). These factors will mean that, to maximise the return on investment, local plant breeders and selectors will have to consider the worldwide release of any new material. The Centre for Australian Plants has developed a policy to guide the international testing and commercialisation of new cultivars.

CONCLUSION

The uniqueness and variability in the Australian native flora provides many opportunities for selecting and breeding new material for domestic and export markets. Maintenance and protection of genetic variation in the conservation estate is critical to any selection and breeding program. The increased research outputs that will result from collaborative activities such as the Centre for Australian Plants will see the ongoing development and release of new and exciting cut flowers, pot plants, bedding plants, and amenity plants.

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Exploiting Variation in Boronia

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Boronias are well known for their perfume and floral displays. Plants are grown for cut flowers and ornamental plants. Cut-flower production is dominated by one cultivar of *Boronia heterophylla*, which has deep pink (red) petals. Flowering usually occurs over a short period and these factors restrict sales. The remaining natural populations of *Boronia heterophylla* in the south west of Western Australia were surveyed for new forms. A breeding program was commenced at the University of Western Australia. New cultivars with different colour forms and different flowering periods have been selected and these are undergoing further trials.

INTRODUCTION

Boronias are well known for their floral displays and sweet perfume. Boronias were originally bush picked, and picking and clearing have reduced the original populations. *Boronia heterophylla* and to a lesser extent *B. megastigma, B. serrulata, B. clavata*, and *B. muelleri* have been brought into cultivation for cut flower production. *Boronia megastigma* is also grown for oil production and a wider range of species are grown as garden plants (Plummer, 1996). Virtually all of the *B. heterophylla* grown is the deep pink ('Red') cultivar, which is harvested over a short period of about 2 weeks. Unlike *B. megastigma*, hormonal treatments do not shift the flowering period of *B. heterophylla*, and even climatic differences within the limited growing areas have little effect on flowering time (Plummer et al., 1998). A less vigorous, white-flowered form 'Moonglow' and a pale pink form 'Cameo' have been recently identified (Watkins, 1990). However, the short flowering period and limited colour range, restrict sales of both cut flowers and potted plants and this has held back expansion. Boronias also have a reputation for being somewhat difficult to propagate and short-lived in production areas and gardens. Seed germination is very low, often < 2%, and plants are usually propagated from cuttings. The aim of this research was to examine variation in flower colour, flowering period, vigour, and propagation success in the remaining populations of *B. heterophylla* and to explore the possibility of breeding boronias with new traits.

MATERIALS AND METHODS

The flower colour, flowering period, and plant vigour were recorded for 25 plants selected from each of nine natural *B. heterophylla* populations in south-western Western Australia. Most plants were selected randomly, however, unusual forms were also collected. Cuttings were collected over the summer, propagated, and the resulting plants transferred to a field plot. Flowering time, flower colour, and plant vigour were determined 2 years later. After 4 years 20 cuttings were taken from each of the remaining plants and propagation success from cultivated material was determined. Cuttings were dipped in a gel formulation of 3 mg litre^{-1} IBA (Purple Clonex™) and propagated under intermittent mist in a heated glasshouse (minimum 18C, cooled, and vented at 23C).

Hybridisation within *B. heterophylla*, using 'Red', 'Moonglow', and 'Cameo', and between *B. heterophylla* and a range of other taxa was attempted. The genotypes were *B. deanei* (pink flowers), *B. megastigma* (brown and yellow flowers), *B. megastigma* 'Lutea' (yellow flowers), *B. megastigma* 'Harlequin' (red and yellow striped flowers), *B. purdieana* (yellow flowers), *B. crenulata* (pink flowers), *B. crassipes* (pink flowers), *B. denticulata* (mauve-pink flowers), *B.* 'Telopea Valley Star' (pink flowers, *B. mollis* 5 *B. fraseri*), *B. ramosa* (blue flowers), *B.* 'Morande Candy' (pink flowers), and *B. stricta* (pink flowers). Usually fresh pollen was used but for species, which flowered at different times, pollen was collected and stored at -20C (Astarini et al., 1999). Seed were collected and embryos were removed and germinated in vitro on half-strength Murashige and Skoog (1962) medium supplemented with naphthalene acetic acid (0.1 mg litre^{-1}) and benzyladenine (0.4 mg litre^{-1}). Plants were grown in pots in a shade house for 2 years. Flower colour and flowering period were then recorded.

RESULTS AND DISCUSSION

Very few colour variants were identified during flowering in the natural populations. *Boronia heterophylla* petals do not readily abscise but fade on the bush and thus true flower colour must be observed at anthesis. This was not always possible when genotypes were observed and selected during flowering in natural stands. Only one worthy colour variant was observed in the field plot. This genotype bore pale pink flowers similar to 'Cameo' but the leaf shape and length, and plant vigour were different.

Harvest date was also very consistent with few outliers. One third of genotypes, including the 'Red' form of *B. heterophylla*, were harvested within 3 days of the mean harvest date of 24 Sept. 1996 and 72% of genotypes were within a week of this date. One genotype flowered 10 days earlier, another 20 days earlier, and two genotypes from the same population flowered 20 days later. Most genotypes (67%) had a low propagation success (< 25% strike rate). However, the proportion of cuttings producing roots varied from 0% to 100% and some easy-to-propagate (>75% strike rate) genotypes exist. The susceptibility to damping off in the misting area and subsequently in the shade house also varied between genotypes.

Hybridisation was possible both within *B. heterophylla* and between *B. heterophylla* and several species. All but one intraspecific *B. heterophylla* hybrid were red (deep pink). These included crosses with 'Moonglow' and 'Cameo' and selfed plants. One of the selfed 'Cameo' progeny had pale pink flowers of similar colour to the parents but with different leaf form. This also flowered 2 weeks earlier than 'Red' but at a similar time to 'Cameo'. Only a few of the interspecific hybrids were successfully rescued and grown to mature plants. Parents of some hybrids had a similar number of chromosomes, such as *B. heterophylla* (2n =14,15) and *B. megastigma* (2n=14), whereas others were different, such as *B. molloyae* (2n=16), *B. purdieana* (2n=18), and *B. ramosa* (2n=36) (Smith-White, 1954; Astarini et al., 1999). Hybrids between *B. heterophylla* and *B. molloyae* were all red flowered and reached harvest date at the same time as the *B. heterophylla* 'Red' parent. One hybrid between *B. heterophylla* and *B. megastigma* 'Harlequin' was more vigorous than either parent and had deep maroon petals. These flowers had a perfume similar to *B. megastigma*. None of the other hybrids had flowered.

Little natural variation exists in the petal colour and flowering period of *B. heterophylla*. This is unlike other closely-related boronias, such as *B. molloyae* and *B. megastigma*, where petal colour varies from yellow though pink or red to deep

purple or brown (Plummer, 1996). Even selfed plants with white ('Moonglow') or pale pink ('Cameo') flowers generally produced progeny with red petals. Expression and inheritance of petal colour is complex in most ornamental plants and a better understanding of pigments is required to support breeding of boronia for novel flower colour. Interspecific hybridisation showed considerable promise as a means of introducing new cultivars. Many crosses were possible even with species of different chromosome number. Flower colour within *Boronia* varies from white, through many shades of pink and red, yellow, brown, and even pale blue and this provides considerable opportunity to expand the petal colour range. Unfortunately, many of these other species are difficult to propagate and lack sufficient vigour for pot- or cut-flower production. Success in propagation varied with genotype and incorporating good strike rate along with appropriate vigour will be essential in the breeding of new boronias for pot- or cut-flower production.

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Developing a Collection of Genetic Material

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INTRODUCTION

A systematic collection of plant material is normally done to improve crops which are already cultivated by adding such attributes as disease or insect resistance, higher yields, or cosmetic appearance, or to bring entirely new crops into cultivation. These objectives are part of the current focus of the Centre for Australian Plants, a cooperative venture between Agriculture Western Australia, the University of Western Australia, Kings Park and Botanic Garden, the Department of Conservation and Land Management, and industry.

The collection of plant material which will represent some of the genetic variance of a species needs to be well planned and well resourced. The reason for collecting the material should be clear, with some understanding of the biology and geographical location of the species.

Resources, both financial and physical, are needed for the actual collection, plus the maintenance of the collection for a number of years.

GERALDTON WAX

The collection of Geraldton wax (*Chamelaucium uncinatum* Schauer) is a project funded over the years by the Horticultural Research and Development Corporation, the Rural Industries Research and Development Corporation, the University of Western Australia, Agriculture Western Australia, and industry.

Geraldton wax has been cultivated in home gardens since the early days of settlement, both in Australia and overseas, and in the last 15 years has become highly sought after as a cut flower (Manning et al., 1996). However, the cultivars planted for cut flowers were selected mostly for flower colour while other important characteristics, such as flowering period, yield, stem length, colour range, plant form, disease resistance, and flower size, were largely ignored. The aim of collecting the genetic variance of this species was to improve on these aspects for the cut-flower trade, and to bring into cultivation plants suited to the pot- and amenity-plant trade.

Geraldton wax is primarily an outcrossing species, with some degree of selfing evident. Its height ranges from 0.5 to 5 m, and its form from prostrate to bushy to an upright single trunk. Flowering time is usually spring, however some populations are much later, flowering in early summer, while some individual plants flower in late autumn.

The level of funding for this activity was initially $100,000 per year over 3 years, later extended for 3 more years. Extra funds have been recently supplied for a breeding program using superior genotypes from the original collection. The funds included provision for a four-wheel-drive vehicle plus a salary and operating for a full-time research officer.

Following receipt of funding, the first task was to locate populations. A start was made using records of the Western Australian State Herbarium. Paradoxically, given that it is such a well known plant, there were few accurate records of population locations for this species. The majority were located through exploration and contact with wildflower pickers, farmers, and members of the Western Australian Wildflower Society.

All plant species researched in detail have shown widespread variability at the geographical level and within each population (Allard, 1970). It is, therefore, vital to sample all known populations, and the genetic variance within each population. A prime focus of the Geraldton wax project was, therefore, to locate as many populations as possible.

The sampling method chosen was a reflection of the need to collect as much of the genetic variance of the species possible within the confines of the space available for growing the sampled plants and the financial resources to maintain them. Random sampling allows the greatest variance of hidden characteristics, such as disease resistance and vase life, to be collected. Such characteristics can then be screened for under cultivation (Creech, 1970).

For each Geraldton wax population six plants were sampled at random, plus those outliers at the extremities of the population. The outliers were selected because these plants will be the least related within the population. In addition plants with rarely occurring though horticulturally important attributes, such as purple or white flowers, early or late flowering time, or multi-layered petals were sampled. Such biased sampling for particular attributes needs to be combined with random sampling to ensure the maximum possible genetic variance is collected for the particular purpose of the project (Bennett, 1970).

Cutting material was taken from each plant, and once propagated and grown on was planted out in the autumn under fertigation. Three replicates of each genotype were planted, both for statistical purposes and to secure the genotype in cultivation. Plants were assessed for attributes including flowering time, vase life, yield, flower colour, plant morphology, flower size, resistance to dieback disease (*Phytophthora cinnamomi*), and tolerance to alkalinity. Superior genotypes were selected for further trialing and a breeding program was undertaken to produce intraspecific, interspecific, and intergeneric hybrids.

To date over 60 populations of Geraldton wax have been located. These populations range from Perth to Kalbarri, and east to the Midlands Road. Within these populations eight different ecotypes, based on morphology and ecology, have been identified.

Nearly all populations are within 50 km of the ocean, and none are more than 100 km. Rainfall averages between 450 mm and 900 mm per year. Most of the Geraldton wax populations occur in deep sand. Two ecotypes have occasional silt associations, mostly due to their strong association with water bodies while one ecotype has a sandstone association.

Six of the eight ecotypes have good access to summer water, rarely needing to go more than 5 m to the water table. Some of these occur close to water bodies while others grow on a perched water table. Two of the eight grow over 20 m above the water table.

Flower size varies between ecotypes. The small-flowered taxa have sizes ranging from 9 to 16 mm, while four ecotypes have some flowers over 20 mm. Flowering time also varies with ecotype. Four ecotypes flower early to mid season, two flower predominantly in mid season, and two ecotypes flower mid to late season.

There are wide differences in form. One ecotype, which occurs on coastal dunes, is rarely more than 1.5 m high and often smaller than 1 m. This characteristic is maintained in cultivation. Three ecotypes have a bushy, multibranched form, often attaining 3 to 4 m in height. Three other ecotypes are usually few stemmed and upright, also often reaching 3 to 4 m, although they will bush out in response to

pruning. The final ecotype is very spindly and upright, few stemmed and usually 2 to 2.5 m in height. They are, however, very vigorous in cultivation.

Flower colour ranges from white to deep purple. Pale purples and pinks are the predominant colours. White is found rarely in most populations, although two have a much higher percentage. Dark purple is the rarest colour, not expressed in some populations and rare in others. Two of the northern ecotypes have much longer and thicker leaves, sometimes over 50 mm in length. Leaves of other types rarely exceed 30 mm.

The success of the sampling strategy can be judged on how many randomly sampled plants had superior characteristics. In the original collection 52% of the plants were selected randomly, 10% were outliers, and the remaining 38% were selected on horticultural merit. Of the superior genotypes, 35% originated as random selections, 12% as outliers, and 53% as plants selected on horticultural merit. This result verifies the crucial nature of random sampling when collecting the genetic variance.

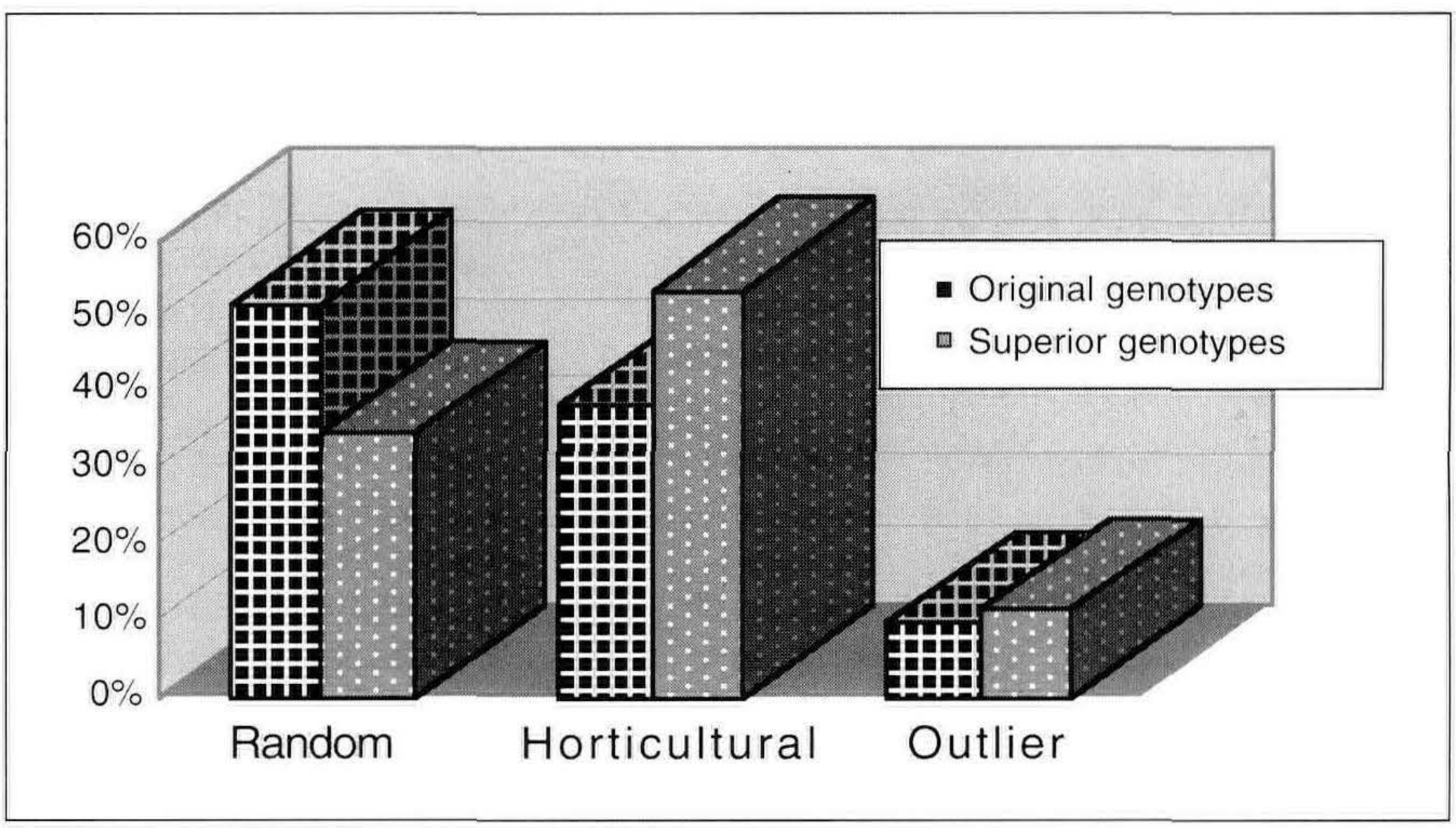

Figure 1. Percent variation in selection criteria between original and superior waxflower genotypes.

OTHER CROPS

Collections of other species made by the Centre of Australian Plants have shown similar variation at both the geographical and intrapopulation level. These include *Verticordia* spp. (Growns, Seaton pers. comm.), *Chamelaucium* spp. (Growns, Webb pers. commun.), yellow bells (*Geleznowia verrucosa*) (Growns, Crawford, Broadhurst pers. commun.) smokebush (*Conospermum* spp.) (Seaton pers. commun.) and *Boronia* spp. (Plummer, pers. commun.).

CONCLUSION

The wide variation both between and within populations of Geraldton wax and other species of Western Australian plants highlights the improvements which can be made to those species already in cultivation through collecting the genetic variance of a

species. However, this is an expensive and time-consuming process, therefore any project involving the collection of genetic material needs to have a clearly defined purpose and the resources committed to achieve the goals.

However, apart from critically endangered plants, any collection of genetic material will only represent a small amount of that present in nature. Changes in funding and vision may also affect the viability of such a collection. Therefore ensuring the conservation of ecological systems which will support the long-term survival of species is crucial to preserving the genetic variance of these species, and to preserving our ability to gain maximum benefits from them.

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Conospermum: A Cultivated Cutflower

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Conospermum **is an Australian native flower being developed by Agriculture Western Australia as a cut flower.** ***Conospermum*** **is a diverse genus with genotypes varying in colour from white/grey to blue, and varying in forms from shrubs to small trees. Some** ***Conospermum*** **species readily propagate from cuttings with strike rates up to 50%, while others can only be propagated from tissue culture.** ***Conospermum*** **species respond favourably to cultivation.**

INTRODUCTION

Development of new Australian native plants is seen as crucial for the long-term growth of the Australian cut-flower industry. Smokebush (*Conospermum* species, Proteaceae) has considerable potential for commercialisation. There are 53 species of *Conospermum* in Australia with 42 species occurring in Western Australia (Bennett, 1995). They occur in 200- to 800-mm rainfall isohyets and flower from winter to late summer depending on the species. Species vary widely in appearance with several having blue-coloured flowers. Few species have been domesticated (Tan et al., 1994).

Research has identified several selections of *Conospermum* species (Seaton, 1996; Seaton and Webb, 1997, 1998) suitable for the cut-flower trade.

MATERIALS AND METHODS

Natural populations of *Conospermum* species were sampled in WA from north of Kalbarri to east of Esperance. Cuttings were surface sterilised in 1% (w/v) sodium hypochlorite for 10 min then washed in distilled water. Stem ends were treated with 3000 ppm indol-3-butyric acid (IBA) in a gel (Clonex®) and placed in a sand, peat, and perlite propagation mix (1 : 2 : 4, by volume) in individual cells. These were placed on a heat bed maintained at 26C within an air-conditioned propagation house (maximum air temp 26C) with misting sprayers controlled by a Weather Watch® system (Sage Horticultural).

Rooted cuttings were grown on in a sand and pine bark (composted) potting mix (1 : 1, v/v) and finally planted at Medina Research Station (coarse sand with pH 6 to 6.5). These were watered using 4-litre h^{-1} drippers and N, P, K fertilisers (76 kg ha^{-1} per annum of N and K and 10 kg ha^{-1} per annum of P) were applied through the irrigation system.

RESULTS

Selections. *Conospermum* species occur as small trees and shrubs. Small trees are typified by *C. triplinervium* (tree smoke) that vary considerably in leaf form and are high-stem producing plants with grey/white panicles of flowers. Small shrubs

include *C. amoenum* with blue glabrous flowers; *C. floribundum* with a white perianth, blue lobes, and bract; *C. incurvum* (plume smoke) with a white perianth and black lobes and bract; *C. eatoniae* (blue lace) with erect leafless stems and masses of striking blue glabrous flowers; *C. caeruleum* (slender smokebush) with fine drooping stems, few leaves, and blue flowers; and *C. crassinervium* (tassel smoke) with a rosette of strap-like leathery leaves, corymbs of white woolly perianth, and brown to black bracts. All these species flower in winter to spring, except *C. crassinervium* which flowers in summer.

Propagation. Wide variation in the strike rate occurs in *Conospermum*. *Conospermum triplinervium* cuttings strike readily with a success rate of up to 50% depending on selection. Strike rates for *C. incurvum* are lower and *C. eatoniae* can only be propagated using tissue culture (Fig. 1). For *C. amoenum* only one clone was propagated out of 19 tested. In general, strike rates from cultivated material is up to 3 times higher than from cutting material from natural populations. *Conospermum* takes 6 to 24 weeks to initiate roots and propagates best from nonflowering material.

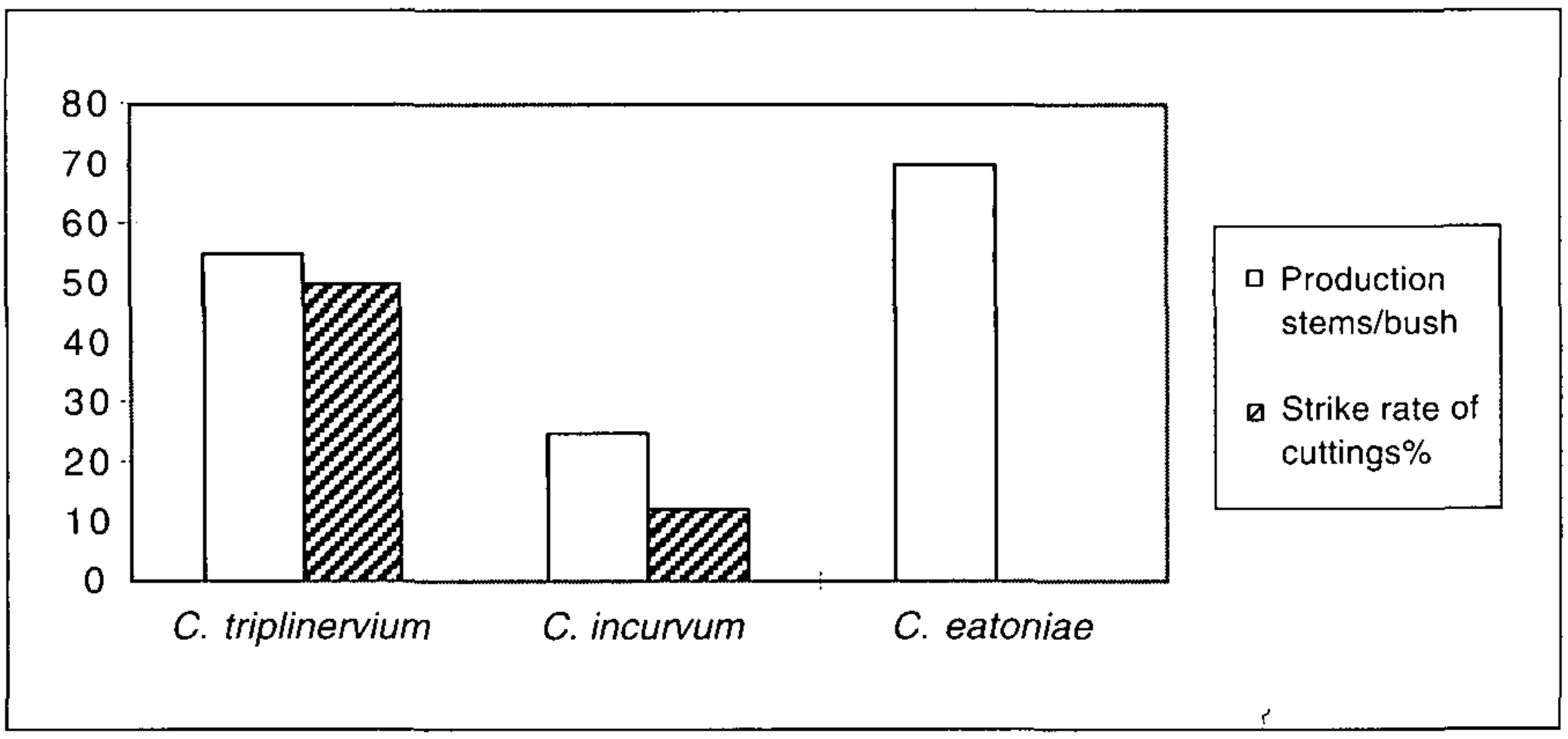

Figure 1. Cutting strike rate of bush picked material and stem production of 3-year-old cultivated *Conospermum* species.

Cultivation. In cultivation *C. triplinervium*, *C. eatoniae*, and *C. caeruleum* produce flowers in their 1st year. They respond to regular watering and are sensitive to high phosphorus fertilisers. Pruning after flowering in the 1st year increased stem numbers which increased by 5 to 10 times in the following season. Stem production of 3-year-old bushes was highest for *C. eatoniae* followed by *C. triplinervium* and lowest for *C. incurvum* (Fig. 1). For *C. eatoniae* and *C. caeruleum* floral stem growth occurs from early spring to autumn. For *C. triplinervium* floral stems are initiated in June and elongate rapidly until flowering in September. *Conospermum triplinervium* flowers over a longer period than *C. eatonaie* and *C. caeruleum*. High postplanting losses were observed for *C. floribundum* and *C. incurvum* with the surviving plants growing slowly.

DISCUSSION

Several *Conospermum* spp. have been selected which show considerable potential in cultivation. Cut flowers of *C. eatoniae* were marketed in trial quantities in 1996 and 1997 and were eagerly sought by florists in Australia and Japan (James, 1997). Inconsistent propagation of *Conospermum* spp. has limited the availability of plants for cultivation. The extended time taken for cuttings to strike roots increases the risk of disease. Propagation results with *Conospermum* suggest a dependence on genotype. A similar relationship has been observed with *Banksia* (Sedgley, 1996). Research is continuing to develop commercial methods of propagation of selected *Conospermum* species.

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Western Australian Species as Summer Annuals

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INTRODUCTION

Western Australian flora is known worldwide as one of the most unique. However there is a perception, "that once spring is over there is nothing to be admired". One of Kings Park and Botanic Garden's current challenges is to prove to the world that this perception is incorrect. The strategy adopted has been to focus on the development of year-round native floral displays throughout the gardens. Annuals are proven winners when visual impact is the desired effect, so the move to develop the Western Australian summer annuals for their bedding potential was one logical way to improve perception of Western Australian plants as year-round displays.

BACKGROUND

Since the mid 1960s Kings Park and Botanic Garden has undertaken field trips to the Kimberley and Pilbara regions to the North of Western Australian. Its major growing season is centred around Monsoonal weather patterns. So when looking for potential summer bedding annuals which would thrive in the Perth hot dry summer conditions, the flora from these regions is most suited to achieve our goals. Initial trials and developments were focused on potted specimens to gain cultivation knowledge and assess those with display potential. Trialing of this flora began in the early 1980s and it wasn't until 1997-98 seasons we achieved satisfactory success with summer bedding displays within the Botanic Garden.

METHODS OF CULTIVATION

The following methods were used for most of the species tested.

- Bottom heat
- Seeds sown in October
- Planting in ground with slow-release fertiliser
- Liquid feeding weekly until point of flowering
- Subsurface irrigation
- Full sun aspect.

ACHIEVEMENTS

The species considered and trialed for future bedding potential were from the following genera: *Gomphrena, Ptilotus, Calandrinia, Portulaca, Swainsona, Borreria, Solenostemon,* and *Amaranthus.*

The genera with the most broad-scale potential for bedding are: *Gomphrena, Ptilotus, Swainsona*, and *Calandrinia.*

Sufficient seed has allowed us to successfully display: *Ptilotus exaltatus, P. fusiformis, P. macrocephalus, P. aervoides, P. chamaecladus, Gomphrena affinis, G. canescens, G. flaccida, G. tenella, G. leptoclada, Swainsona formosa,* and *C. polyandra* within the Botanic Gardens.

CONCLUSIONS

This group of plants has enormous potential and has shown enough positive signs to be developed further. One of the major challenges that lie ahead is to make these species available to the general community. Some of the areas that require further development focus on seed becoming readily available and/or vegetative material. The continuation and development of inspirational displays within Kings Park and Botanic Garden will only further show that Western Australian floral displays are beautiful the year round.

How Do Your Daisies Grow?

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Rhodanthe chlorocephala ssp. _rosea_ (pink paper daisy) and _Schoenia filifolia_ ssp. _subulifolia_ (yellow strawflower) are Western Australian daisies with potential for use as bedding plants and pot plants. The influence of irrigation on seed production was examined in field trials. Water deficit reduced branching which limited sites for terminal flower development and seed production. _Rhodanthe chlorocephala_ seed was dormant at harvest but 97% germinated after 3 months storage at 30C. _Schoenia filifolia_ seed was still dormant (8% germination) after 3 months storage. Dormancy could be overcome by application of gibberellic acid (GA_3, 30% — 87% germination) or by exposure to 80C for 11 days (79% germination).

INTRODUCTION

Rhodanthe chlorocephala ssp. *rosea*, pink paper daisy, and *Schoenia filifolia* ssp. *subulifolia*, yellow strawflower, are everlasting daisies with potential for development as bedding and pot plants. *Rhodanthe chlorocephala* is native to the interior of southwestern Western Australia between the Moore and Murchison rivers and *S. filifolia* to the Geraldton district (Wilson, 1992). In their natural habitats these species provide a spectacular display in late winter and early spring. Most pot or bedding plants are commercially propagated from seed. For commercial production seed must be available, viable, germinable, and hence not dormant. However, seed for most Australian species is bush picked and of inferior quality compared to traditional bedding plant species. The availability of bush-picked seed varies with season and rainfall, viability may be low, dormancy is common, and germination often poor (Bell et al., 1993). These factors have severely restricted the exploitation of Australian herbs suitable for bedding or pot plants. Bush picked *R. chlorocephala* and *S. filifolia* seeds have relatively high viability but are dormant when collected. There is little information about the water requirements of Australian species from the southwest of Western Australia, which has a Mediterranean-type climate of winter rains and summer drought. Species which originate from areas of seasonal drought may avoid dry conditions by existing as dormant structures such as seeds during this period, tolerating drought through various morphological and physiological adaptations, or having short life cycles which use water when it is available (Turner, 1986).

The aim of these experiments was to provide information on the water requirements for production of high yields of viable seed, conditions suitable for storage, and a method to break dormancy and provide high germination of seed.

MATERIALS AND METHODS

Irrigation During Production. Plants were grown in field plots at the University of Western Australia, Perth. Seed of *R. chlorocephala* and *S. filifolia* were sown in 10-m^2 plots with a 50-cm row spacing and were thinned to 5 cm between plants

within rows 30 days after emergence. Seedlings were irrigated by sprinklers with an equivalent of 100% class A pan evaporation until 45 days after sowing. Plants were then treated with three irrigation regimes, water replacement to the equivalent of 100%, 50%, or 25% class A pan evaporation. Plants were harvested 112 days after planting and the number of stems, flowers, and seed yield were recorded. Branching was examined by division of shoots into primary, secondary, tertiary, and quaternary stems. Inflorescence heads will be termed flowers. Data were analysed using analysis of variance and Fisher's Protected least significant differences were used to compare means.

Seed Storage. Seed from the field trial was cleaned and stored at ambient temperatures for 3 months before transfer to controlled temperatures of 5, 15, 25, 30, 40, 55, or 65C. Viability and germinability were monitored at 2-month intervals for *R. chlorocephala* and 1-month intervals for *S. filifolia*. Viability was determined either by germination test or germination followed by a tetrazolium test (Moore, 1973) of nongerminating seeds. The germination test was carried out in petri dishes using three replicates of 25 seeds incubated for 35 days in the light at 20C (Plummer and Bell, 1995).

Breaking Dormancy. Newly harvested seed of *S. filifolia* was 100% dormant. Dormant seed was treated with various concentrations of gibberellic acid (GA_3: 0.01, 0.03, 0.1, 1, 3, 10, 30, 100 μM) and incubated in the light at 20C. Other dormant *S. filifolia* seed was incubated at 65, 80, 95, or 105C for 0.5, 3, 5, 7, 11, or 14 days. Germination and viability were assessed as above.

RESULTS

Irrigation During Production. Decreasing irrigation reduced vegetative growth, flower number, and seed yield (Table 1). Most stems of *R. chlorocephala* (80% to 89%) and *S. filifolia* (99% to 100%) produced terminal flowers irrespective of irrigation treatment. Hence the effect of water regime on branching and stem number was also critical for flower production. Seed yield per flower decreased with reduced irrigation with *R. chlorocephala* having means of 109, 85, and 80 seeds per flower in 100%, 50%, and 25% A pan treatments, respectively, and *S. filifolia* having 134, 101, and 86. However, this effect contributed less to the decline in seed yield with reduced irrigation, than reduced stem number.

Table 1. The influence of irrigation on stem number, flower number and seed number per plant in *Rhodanthe chlorocephala* ssp. *rosea* and *Schoenia filifolia* ssp. *subulifolia*. Different letters indicate significant difference within columns (p=0.05).

Irrigation (% A Pan)	*Rhodanthe chlorocephala*			*Schoenia filifolia*		
	Stems	Flowers	Seed	Stems	Flowers	Seed
100	18.3a	16.6a	338a	22.3a	22.3a	404a
50	14.3ab	11.3b	255b	13.7b	13.4b	304b
25	13.0b	10.4b	208b	8.7c	8.5c	201c

Seed Storage. At harvest seed from all water regimes of both species had high viability but was dormant. After 3-months storage at ambient temperatures *R. chlorocephala* had broken dormancy and 96% of seed germinated, whereas *S. filifolia* were 96% viable but only 8% germinated. Storage of *R. chlorocephala* seed for a further 3 months at 15 to 55C did not affect germination (94% to 97%), however, germination of seed stored at 5C or 65C decreased to 90%. Storage temperature influenced dormancy release of *S. filifolia*. Seed stored at 5 or 15C for 3 months had 53% and 63% germination, respectively, and approximately 90% of seed stored at 25 to 40C germinated. Seed stored for 2 months at 65C had high germination (80%) but this decreased to 60% after 3 months due to reduced viability.

Breaking Dormancy. Application of GA_3 broke dormancy in *S. filifolia*. The optimum concentration was 30 µM, which resulted in 87±4% germination. Temperature and duration of exposure influenced seed viability and germination. All seed remained viable when treated for 0.5 to 14 days at the lowest temperature (65C), however, dormancy was not completely broken even in seed stored for the maximum duration. Seed treated with 105C were all dead after 1 day and more than half of the seeds treated with 95C died after 3 days. Intermediate temperatures were more successful in breaking dormancy and maintaining viability. Seed treated with 80C for 7 days were completely viable (94±4%) but not germinable (0%). However, after 11 days at 80C 79±3% germinated and 87±3% were viable.

DISCUSSION

Supply of adequate water is important for seed production in these everlasting daisies. Water deficit restricted branching and this was the major factor influencing seed yield. When less water was applied the number of stems was reduced and this limited the number of flowering sites. Flowers are borne terminally on stems and the number of stems per plant, which produced flowers, was not affected by irrigation regime. Hence a reduction in stem number flowed on to a reduction in flower number. Seed number per flower was reduced by water deficit but the impact on seed yield was less. These daisies avoid summer drought as dormant seeds but once germinated and growing were luxury users of water and showed considerable developmental plasticity (Turner, 1986) in their growth response to irrigation.

Storage temperatures greatly affected seed viability and germinability. *Rhodanthe chlorocephala* seed was able to tolerate a wide range of temperatures (15C to 55C) with little effect on viability and germinability over the 3-month period. However, low storage temperatures appeared to be detrimental and germination declined at 5C. In *S. filifolia* moderate temperatures (25C to 40C) improved germination by breaking dormancy over the 3-month period. Low temperatures did not completely overcome dormancy and high temperature (65C) had a detrimental effect on seed viability and germination. Generally (Harrington, 1972) low temperatures prolong longevity but ambient storage temperatures appear to be appropriate for short-term storage of these species.

Seed dormancy in *S. filifolia* was overcome by the application of 30 µM GA_3 resulting in 87% germination. It would not be easily employed in a commercial situation as the procedure involves treatment with an aqueous solution of GA_3 and seed would have to be dried before shipment. Treating seed for 11 days at 80C overcame dormancy without substantially reducing viability and resulted in 79% germination. Seed could be treated in bulk without the need for wetting and drying.

Rhodanthe chlorocephala and *S. filifolia* have potential as bedding and pot plants. Cultivated plants yielded substantial quantities of seed with high viability. *Rhodanthe chlorocephala* seed broke dormancy with 3-months storage at ambient temperatures. *Schoenia filifolia* seed required 11 days at 80C. This enables seed of both species to be harvested over summer and sold for autumn planting. High levels of irrigation increased seed yield in *R. chlorocephala* by more than 50% and doubled it in *S. filifolia*. Increased irrigation improved branching and this was the major factor contributing to increased flower production and seed yield. Increased flower number would also improve aesthetic appeal of bedding plant displays and value of pot plants and irrigation regimes should also be considered for these uses.

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Hybridisation Biology Within the *Chamelaucium* Alliance—Preliminary Studies

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Intraspecific, interspecific, and intergeneric crosses involving nine species from the genera *Chamelaucium*, *Verticordia*, and *Darwinia* were conducted. Pollen-pistil interactions and the formation of seed were studied in order to locate any hybridisation barriers that may exist. Whilst seed set was recorded from 16 crosses indicating no hybridisation barriers, the presence of barriers was observed in the remaining 55 crosses. The long styles of *D. squarrosa* and *Darwinia* spp (novo) may have been responsible for the incompatibilities when used as female parents, as the pollen tubes of the shorter styled species were unable to transcend the longer styles. According to the above results, methods to overcome the hybridisation barriers were suggested to facilitate the union of desirable characteristics in new hybrids.

INTRODUCTION

Myrtaceae is one of the largest and most important families in Australian flora, containing 144 generic groups (Briggs and Johnson, 1979). The genera *Chamelaucium*, *Verticordia*, and *Darwinia* form part of the tribe Chamelaucieae (Bentham and Mueller, 1967) belong to the *Chamelaucium* alliance, and are largely endemic to Western Australia. The *Chamelaucium* alliance contains genotypes which have attractive flowers, with *Chamelaucium uncinatum* being one of the major floricultural crops of the export flower market. There is a constant demand for new genotypes with novel flower types and colours, which flower at different times of the year.

Hybridisation is an effective method for plant improvement by creating new genetic combinations (Maluszynski et al., 1995). Although intraspecific, interspecific, and intergeneric hybridisation all have the potential to improve the germplasm, interspecific and intergeneric hybridisation are more likely to produce spectacular results. The vibrant flower colouration of *Verticordia* spp. and *Darwinia* spp. combined with the vigour of *Chamelaucium* spp. would produce a desirable hybrid.

Difficulties have been reported when attempting to create interspecific and intergeneric hybrids within the *Chamelaucium* alliance. The failure of seed set in interspecific crosses within *Chamelaucium* (Lamont, 1989) and *Verticordia* (Tyagi et al., 1991) suggests the presence of incompatibilities. It is recognised that interspecific and intergeneric crosses are difficult to accomplish and the complex cytogenetic background of *Verticordia* indicates that wide crosses with this genus may be challenging. However, a number of interspecific and intergeneric hybrids within the *Chamelaucium* alliance have been identified confirming that wide crosses are possible.

Much of the work conducted within Myrtaceae has been on *Eucalyptus*, with interspecific breeding barriers being discovered in this genus (Ellis et al., 1991). In order to devise methods to overcome the breeding barriers in the *Chamelaucium* alliance, the site of the incompatibility must first be identified. Pollen-pistil interac-

tions via aniline blue staining and fluorescence optics are used to locate the site of hybridisation failure. Once the hybridisation barriers are located, techniques can be employed in order to overcome them to facilitate wide crosses.

MATERIALS AND METHODS

Plant Material. Nine genotypes from the *Chamelaucium* alliance were selected: *C. uncinatum* (514*), *C. uncinatum* (772*), *C. uncinatum* (773*), *C. floriferum*, *V. helmsii*, *V. multiflora*, *V. plumosa*, *D. squarrosa*, *D.* spp. (novo). * These numbers represent accessions held at the University of Western Australia.

Pollen Viability. A pollen viability assessment was conducted for each plant within the breeding program to ensure that pollen was viable for use in the pollinations. The pollen was germinated in vitro in a 20% sucrose solution for 24 h at 25C, stained with aniline blue, and observed under fluorescence optics.

Pollination. The presence of secondary pollination mechanisms in all of the genera used necessitated the need for emasculation in order to prevent self pollination. *Darwinia squarrosa* and *Darwinia* spp. (novo) were not emasculated. Branches containing emasculated flowers were covered with a perforated plastic bag to prevent insect pollination. Reciprocal crosses were conducted using the nine genotypes. Flowers were pollinated approximately 10 days after emasculation and five flowers from each cross were collected 48 h after pollination for pollen tube investigations. The styles were stained in aniline blue and observed under fluorescence optics. Where pollen tubes were seen at the ovary end of the style, the ovaries were also examined for pollen tube presence.

Plants Collected for Seed Set. At least 10 flowers from each cross were left intact for seed set assessment. The fruits were harvested when mature and raised via embryo-rescue techniques. Once cuttings had developed roots, they were placed in Growool^{TM} and moved into a glasshouse environment. The well established plants were then transferred to potting mix for evaluation.

Floral Measurements. Due to the large variation in style length between members of the *Chamelaucium* alliance and the expected implications on pollination success, the style length of each genotype used in this program was measured.

RESULTS

Pollen Viability. All of the pollen used for pollinations was of sufficient viability. *Verticordia multiflora* had between 20% to 50% germination; *D. squarrosa* and *D.* spp (novo) had 50% to 70% germination; and *C. uncinatum* (514, 772, and 773), *C. floriferum*, *V. helmsii*, and *V. plumosa* all had excellent viability with greater than 70% germination.

Pollen-Pistil Interaction. Table 1 summarises the results of the pollen-pistil interactions.

Seed was recovered from *C. uncinatum* (514, 772, and 773) suggesting that this species is a superior female parent. Conversely, *V. helmsii* and *D.* spp (novo) showed poor female parentage with little or no pollen tube growth and subsequent lack of seed production.

Style Length. Whilst the stigmas of *Chamelaucium* spp. and *Verticordia* spp. used in this program were relatively similar in length, ranging between 2.9 to 5.4 mm, the *Darwinia* spp. were much longer with *D. squarrosa* being 16.6 mm and *D.* spp. (novo) 14.6 mm in length.

Table 1. Pollen tubes scores for intraspecific, interspecific, and intergeneric crosses within the *Chamelaucium* alliance.

	Male								
Female	*C. uncinatum* 514	*C. uncinatum* 772	*C. uncinatum* 773	*C. floriferum*	*V. helmsii*	*V. multiflora*	*V. plumosa*	*D. squarrosa*	*D.* spp. (novo)
C. uncinatum 514	5	6	6	6	0	4	4	4	3
C. uncinatum 772	6	6	6	6	0	6	6	4	4
C. uncinatum 773	6	6	6	5	6	6	5	6	6
C. floriferum	0	1	5	4	0	1	4	0	0
V. helmsii	0	0	0	0	0	0	1	3	0
V. plumosa	4		4	4	4	4	4	4	4
D. squarrosa	5	4	0	2	0	0	5	5	5
D. spp. (novo)	1	0	0	0	0	0	0	0	0

[1]*C. = Chamelancium, V. = Verticordia, D. = Darwinia.*

Scores are classified as follows: 0, no pollen germination; 1, pollen germination; 2, pollen tube penetration into the stigma; 3, pollen tube penetration into the style; 4 pollen tube presence at the ovary end of the style; 5, pollen tube presence in the ovary; 6, seed set.

DISCUSSION

Of the 71 crosses conducted (involving nine species within the *Chamelaucium* alliance) epifluorescence microscopy indicated that 28 combinations showed immediate pollen-pistil incompatibility with pollen failing to germinate, or pollen tubes not penetrating the stigmatic surface. Such prefertilisation incompatibilities may be overcome by the use of mentor pollen (Pryzywara et al., 1989) or the addition of growth hormones to aid the germination of pollen and the growth of pollen tubes (Shrivastava and Chawla, 1993).

Three crosses, including *D. squarrosa* 5 *C. floriferum*, displayed pollen tube arrest in the stigmatic or stylar tissue. The hybridisation barrier in some crosses were caused by differences in pistil length where the pollen tubes of the species with shorter pistils were unable to transcend the styles of species with longer pistils. The *D. squarrosa* and *D.* spp. (novo) styles were much longer than the other genotypes and were responsible for the incompatibility. This may explain why the reciprocal crosses involving the two species were different.

Epifluorescence microscopy indicated that some crosses were apparently viable with pollen tubes reaching the ovary ends of the styles. The lack of seed from such crosses indicates that postzygotic barriers may have been present preventing hybrid zygote formation. In vitro pollination (Zenkteler et al., 1987) or earlier embryo rescue are effective techniques for overcoming postzygotic barriers.

Although breeding barriers have been detected in the *Chamelaucium* alliance in interspecific and intergeneric crosses, there remains great potential for the exploitation of breeding on all levels for the creation of new cultivars once work has been invested into overcoming these barriers.

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Improving the In Vitro Culture of Geraldton Wax (*Chamelaucium uncinatum*)

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Experiments were carried out to study the in vitro culture of *Chamelaucium uncinatum* hybrids. As the concentration of 6-benzylaminopurine (0 to 1.2 μM) in the medium increased, so did the number of lateral shoots (0 to 10.45). Rootstrike was shown to be significantly influenced by genotype and concentration of indole-3-butyric acid (0 to 10 μM) with 2.5 μM being optimal (93.3%). Transfer to Growool™ increased the survival rate of deflasked plantlets (97.1%) when compared to direct transfer to potting mix (51.4%).

INTRODUCTION

Geraldton wax (*Chamelaucium uncinatum* Schauer) is the most promising of the new floricultural crops selected from the Australian flora (Considine et al., 1994). The waxflower industry is mainly based on cultivars selected from wild and cloned via tip cuttings; however, continued growth will require improved second and third generation cultivars. Therefore, a joint breeding program between the University of Western Australia and Agriculture Western Australia was formed. Embryo rescue has been successfully employed to overcome problems associated with dormancy and postzygotic abortion in the breeding of this plant (Yan and Newell, pers. commun.).

Little is known about the in vitro propagation of this species, especially the highly variable hybrids from the breeding program, and problems were soon encountered with regard to in vitro rhizogenesis and transfer of plantlets to soil. This research aims to explore the use of cytokinin and auxin to optimise the growth and morphogenesis of in vitro Geraldton wax hybrids and to evaluate the use of Growool™ as an alternative substrate for deflasking.

MATERIALS AND METHODS

Three *C. uncinatum* hybrids were chosen at random for all experiments. Embryos were rescued and established in vitro and shoots formed were regularly subcultured to medium containing MS salts (Murashige and Skoog, 1962), with 0.3 μM 6-benzylaminopurine (BAP). The media used in all experiments contained 8 g litre^{-1} agar powder and 20 g litre^{-1} of sucrose. The pH was adjusted to 7 and 8 ml of the medium was dispensed into each 30-ml culture tube. All cultures were incubated in a culture room at 25±1C under fluorescent light providing a fluence rate of 30 μmol m^{-2} sec^{-1} for a 16 h photoperiod.

The effect of BAP concentration on multiplication rate was assessed using media as above but containing either 0, 0.15, 0.3, 0.6, or 1.2 μM BAP. One shoot tip 15 mm long was inserted approximately 3 mm into the medium per tube with ten replicates for each treatment/genotype combination. After 60 days in the culture room the cultures were measured and shoots divided into 3 size groups; <10 mm, 10 to 20 mm, and >20 mm.

The media used in rhizogenesis trials were as above except they contained half-

strength MS salts, no BAP and either 0, 1.25, 2.5, 5, or 10 μM indole-3-butyric acid (IBA). Cuttings 25 mm long had leaves from the lower three nodes removed and each microcutting was inserted approximately 5 mm deep in the medium per tube with ten replicates for each treatment/genotype combination. After 21 days in the culture room, the rooting percentage was measured.

To determine the carryover effect of BAP concentration used in the multiplication stage on rootstrike, shoots greater than 20 mm from the multiplication experiment were cut to 20 mm and transferred to media identical to that used in the rooting trial containing 2.5 μM IBA. Where available 10 replicates for each genotype/BAP pretreatment combination were used and rootstrike was assessed after 21 days in the culture room.

Seventy rooted shoots were used in a transfer trial. Half of the shoots from each genotype were transferred to individual pots (70 mm 5 50 mm) containing Waldecks™ potting mix and the other half were transferred to Growool™ cubes (25 mm 5 25 mm 5 40 mm) prepared by soaking in a half-strength solution of MS. Every attempt was made to ensure that similar shoots were used in both treatments. Pots and cubes were kept at high humidity and under 75% shade inside a glasshouse. Plantlets in soil were watered daily. Plantlets in Growool™ were watered with a half-strength MS solution (pH 7) so that cubes were always moist. Humidity was gradually reduced and the plastic covers were completely removed after 1 month.

RESULTS

The concentration of BAP significantly influenced shoot number ($p < 0.05$); however, genotype had no significant effect ($p > 0.05$). Although the total number of shoots produced increased as BAP concentration increased, this was mainly due to an increase in small lateral branches (Fig. 1). The number of shoots <10 mm and 10 to 20 mm is significantly greater at the higher concentrations of BAP when compared to the number of shoots >20 mm which remains relatively constant as BAP concentration increased.

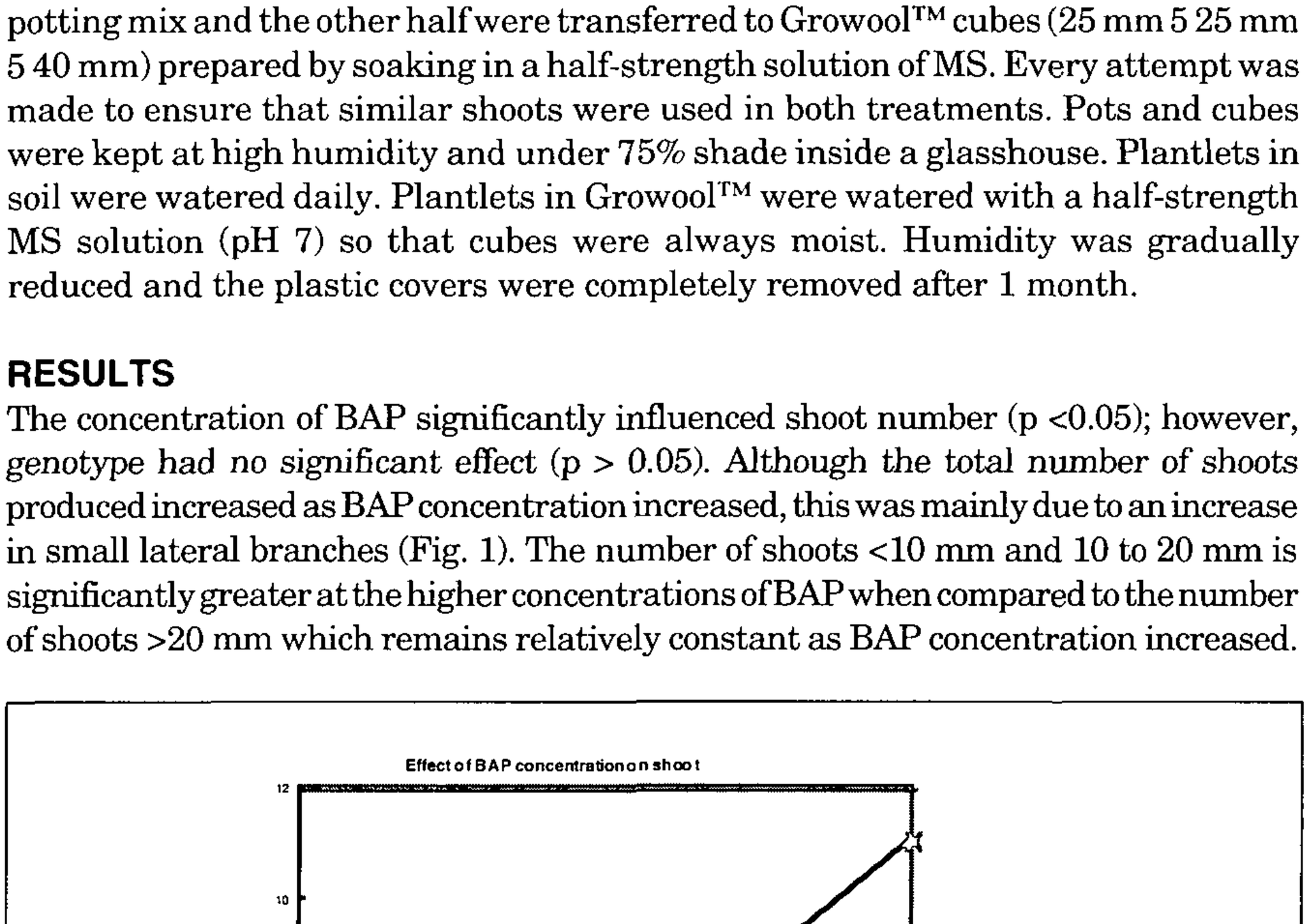

Figure 1. The effect of BAP on shoot number

In cultures where BAP was excluded no additional shoots were produced, the initial explant had grown less, greater than 10% of their leaves had senesced, and some roots formed which did not occur in any of the cultures containing BAP.

The percentage of shoots which formed roots was dependant on genotype and concentration of IBA (Table 1). As IBA concentration increases, rootstrike increases to a peak with IBA concentration at 2.5 μM and then decreases at higher levels up to 10 μM (Fig. 2).

Table 1. Rooting percentage of *Chamelaucium uncinatum* explants cultured for 21 days at various concentrations of IBA.

	IBA concentration (μM)				
	0	1.25	2.5	5	10
548/OP-1	40 a*	40 a	90 b	60 a	40 a
640/OP-3	70 a	90 ab	100 b	100 b	100 b
772/OP-1	70 ab	70 ab	90 bc	100 c	40 a

* Numbers followed by different letters are significantly different (p=0.05).

Pre-treatment with BAP had little effect on rootstrike percentage with few interesting differences between treatments and no general trend (Table 2).

More rooted plantlets survived the transfer to the greenhouse when Growool™ was used (97.1%) compared to direct transfer to potting mix (51.4%).

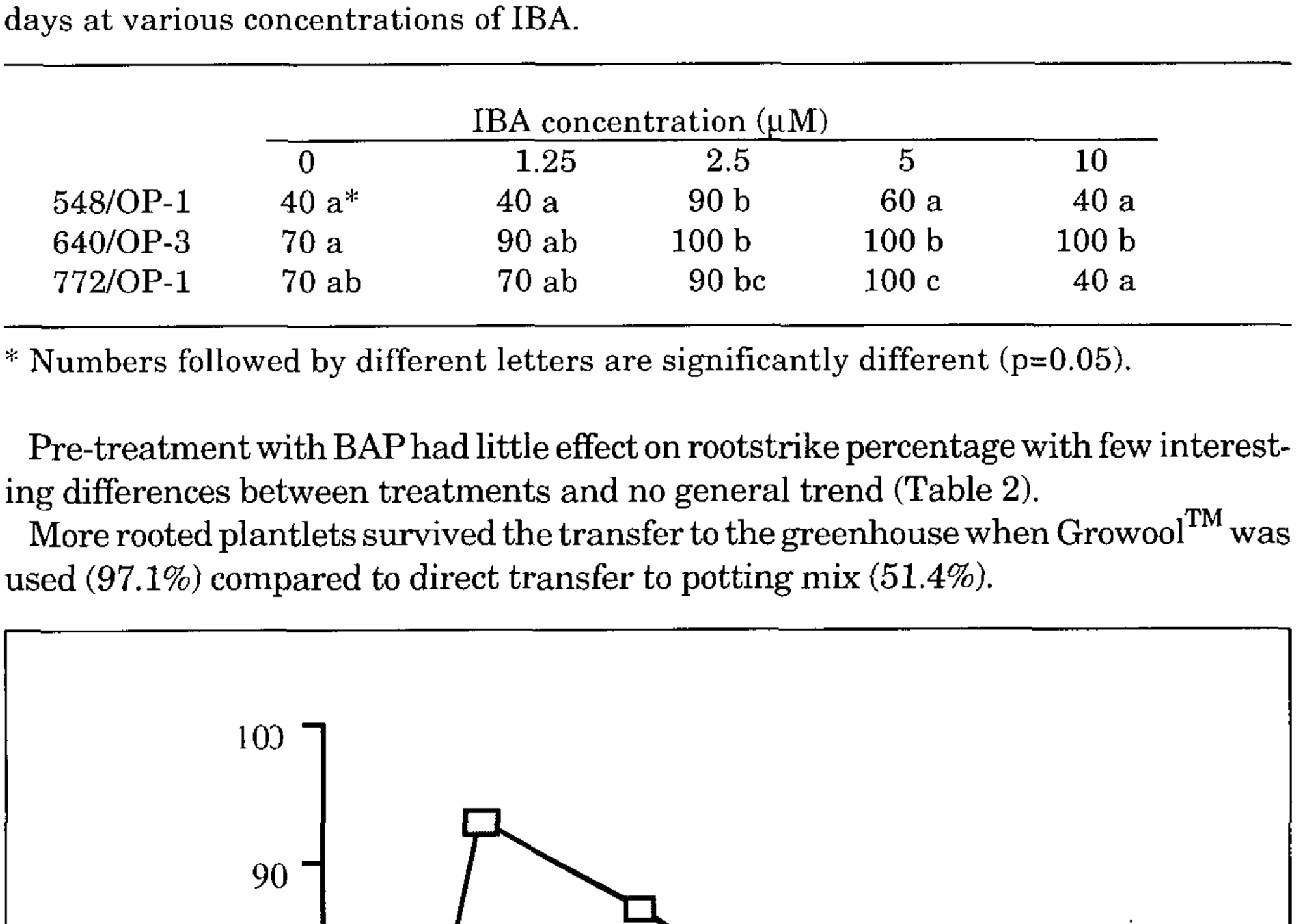

Figure 2. The effect of IBA (μM) on rooting.

Table 2. Rooting percentage of *Chamelaucium uncinatum* explants cultured for 21 days at 2.5 µM IBA following multiplication on different concentrations of BAP pretreatment.

		BAP pre-treatment (µM)				
	Genotype	0	0.15	0.3	0.6	1.2
% Rooting	1	66.7 a*	66.7 a	70 a	88.9 a	80 a
	2	25.0 a	85.7 b	80 b	75.0 b	80 b
	3	33.3 a	55.5 a	50 a	22.2 a	40 a

* Numbers followed by different letters are significantly different (p=0.05). .

DISCUSSION

The multiplication results are consistent with Speer (1993), and support a two-step multiplication stage where several small shoots are produced at high (1.2 µM) BAP that can be excised and transferred to low (0.15 µM) BAP medium and allowed to elongate without further branching and thus be suitable for rootstrike. Exogenous cytokinin was shown to be essential for growth and multiplication of these shoot tip cultures as root apices are the main centre for cytokinin production (Koda and Okazawa, 1980). Problems caused by insufficient cytokinin levels included poor shoot growth, inhibition of lateral bud break, and senescence. Rootstrike was completely inhibited by BAP.

No effect on rootstrike was observed in shoots cultured for 60 days at different concentrations of BAP up to 1.2 and then transferred to media containing IBA, suggesting little BAP is transferred to rooting stage or that BAP transferred is quickly degraded or used. The low rootstrike rates when no BAP was used in the multiplication stage is likely to be due to the poor health of cytokinin-deficient cuttings before being transferred to cytokinin-free rooting media. Surprisingly there was little genotypic difference in the response to applied BAP.

The percent of shoots that formed roots was shown to be influenced by both genotype and the concentration of IBA in the media. These results suggest that there is an optimal IBA concentration for rootstrike. This concentration is likely to be influenced by endogenous auxin levels and sensitivity to exogenous auxin. It is likely that individual genotypes differ in these aspects and hence optimal concentration for rootstrike.

Transfer to Growool™ was more successful than direct transfer to soil. Due to the high humidity and regular watering required for the survival of these plantlets, the oxygen content of potting mix is reduced and root growth suffers due to reduced respiration. Growool™, however, will maintain a percentage of air while providing easily available water (Donnan and Biggs, 1984).

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Chelsea Flower Show 1997 — Planning and Perseverance

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INTRODUCTION

The Chelsea Flower Show, London (officially The Royal Horticultural Society Great Spring Show), is the world's most prestigious horticultural event. Chelsea attracts 170,000 visitors from all around the world, and involves another 30,000 exhibitors, contractors, and officials.

Kings Park and Botanic Garden initiated the project as a tourism and promotional event for Western Australia. It became reality when support was promised from the Flower Export Council of Australia for cut flowers, and links to a week of Western Australia product in London (Good Living — Western Australia) by the Department of Commerce and Trade provided sponsorship from John Brown Engineering and British Airways.

Linda Lukies, of Flowers & Studio, Mosman Park was invited to join Roger Fryer, Curator — Technical Services, and Grady Brand, Curator — Collections and Displays , to implement the design. Using Western Australian wildflowers, the design showed a south west swamp in contrast to the arid interior on the two sides of a sand dune representing the two faces of Western Australia.

All hard landscape materials were transported from Perth inside a sea container and plants and cut flowers were flown over. The Royal Botanic Gardens, Kew, assisted by providing glasshouse space and staff to assist with the set up and take down of the display. Phytosanitary reasons prevented us from returning plants used in the display, so these were donated to Kew. They have established a post-Chelsea display, using our plants, labels, and signs, that attracted considerable public attention.

PLANNING

Planning began 18 months out and involved display design and logistical planning. Factors influencing these were plant and cut flower selection and availability, U.K. import restrictions, and Australian export restrictions. Transport methods as well as the design requirements for artefacts and their source, signage, pamphlets, and the Royal Horticultural Society (RHS) restrictions for the display and associated signs and labels were all considered.

PLANT IMPORT AND PHYTOSANITARY PROCEDURES

Contact with the Australian Quarantine Inspection Service (AQIS) and the United Kingdom Ministry of Agriculture, Fishery, and Food (MAFF) provided a prohibited species list for guidance. Plant selection was made 12 months in advance based on those species flowering at the correct time and relating to design requirements.

Design requirements to take both potted and cut flower material together meant that we had to meet phytosanitary requirements and export licences for importing plants in potting mix into the U.K.

We met these by:

1) Ensuring no plants were on the prohibited species list, Solanaceae and Gramineae were the problem families.
2) Proposed treatments and plant lists were faxed to AQIS and MAFF for comment.
3) AQIS inspected the plants 7 days prior to export and advised on problems and treatment. The formal inspection was made 2 days prior to export to allow time for packing.
4) All documentation was faxed in advance to MAFF to allow time to check and assimilate before the plants arrived.
5) We obtained export licences through the Australian Nature Conservation Agency (ANCA) and the WA Department of Conservation and Land Management (CALM) for all plants. Application for plant licences need to be made at least 6 weeks prior to export. Botanical descriptions were required for species which did not occur on the ANCA database.
6) We met CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) requirements because all plants were propagated and cultivated in Kings Park nursery.

PLANT GROWING

Plants were grown hydroponically and by normal container methods. We applied strict hygiene in both cases. Larger plants were bare rooted, washed, and repotted into a pasteurised potting medium.

LANDSCAPE MATERIALS — IMPORT PROCEDURES

Landscape materials such as sand, timber, and rocks were dealt with in a similar fashion to the plants. The appropriate authorities in the U.K., e.g., MAFF and Forestry Commission, were notified in advance and clarification was sought for fumigation and hygiene requirements. These vary depending on the type and source of the material.

AIR FREIGHT

We approached our freight forwarder, AEI (both for sea and air freight) and British Airways to decide best transport options. For both companies this was a first time to transport potted plants in an air container, new methods and procedures had to be devised. Large volumes of freight need booking several months in advance to ensure space was available.

Over 350 plants ranging from 2.5 m high to 20 cm high were packed into an air container 4 m 5 2 m 5 1.5 m high using a tiered decking arrangement. Large plants were laid flat on the base and any gaps between branches filled with smaller plants. Pine legs were inserted between the plants and a plywood decking was installed. Hessian was stapled to the boards, brought up, and stapled around the plant pots as they were packed, to prevent them moving.

A second deck was installed and the remainder of the plants, boxes of pamphlets, and seeds were stacked on this. Edging strips were installed to ensure plants and boxes could not fall off.

The air container was loaded Wednesday morning, left Perth that afternoon, and we unpacked it at Kew late on Friday, 61 h later. Nearly all plants arrived in good condition, only three were damaged physically and had to be discarded.

The plants grown hydroponically were sealed in "Gro Fresh" bags. This should have allowed ethylene to disperse, but ten of the *Swainsona maccullochiana* suffered damage from ethylene build up that affected flower development after arrival.

Cut flowers were provided through the Flower Export Council of Australia (FECA) and were flown over separately. They were handled by Total Flower Exports as a standard export procedure. These were sent on the Thursday and delivered on the Friday evening, 13 h after landing.

SEA FREIGHT

Approximately 11 m^3 of hard landscape material, a dry blower, tools, and construction materials were packed onto pallets, shrink wrapped, and sent sea freight in containers. All material arrived in good condition apart from a few damaged bags of sand. In the U.K. it took 10 days for the pallets to clear customs and be delivered. There were some problems over a Value Added Tax (VAT) number but on the whole this was a relatively smooth operation.

IMPLEMENTATION

The Royal Botanic Gardens, Kew gardens were used as a staging area for the plants and display material and they also provided staff to assist with set up and take down. We were able to work on the plant material in good glasshouses for 5 days which helped to get the kinks from the packing out of most of them. Without this area it would not be possible to transport many of the softer plants and have them in display condition. Kew provided two staff and a supervisor for the first day and two or three staff for the rest of the set up time. Without their assistance it would not have been possible to set up in time.

In planning for set up we organised tools, sand, etc. to be delivered on site in sequence and for the plant transport from Kew to the Chelsea site. Water, power, and lighting were all organised in advance.

SWAN SONG

After the display we donated the plants to Kew and they set up a post Chelsea display in the Princess of Wales glasshouse using surplus red sand, our labels, and the "Plants supplied by Kings Park, Perth W. Australia" signs we had. This gives Kings Park and Botanic Garden an ongoing display and maintains our links with Kew. (Ed's note: The Black Swan is an integral part of Western Australia's coat of arms).

CONCLUSION

While this was an expensive project both financially and in staff involvement the returns were enormous. Benefits included:

1) Very good publicity here and in the U.K., with potential for ongoing support from local radio stations.
2) International credibility of our horticulture standards and our ability to deliver.
3) Closer links to Royal Botanic Gardens, Kew, the RHS, and Edinburgh Botanic Garden.
4) Potentially increased exports of wildflowers to the U.K.
5) Potentially increased visitor numbers to WA and Kings Park and Botanic Gardens.

6) Increased confidence of our staff in their abilities.
7) Increased staff knowledge in display work and horticulture generally.
8) Closer ties to the commercial side of horticulture in Perth and increased support from the industry.
9) Giving Kings Park and Botanic Garden a worldwide view.

Despite all the restrictions and complications of international export and import, if good hygiene and horticultural practices are followed, this exercise proved that container plants can be transported and displayed in good condition. Whether it is commercially viable is another matter.

My Knowledge

George Lullfitz
Lullfitz Nursery P/L, PO Box 34, WANNEROO WA 6065

My knowledge has been acquired over many years by practical experience and with some assistance in the early years from special people who were pioneers in their field. Fred Lullfitz and Charles Gardiner were my earliest mentors. Later inspiration in nursery practices was gained from George Gay, Ben Swane, and Jack Pike. I have been associated with the growing and promotion of Western Australian native plants for 35 years and a member of the I.P.P.S. since 1972.

Through my knowledge and experience it has been possible to introduce new plant cultivars into local, national, and international horticulture with application to nurseries, landscaping, and floriculture (cut flowers). Some recognition for my contributions made to the WA flora and horticulture has been the inclusion of the name Lullfitz in the species of some recently named plants. These new selections have come about through:

- Careful observation of plants in nurseries and local and natural environments,
- Having the ability to recognise potential for something out of the ordinary, e.g., mutations, flowering times, hybrids.
- Specialist selection and propagation experience.

Good new cultivars are highly sought after. But in the past the person who had put in years of hard work to get a new cultivar into cultivation was not adequately renumerated. So here is my accumulated knowledge, distilled into four points of advice to those of you investing considerable amounts of time and money to research and develop new plant selections:

- Identify your opportunities, if you have something worthwhile do something with it!
- Be aware of threats, someone else may somehow obtain your idea or product. So use it or, sadly, potentially lose it!
- Capitalise on your knowledge, make sure that you are the one rewarded for your efforts.
- Protect your knowledge, through Plant Breeders Rights, propagation agreements, etc., and you can continue to prosper from your investment.

6) Increased confidence of our staff in their abilities.
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Commercial Varieties of Olives

Lui Bazzani
Olea Nurseries, RMB 44, WEST MANJIMUP WA 6258

In the past few years there has been, and still is, an unprecedented demand for olive trees. Eager requests have been made for information with regard to the cultivation and other conditions necessary for the success of this crop. Invariably the choice of cultivars figures prominently amongst these questions. As growers of plants we know very well how important it is to make the right decision as far as the choice of cultivars is concerned, especially when we deal with commercial fruit crops. For the olive there is no exception. What the grower must be informed of before selecting any particular cultivar is the characteristics that the cultivar(s) must possess to achieve optimum production in the environment in which it is to be grown.

BOTANICAL HISTORY

Before we set out to explain the diverse properties of this remarkable tree, I would like to go back and trace the olive's botanical background, its origin, development, and its expansion around the world, albeit in a superficial manner.

The olive belongs to :

Family :	Oleaceae
Sub family or tribe :	Olineae
Genus:	*Olea*
Species:	*europaea*

We shall overlook the distant members of this family and concentrate briefly on the genus *Olea.* The cultivated olive has many close relatives which are scattered over the five continents. The majority of these are to be found in Asia; the Pacific, including Australia and New Zealand; Africa is well represented; and to a lesser extent the Americas and Europe.

The species or subspecies of the genus *Olea europaea* are localised in the Mediterranean basin and in Portugal on the Atlantic.

Olea europaea* ssp. *euromediterranea. *Euromediterranea* comprises two lines or series:

The cultivated olives or sativa which have now spread from the Mediterranean to the America's, Asia, Australia, New Zealand, and South Africa.

The wild olive or oleaster. These are seedlings from the cultivated olive often in different phases of evolvement. They can be seen growing spontaneously along road verges on vacant land all over olive growing areas of the world, including the southern states of Australia and in particular South Australia.

The fruits of both species can vary in size and quality and can be used for oil production and preserving. The shape and size of the leaves and the general aspect of the plants change very little.

There are another three subspecies of the *Olea*, closely related to *O. europaea*. They are of little interest to us at the moment but are valued by the scientist for the development of new cultivars and rootstocks.

1) *Olea europaea* ssp. *laperrini*: Typically from the Sahara mountain of the Haggar-Tassil altitude 2000 to 2700 m. The fruit are of little value and the trees are small.
2) *Olea europaea* ssp. *cyrenaica*: A vigorous tree, the fruit are bigger than *laperrini*. This subspecies is found in Cyrenaica.
3) *Olea europaea* ssp. *mariena*: Again from the areas of North Africa, south of the Atlas Mountains.

Another close relative can be found on the Himalayas in India, Belucistan, Nepal, and Tibet. This subspecies is called *O. europaea* ssp. *cuspidata*. The leaves of this olive are dark green on the surface and reddish on the lower part (ferruginea). The natives of these parts have been known to use the small fruits. Ferruginea has an affinity with all the cultivars of *O. europaea* (sativa). From the African continent including Madagascar, Mauritius, east Africa, Upper Egypt, and Saudi Arabia we have *O. chrysophylla* (see *O. europaea var. cuspidata*). From South Africa, Natal, and Transvaal we have *O. verrucosa* (see *O. europaea* ssp. *africana*), and from Somalia *O. somaliensis*. Further to the west of the Indian sub continent in Belucistan, Anatolia, Syria, and Arabia, many forms of *O. europaea* are to be found. Most of them have large silvery coloured foliage and good-sized fruits. It is not unreasonable to presume that the so called *O. europaea* originated from plants introduced into the Mediterranean from the areas mentioned above.

The longevity of the olive is widely accepted. In combination with its capacity to regenerate from seed and the aptitude to be propagated asexually, we are given reason to believe that the high number of cultivars we have at the present time had their origins in the distant past. Additionally we have a large number that throughout the cross fertilisation and the dissemination of seeds have evolved from the juvenile stage into new cultivars. The duplication of names (synonyms) does not help and the subtle changes that these cultivars have undergone throughout the diverse environments where they have been transplanted over the years have contributed to the diverse forms or clones that we have today. The number of cultivated cultivars of olives are very many indeed. Amongst those there are only a few that fulfil the needs of modern oliviculture.

AGRONOMIC EVALUATION

The classification of plants has traditionally been based on morphological data. That is, the science and study of external structure and form. DNA fingerprinting is now common for the identification of diverse cultivars. However the evaluation of most of the fruiting cultivars is still based on the appearance of their fruit and the smoothness of the skin (cosmetic look), often the flavour of the flesh is forgotten. To some extent sugar content or brix is evaluated.

Beauty and an appealing name is what is needed for commercial success of the ever-increasing numbers of cultivars of peaches, nectarines, and plums that make their way onto the market every year. For the olive cultivars, this is not of any importance, the final outcome of their fruits is everything but pretty. The oil cultivars are crushed beyond recognition and their pickling relatives do not end much better off.

The system to classify olive cultivars to be of any value to prospective growers, therefore allowing them to choose the right selections, should only be based on the cultivars performance or agronomic properties.

For modern olivioculture, the positive or negative features of any particular cultivar should be evaluated and then compared to the features of the other cultivars that we can choose, in this way the right selection of cultivars necessary for a modern olive plantation can be made.

We will concentrate on the oil cultivar which makes up 90% of the total olives grown at the moment. The balance being processing or table olives. The conditions needed by an oil producing cultivar to satisfy current demands are: (1) machine yield, (2) quality, (3) quantity and early cropping, (4) fertility, (5) disease resistance, (6) adaptability, and (7) growth habit.

Machine Yield. A term used to indicate the percentage of fruits that can be shaken from the tree by a shaker-machine at harvest time. This percentage varies greatly from one cultivar to the other, at times it can be as low as 10% and at best as high as 95%. The higher percentage can be achieved by employing a shaker which features an abrupt, high-powered shake lasting a maximum of 5 sec, as any longer will cause damage to the bark.

The structure of the entire tree, i.e., the way the secondary branches are located, can determine the outcome of the harvest. However, the genetic factor at this point must be given the greatest consideration. There are chemical treatments which use ethylene-based compounds to assist with harvest but so far the abscission rate of the fruits has been erratic and in some cases catastrophic. The degree of ripeness of the fruit has a big influence on the quality of oil, i.e., the greener the olive, the better the oil, but the more difficult to remove from the tree with a machine harvester. With increasing ripeness, there is better machine harvest yield, but the quality of the oil decreases.

Olives require five times more energy to remove from the tree than other fruit crops like almonds or walnuts. Improvement in mechanical harvesting is continuing and a new generation of machinery is on its way.

Quality. The quality of olive oil is determined by several factors. The first is genetically inherited and therefore entirely dependent on the cultivar. The timing of harvest and the extraction process plus the storage of the oil are crucial in determining quality. Also the cultural practices, an example of this is choosing to irrigate or rely on natural rainfall, or how to achieve control of pests and diseases. We will concentrate entirely on genetic heritage.

A good cultivar must produce an oil that expresses its distinctive organoleptic properties like any other fruits of the soil. Also it must possess the ability to safeguard these genetically inherited properties. The fruits of a cultivar must have low initial acidity (vacuolar oil), 0.2% pre-extraction and a final acidity level of 0.4% to 0.5% oleic acid. By law for top quality oil it is 1%. Polyphenol (antioxidants) optimal value is 2000 to 3000 ppm, in some cultivars it is as low as 40 ppm.

The structural stability of the fruit is the most important aspect which will determine the final result, The cellular walls of the fruit are maintained by the presence of the pectines. These substances protect the vascular oil from coming in contact with the enzyme and the subsequent ossidatiance.

The Kreiss Test. It has to be a negative value, a positive result will indicate a process of rancidity in action.

Acidity. Expressed in oleic acid, must be less than 1 (which is the legal maximum). A good oil should have a value between 0.4 to 0.5.

Peroxide P.V. A process of rancidity, initially can only be detected with analysis. The legal value is 20, a good oil should be around 10.

Polyphenols. Antioxidant substances. High values will result in oils with more stability or a longer life. Optimal value is 200 to 300 ppm.

I : S. The relation between insaturated acids and saturated acids. A higher ratio of insaturated acids results in an oil which is easier to digest. Oils from cool regions contain proportionally more insaturated acids than oils from hot areas. Saturated acids are mostly prevalent in animal fats.

Quantity and Early Cropping Fertility. We refer to this as the productive potential. The profile of quantity starts with the onset of flowering, following with the setting, and then to the retention of the fruits on the tree. Some cultivars undoubtedly have the ability to set and carry more fruits than others. This is due to: the number and length of the fruiting branchlets, the number of flowers per branchlet, the percentage of fruits set, the number of perfect flowers, the percentage of fruit shed before harvest, and percentage of oil in relation to the weight of the fruit.

All factors mentioned above are influenced by cultivation practice and environmental conditions, however, the genotype is still very prominent.

Fertility. Some cultivars are self-fertile and some are not. Cross pollination is imperative for the first and beneficial for the second.

Disease Resistance. We are lucky in Australia in that we do not have so many of the diseases endemic to the Mediterranean basin. The climatic conditions are also on our side. *Pseudomonas savastanoi*, *Cycloconium oleaginum*, and *Verticillum dahliae* are the most troublesome of these diseases. *Cycloconium* has affected some cultivars of olives in New Zealand already. Humidity caused by summer rainfall can be a problem. There are some cultivars with a resistance to the three diseases.

Adaptability. So far all of the cultivars introduced in the last 20 years have performed well under Australian conditions. Naturally in time, particular areas will be more suitable than others to the diverse cultivars, seasonal conditions may prove to be more influential.

Growth Habit. This refers to the way a particular tree grows, i.e., upright, spreading, weeping, vigorous, or not so vigorous. Smaller and upright trees can be planted closer together in the rows than vigorous and spreading trees. A knowledge of the growth habit of any particular cultivar will be very useful in deciding the planting density of an olive grove. With the introduction of new cultivars, the planting distance can vary from 8 m × 6 m to 5 m × 2 m.

Asexual Reproduction of *Wisteria* by Root Cuttings

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INTRODUCTION

Wisteria is a genus of woody, twining climbers belonging to the family Leguminosae. About six species are commonly cultivated. The best known are the Chinese (*W. sinensis*), the Japanese (*W. floribunda*), and the American (*W. frutescens*). *Wisteria* is commonly planted for training over trellises, doorways, or porches and also looks good as standards and in pots. They bear showy hanging racemes of pea-like blue, pink, white, or violet flowers during spring. *Wisteria* taxa are deciduous vines, some species produce canes up to 30 m in length, which are long enough to reach across a large house! The leaves are compound having 7 to 19 leaflets. The fruit is an elongated pod which is toxic. *Wisteria* species do well in most climates and should be planted in areas of good drainage. Mulch should be added to the soil in summer to prevent the soil from drying out.

PROPAGATION

Wisteria species can be propagated in a number of ways. They can be grown from seed, soft or hard wood cuttings, layers, and root cuttings. Root cuttings are not the most common method to produce new *Wisteria* stock but can be very effective. Root pieces also have nitrogen-fixing nodules which enable nitrogen that is absorbed from the atmosphere to be used by the developing plant.

Root cuttings are much like stem cuttings except that the root, or part of it, is used rather than the stem. The best results with root cuttings are obtained if root pieces are taken from young stock plants in late winter or early spring, when the roots have adequate stored food but before the new seasons growth begins. A few small pieces can be chopped from the roots without greatly disturbing the stock plant. However, the usual method is to dig up the entire plant, cut the roots and either replant the remainder of the old plant or throw it away. If it is to be replanted the foliage must be cut back so that the reduced root system can cope with transpiration demands.

One of the main advantages of asexual propagation is that the new plant has the exact physical characteristics of the parent plant. However with root cuttings care must be taken to ensure that the original plant wasn't grafted onto a rootstock. In this case you would need to use stem material from above the graft to obtain cuttings true to type.

Once the roots are exposed they need to be carefully inspected for any damage or disease; poor quality material should be discarded. The remaining healthy material is then cut up into lengths of about 10 cm with a flat cut at the top and a slanted cut at the bottom end of the cutting, to easily determine proximal and distal ends. The distal end of the cuttings should then dipped into hormone powder which consists of 4000 ppm IBA plus 2000 ppm NAA.

The propagation medium used was 15 cm of our standard potting mix in a polystyrene box, to ensure sufficient depth to accommodate the cuttings, with a 3-cm layer of grit spread on top to assist drainage. The cuttings were pushed into the

mix vertically, up to natural soil level, with the proximal end upright to maintain polarity. The cuttings were then placed in the propagation igloo.

The cuttings take about 6 to 8 weeks to shoot. The root pieces will develop by first producing an adventitious shoot.

GROWING ENVIRONMENT

The propagation igloo used has state-of-the-art equipment to provide an optimum growing environment for plants. The environment in the igloo is controlled by a computer which monitors temperature and humidity levels. The control box makes the necessary adjustments to ensure that temperature and humidity are kept within programmed levels by triggering off the exhaust fans and/or foggers when required. The igloo also has internal shade screens which block out 70% of sun light when closed or act as a blanket to reduce heat loss at night. Over summer we also put over an external cover of white shade cloth to block out excess sunlight and heat. On the benches we have electronic heat mats which provide a constant bottom heat to the propagation medium.

There are three full-time staff in the igloo who all work under strict hygiene protocols to reduce any chance of disease. These include: stepping into a footbath of biocide solution before entering the igloo to avoid walking in any diseases, washing all tools and work benches before use with biocide, washing down benches with biocide solution after moving stock, and regularly sweeping and hosing the igloo out. These protocols ensure that: the igloo is always kept clean and tidy, space is used efficiently, and that our excellent productivity (strike rates) is maintained.

The Challenges of Live Plant Exporting

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The Australia business sector is frequently being enticed to reap the financial rewards of product export to international destinations. However many potential "exporters" hesitate at the first phase of marketing due to the unforseen *complexity of the challenge. Following is a summary, from personal experience*, of the steps which were taken to develop a market for Australian-produced nursery products. Our number one marketing goal was to: BUILD GLOBAL RELATIONSHIPS BY GIVING CUSTOMERS WHAT THEY WANT

STEP 1: MARKET IDENTIFICATION

Potential markets were initially targeted from information provided from the following sources:

- Austrade
- Department of Economic Development and Trade
- Department of Foreign Affairs and Trade
- State Chamber of Commerce and Industry
- Department of Tourism, Small Business and Industry
- Internet
- Allied multinational companies (i.e., landscape design companies)

From the initial market information, a program of regular visits to the potential market place by the directors and key employees was undertaken to gather background information on the "local" market, identify possible products for that market and company introduction to possible customers. The markets with the best potential for Australia nursery products were identified as:

- Indonesia, Malaysia, Brunei, Philippines
- Japan, Taiwan, China
- New Caledonia, Tahiti, France
- United Arab Emirates, Bahrain, Kuwait, Saudi Arabia

STEP 2: MARKET DEVELOPMENT

The following strategies in sequence were employed:

1) Establishment of a dedicated export division:
   Export services coordinator;
   Export manager.
   This shows a professional commitment to your customers.
2) Build a network of suppliers (Australian and international) and influencers:
   Designed around customer requirements;
   With a reputation for timely delivery and continuity of supply.
3) Obtain Quality Assurance Accreditation to ISO 9002 standard. This standard is internationally recognised by the most desirable clients.

4) Promotion and advertising: Best results have been obtained through the latest multimedia technology, i.e., Internet and CD ROM.
5) Invite overseas clients to Australia:
   To visit your business facilities;
   To visit appropriate suppliers within your network who can supply your client requirements.

It is very important to provide hospitality to an international standard, be patient and take the time to fully explain all questions. This provides a solid foundation to building those long-lasting, mutually beneficial relationships. Many of the potential customers for live plant products are from emerging third world countries and they may not be familiar with the technology.

- Training our customers' and suppliers' staff — overseas and in Australia. Plants are highly perishable items so all steps in the supply chain are very important for maintaining product quality for the end user. This step is most critical in the continuation of a business relationship.
- Meeting challenging requests. A common request from potential customers, "We would like something different". Australia is an unique position of having an extensive variety of different plant products. The challenge is being able to fulfil these requests. It often requires the adoption of basic plant production procedures, careful but thorough logistics planning, and the confidence to succeed. Success in meeting requests builds company reputation and generally leads to an expanding market as "happy customers spread the word".

The marketing of plants internationally should be viewed as an extension of your marketing program for your existing customers. Servicing this market will require patience and tenacity but the returns both financially and culturally are worth the effort.

Back to Basics

Clive Larkman
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It is nearly 10 years since my first I.P.P.S. conference. Over that time a huge range of topics have been covered. Many papers have been on leading edge technology. Just as many have revisited some of the real basic principles of plant propagation. I have subtitled this paper "A Walk Through Larkman Nurseries". It outlines some of my philosophies on the basic requirements for running a successful propagation nursery.

PROFIT

Profit is a basic necessity of running any business. If you are not making a net profit before tax of 10% of turnover or 7% return on investment then you are not running a successful business.

Sure you may be getting 110% strike rate, but you must still sell each plant for more than it costs you to produce. If you aren't then you must increase your prices or reduce your costs. Cost reduction is not an answer alone and any cuts must not detract from customer satisfaction. Profit increases can be achieved by putting up your prices and/or removing your discounts. Discounts are hard to justify. Whilst price increases do not cost a lot in terms of lost sales.

STAFF

As we all become more technologically literate the major difference between our businesses will be our staff. To run your business at its optimum level you need reliable and motivated staff, and their greatest motivating factor is job satisfaction. This involves making the job as interesting as possible, having good staff morale, and plenty of positive reinforcement from supervisors, managers, and owners. People also like to be involved (in decision making, etc.) and to know what is happening around them. Encourage your staff to contribute ideas, thoughts, and observations, while at the same time be as open as you can.

CUSTOMERS

I have long held that the most important aspect of any business is its customers. Without them you are working for nothing (literally). The customer can always find stock, while the reverse doesn't hold true. As staff are the integral factor in production, service is the key in customer relations. That is service, service, and service. You must treat each and every customer as someone special, they are an integral part of your business. Your customers must be able to trust you (and your staff), and must feel that your product will at least meet their expectations if not exceed them. Your challenge is to increase your customer base without losing any current customers.

This does not mean that all customers are good customers. Indeed some customers are better off being sent to your competitor. These are easily distinguished by the fact that your staff all seem to disappear when they come onto the premises. In general they always complain about the price and will usually tell you that the guy

down the road is 20% cheaper. They want special service, and will complain vociferously if you don't meet their every whim. They will generally want an account but will be slow to pay or want a further discount if they pay COD. Good business practice is to give them to your competitor.

It is important to know what your average sale per customer is, and the average purchases per customer per annum. If you know these figures you can set about increasing them. We would all like to have a 30% increase in sales (especially if the increase comes with a higher margin). Sounds a bit high, well perhaps a 10% increase sounds more achievable?

If you can achieve a 10% increase in your number of customers, plus a 10% increase in their average expenditure, and a 10% increase in the number of purchases per year, then you will have achieved a 30% increase in sales.

THE PRODUCT

Whatever you put your name on should accurately reflect the image you are trying to create. If you are projecting the image of a professional business that insists on top quality, then make sure that your stock looks that way. You need to set standards that are clearly promoted both within the business and to your customers.

Granted, if your are selling to the bottom of the market where price is the only influencing factor and quality can be overlooked if the price is right, then don't spend any extra resources on producing a better-than-expected product. It is critical that you are aware of your customers expectations and individual requirements. If you go too high you will go broke, and if you go too low you will not sell your product. It is your job to find out what the correct balance is and then deliver it to your market. You can be assured that if you don't, your competitor will.

During the 1980s when there were large stock shortages many a customer was told when they would get their stock, what size it would be, where they could collect it from, and how much they were going to pay. I found this an amazing form of customer awareness and liken it to going into a restaurant and being told what you will eat, when you will eat it, what sauce you will have, who you will sit with, and how much you will pay. I suggest that if you went into a restaurant which operated in this way, as soon as you stopped laughing, you would be out the door to another one. The same goes for our industry. Now that there is ample competition, your customer will soon go elsewhere if they feel that they are being taken for granted.

STOCK PLANTS

Quality starts at the source. The first principle is to have good healthy stock plants. They must be correctly identified and labelled. Your customers rely on you to get the labelling right. Once they have bought and potted up your stock they have invested heavily and cannot afford to be wrong. As propagators' we have a moral obligation on behalf of the industry to make sure that we have the nomenclature and identification correct.

When selecting your stock plants make sure they are true to form and are strong in the morphological criteria for which they are named (e.g., for *Rosmarinus officinalis* 'Prostrate' make sure your stock plants are very flat and not just low growing). Any poor performers should be removed.

Stock plants need to be kept healthy and vigorous. Often at past I.P.P.S. conferences papers have been presented discussing the concept of juvenility. Without getting too involved in the details, it refers to the physiology of plants that

are either kept in a juvenile stage (e.g., *Metrosideros* and *Eucalyptus*) or just kept pruned and actively growing. It is often the case that one propagator is able to obtain a good strike rate, yet when you try to repeat their method your results are nowhere near as good. I believe that this is directly related to juvenility. If the other propagator is regularly propagating a plant, logic dictates that it must be being cut back on a regular basis. However when you attempt to strike a new species your plants are being cut for the first time.

There is a strong debate as to whether stock plants should be grown in ground or in pots. We grow ours in the ground and find that we get better results this way. I feel that this is because we are better able to look after them in ground. If we had the resources to give them the adequate care in pots I believe we would get the same results. In other words the ground versus pot debate will depend on your own resources and preferences.

Another debate regarding stock plants is whether they should be replaced every few years. In fact we often debate this within our own company. I personally feel that in most cases they do not need to be replaced regularly but do need to be fertilised and pruned on a regular basis.

The fertilising has to be more than just NPK. Indeed, many plants run very short of the secondary nutrients and some of the trace elements. Some nutrients are very mobile within the plant and are reused, others cannot be moved around the plant and are fixed into the leaves or stems. If the plant is being cut on a continual basis and replacing this with new growth it will need a regular supply of the building blocks necessary for that new growth.

For example, calcium is a major component of cell walls, it is also an immobile element and is not always in abundant supply in the soil. Calcium should be applied at least annually, if not biannually. There is a growing body of research and anecdotal evidence indicating that calcium deficiency may be a major reason for poor strike rates, especially in cuttings from older stock plants. There are several ways to apply calcium to your plants. It can be given as calcium carbonate, gypsum, calcium nitrate, blood and bone, etc. Each product has different properties that may have either a beneficial or deleterious affect. It is important that you understand the genera and species that you grow. In many cases a good knowledge of the natural range and habitats of the wild plant will assist in predicting the conditions for propagating. It will also help to avoid disastrous fertiliser or chemical applications.

CUTTINGS

This is one of the critical steps in the propagation process. It can be nigh on impossible to turn a poor cutting into a good plant. It is not high tech but needs a sensible approach. I have long held the belief that the heart of a good propagator is their record keeping and statistical analysis.

The only way to improve you production rates is by improving your systems. This can be done through the introduction of new technology or by changing work practices. Whichever happens, trials are critical. It is imperative that we continually try out different methods and record the tests and the results. Then next time these plants are propagated refer to the results and either change the method, discard the new method as being of no benefit, or conduct further trials.

In many cases, simply recording details about the plant material each time it is propagated will enable a gradual improvement in propagation. I remember at previous conference one I.P.P.S. member reporting that they had observed a

substantial reduction in the successful acceptance of grafts when the scion material was taken after rain or heavy dew. It took accurate record keeping and several years to deduce this but it made a huge improvement in their production.

The preparation of cutting material can also be a slow process. The trick is to balance speed with accuracy. It is no use if your staff can propagate at 700 per hour but only get a 20% strike rate. Similarly it is pointless if they can get a hundred percent 100% strike rate but can only produce 10 cuttings per hour.

You should remember basic rule number 1 - profit. You can only make a profit if the propagation staff can produce enough cuttings each hour to cover their wages, the wages of all the ancillary staff, your overheads and all other incidental costs. At Larkman Nurseries this means an average rate of at least 320 cuttings per hour. [Includes: preparing the cuttings, dipping the cuttings, sticking the cuttings, watering them in, putting the trays away, and filling out the relevant paperwork.]

A propagation nursery is, in general, a production line. As such, units per hour are critical which means that every movement has to be as short and as productive as possible. Once you get your system running then it is time to start counting seconds. This can be illustrated through the following:

For an hourly average of 300 units, with 40 min cutting and 20 min sticking, a propagator must stick at 900 per hour. This equates to one every 4 sec (3600 sec in an hour). If the procedure can be cut by as little as 0.5 sec then a 12.5% reduction in the cost of this part can be achieved. Remember half a second is a very short time. A change in the way your staff stand can take 1.5 sec of each cutting. Having sharp secateurs can reduce the time by 0.5 sec, changing the size of the secateurs and the way they are held can take 2 sec off the time. There are dozens of other ways to reduce your production times, all you need to do is stand and watch your staff at work and watch other staff at work. Don't be afraid to implement new work practices, even though there will be a great deal of initial reluctance to embrace them.

Be careful that you don't strain the staff. Take a serious look at your work practices from an Occupational Health and Safty viewpoint. Repetitive Strain Injury is a common syndrome in any production line and the chance of it occurring can be greatly reduced by varying their tasks and/or the way they sit or stand. Things like bench height, seat style, and floor covering can be major contributors to worker fatigue and injury as well as slow performance.

Finally, examine all movements and remove any unnecessary ones. Teach the propagators to be ambidextrous and move everything closer. We keep the empty tubes less than 50 cm away from their bodies so that there is no stretching. The rooting hormone is in a jar that sits on the propagation tray.

In preparation of the cuttings there are several areas of concern.

First is the rooting hormone. Rooting hormones are often used simply because the books and the "experts" say they are necessary. This is not always true. In many cases plants perform as well without hormone as with it. In other cases the hormone actually burns the cutting and maybe the cause of disease. It is also true that more does not equal better. For all species and cultivars there is an optimum strength, which can be found by trial and error. Similarly there several different forms of rooting hormones. There is IBA, NAA, IBA plus NAA combinations, and several others. Add to this that they come in powders, gels, liquid in alcohol, and liquid in water and you have mass confusion, which is in turn aggravated by the fact that which form is best will also depend on the time of year and condition of the cutting. Once again trial and error followed by analysis of results is the only way to correctly ascertain which is the best hormone for your system.

Second is how you prepare the cuttings. Once again this varies greatly from plant to plant and season to season. Some of the items to watch are:

- With none, one, or multiple nodes — some plants will only root from nodes.
- To strip or not to strip — in some cases by stripping the plant you greatly reduce the chance of rotting. If you do strip then you need to test to see whether it can be done by pulling off the leaves or if they need to be cut off.
- Cut leaves — with some of the larger leaved plants it is helpful to cut the leaves in half.

These procedures need to be determined through trial and error. Granted you can point yourself in the right direction by asking others, coming to I.P.P.S. conferences, or by reading the I.P.P.S. conference proceedings, but you will still need to do tests within your own nursery.

The final issue is hygiene. Nothing substitutes for prevention in disease control. All your equipment, benches, and hands should be cleaned between batches (even gloves, we had one girl who said that she didn't need to wash her hands between batches because she wore gloves). I cannot overemphasise the need to be hygienic in all production areas and propagation houses.

It is also important for the health of your staff and the viability of your workers compensation record that your staff are informed of the potential hazards of the products they are handling. All of them are safe if used properly, but can be dangerous if not. Even potting mix has been declared as a hazardous product (if ingested) and needs to be handled properly.

The make up of the propagation media is extremely variable and the interplay between the water-holding properties of media, the watering system, and the plant type will be one of the influences on the strike rate. Your mix should be sterile, weed free, have good drainage, a pH of around 5.5 to 6.3, and a low EC. It should also be consistent both within and between each batch. If you mix your own then the ingredients need to meet specific standards, whilst if you buy it in then your supplier should be given very specific parameters. If the mix falls outside these parameters, then it should be rejected.

We have specified the pH, EC levels, bark size, and nitrate levels. We have also stated that these must be measured and communicated to us the day prior to delivery. This may sound onerous on the supplier but once they have the formula set it is not hard. It is also critical that the bark be aged and composted sufficiently. Once again if there is any sign that it is too fresh, do not accept delivery. Remember that a metre of bad mix may cause you to lose up to 30,000 cuttings, which translates into $15,000 to $20,000 of lost sales.

MANAGING THE ENVIRONMENT

The aim is to create the optimum conditions for each plant with special regard to root and air temperatures, light levels, and "irrigation".

Bottom heat is necessary for some plants whilst with others this is a waste. Approximately 70% of our propagation is done on heated beds. They are all heated by hot water that is pumped through pipes placed in the sand beds. We have found this the most efficient method. There are two heating systems. One is an in-line LPG-fuelled hot-water service, whilst the other is a water storage system that is heated with off-peak electricity. This is inexpensive to run but requires a good electricity supply.

The general aim is to have the root zone warmer than the leaves. The starting point

is around 23C. By trial and error you will find that some plants like it a bit cooler whilst others prefer it a bit warmer. Some even do better with a root zone temperature above 30C. Be careful though as it is possible to burn the young root tips and thus slow down or even prevent further root growth. Again, the key factors in determining the optimal temperature are testing and good record keeping. Optimal root and air temperature can vary for each plant species and even within a species for different seasons.

Every few years there is a new piece of "must have" technology. During the early nineties it was fogging. There are several different types of fogging but they all essentially keep the humidity at high levels so that the plants do not stress. This reduces the need for additional watering and keeps the tunnel drier. Fog creates a substantially different environment from traditional mist and can take several years to adapt to it. Not all plants like it and some love it. Either way you must have an open mind and be willing to experiment.

We initially had a lot of *Botrytis* problems which were mostly overcome by the installation of fans to improve air circulation. The air is in effect continually being exchanged with that from the outside. At first we thought this would work against the fogging but soon found that it was beneficial. In fact, during the warmer months we often open the doors as well. This also assists in keeping the temperature down during summer.

We still use conventional misting systems with a weather-watcher controller. These are for those plants that don't respond to the fogging or prefer not to have heated root zones (all our nonheated beds have misters). We also use the misters for hardening off the plants prior to them being tubed up. We have other growing beds that have no misting or fogging as some plants prefer these conditions. It is a matter of having several microenvironments available to provide the optimal conditions for whatever plants you are growing.

The physical layout and construction of a good propagation tunnel can also be quite varied. We have both brick and polycarbonate tunnels and fully plastic igloos. They have differing light transmission properties, especially as they age. It is necessary to make sure that they match the needs of your plants. Both have advantages and disadvantages with the governing factor being the initial construction cost. With the increasing durability of modern film plastics, the cost of a more solid construction is becoming harder to justify. Other aspects to consider include the size, shape, and orientation of the tunnel. Once again there is no right and wrong but more a matter of trying to design your tunnel with respect to the plants you are growing and the layout of your nursery.

All but one of our propagation tunnels have raised benches. The main fogging tunnel has raised benches that have been backfilled with scoria to help with heat retention. Our other benches all have black plastic skirts to help reduce heating costs, whilst the tunnel without benches has a good base of gravel. This keeps out disease and weeds, and also acts as a heat sink.

Finally it is advisable to make sure that your propagation tunnels allow for efficient access by your staff and for ease of stock movement. It is best if they are close to your production area so that the new cuttings do not have to be moved too far. This is important to reduce stress during the hot months, as well as helping to control labor costs. Also, if the production staff are close to the propagation tunnels they are more likely to check them regularly.

TUBING

Quality is as important here as anywhere. The rooted cuttings must be removed properly, taking care to not damage the roots. With trees and large shrubs it is important too make sure that the roots are not twisted, bent, or "J-rooted" as this will result in the adult plant falling over. Root problems are avoided by making sure the roots are not too long and that they are placed in the pots before the soil and not "dibbled". This is a quality-control issue and the consumers of your product will rely on your methodology. One customer of ours used to insist on bare rooting at least one or two plants prior to accepting delivery. If the roots weren't right he would not accept the plants (which never happened to us).

As with the propagation, a balance between accuracy and speed must be determined and maintained. The issues that govern this are almost identical to those governing the propagation and the procedures used to improve production rates are much the same.

The tube mix should be compatible with the plants and your growing environment. Once again we specify a set of criteria for the mix. The results must be phoned through to us the day before and on the day of delivery. If the pH and EC aren't within our specified range we don't accept. Also the pH has to be stable and between 5.8 and 6.3, with a stable EC of between 0.7 and 1.3 (dS/m). This is very important for many species of plant as the sudden shock of going from an EC of around 0.2 or 0.3 to an EC in excess of 1.5 will result in a severe deterioration or death of the young plant. Similarly the mix must not be fresh.

As with the propagation mix, if the consistency is wrong you could lose thousands of tubes. We also do our own tests when the material arrives and then every month so as to ensure it remains within the correct parameters. This enables quicker diagnosis of problems when they occur, as it allows you to either confirm or exclude pH and EC as the cause. It is also advisable to keep samples of each mix for 12 months.

FINISHING AREAS

The use of tunnels to grow in is dependent on where you are located and the type of plants you grow. We grow 80% in plastic tunnels. The balance is grown in our two shade houses. The tunnels keep the plants warmer during the colder winter months and protect them from frost damage, whilst also helping to reduce heat stress during summer. They have drop-down sides to allow good air movement during summer and warmer winter days. They are also white washed in late spring to prevent burning from the summer sun.

All except four of the tunnels have the plants growing on benches. Benches allow for better work practices and reduces weed and disease contamination. They are expensive to set up and can reduce the amount of useable space but this is recovered in improved productivity. In the four tunnels without benches there is a 4-inch-deep bed of gravel for the same reasons as in the propagation tunnels.

FINISHED PRODUCT

This is what we are all about—producing good quality plants ready for sale. Even if you are propagating for in-house use it is still essential that you treat the potting crew as an internal customer with the same quality requirements as a paying customer.

If consistent quality and attention to detail at all stages have been the modus operandi then all your tubes should be ready at the same time and looking the same.

However, as this is not always the case the plants should be graded prior to dispatch. It is not a matter of grading out the order and discarding the rest but more a case of grading to sizes and shapes with reference to the requirements of the specific customer. If a fair percentage are heading to the scrap heap then your procedures at an earlier stage need review.

Any crusting, algae, or weeds in the tubes should be removed, the labels checked, and the plants watered ready to go to the customer. Any dead leaves should be removed and errant branches trimmed so that the plant looks "just right". Ideally there should still be some fertiliser in the mix so that the plants will shoot away as soon as they are potted up. It is no good if your plants look great but fall over soon after the customer receives them.

Well, that ends the "walk through Larkman Nurseries". I set out thinking that this would be a short paper that was both easy to write and easy to deliver. I soon found myself running out to well in excess of ten pages, and still only half way through. It seems that the basics of running a propagation business are quite extensive.

There is one final word of advice: you only have one life so enjoy it. Your business is there to help and not hinder this objective.

Staying Alive and Using Potting Mix

Greg McPhee
National Training Officer, NIAA, PO Box 339, LISMORE NSW 2480

It's amazing what a flamboyant headline can do. I titled my presentation "Staying Alive" after reading the headline "Potting Mix Killer Fear". Both are in some way a misrepresentation of the facts, while neither is factually wrong. The newspaper headline talks about a death where potting mix is implicated. If you read the copy it is not what you may be first lead to believe. Likewise the title of my paper has led some to believe that there is an immediate life threatening risk every time we use potting media. That is certainly not the case.

It is a case of illogical thinking like "have you stopped beating your wife". No matter how you answer you will be wrong. The questioner will be able to manipulate the situation to draw a conclusion that suits his/her purpose. It is alarmist, and so useful to attract peoples attention. But it does not give a true or complete story. Cynics here will agree with the old journalist adage, "Never let the truth get in the way of a good story".

To get some clarity we need to cut to the facts. So here is the bottom line message of my paper. Potting media, composts, and other organic compounds are a potential health risk. You should examine and, if needed, change the way these products are handled in your nursery. These changes will result in nursery workers having a reduced risk of disease. So let's get back to the perception side of what is happening. Here I would like to talk about something that has nothing to do with our industry. It is a stomach bug called *Cryptosporidium parvum*. The bug causes diarrhea, and is spread in the main by body to body contact. It is a notifiable disease.

There has been a recent outbreak in NSW with more than 200 cases reported in Western Sydney. It is not normally considered life threatening, but as you can imagine there is somewhat of a discomfort. The Health Department has been checking to see if they can find the source of the infection.

However, as this is not always the case the plants should be graded prior to dispatch. It is not a matter of grading out the order and discarding the rest but more a case of grading to sizes and shapes with reference to the requirements of the specific customer. If a fair percentage are heading to the scrap heap then your procedures at an earlier stage need review.

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Four of the 200 people had recently visited a swimming pool, which is not unusual seeing it was summer when the outbreak occurred. The Health Department undertook tests and checked overseas data which showed it was possible for the bug to survive in chlorinated water. Note that there was not one Australian case where transmission was certain from a swimming pool. As a result most of the NSW swimming pools were closed whilst the water was replaced and the place disinfected. In Western Sydney this took a week.

The perception is now that swimming pools are to blame for the spread of the disease. The facts are that for at least 98% of the Sydneysiders affected this is not so. Swimming pools make most of their income in 4 months over summer. To close for a week over this period is equivalent to stopping the income in a nursery for 3 weeks, and they had to pay for the disinfestation as well.

The Wallace Lake oyster farmers of the central coast of NSW can also give us a lesson in how perception can lead to devastation. The death from food poisoning after eating an oyster of an elderly and infirm gentleman was regrettable. The oyster farmers involved followed the safety guidelines as set out by the Environmental Protection Authority. They did not skimp on safety and ran the oysters through a decontamination process. The infection was mild and in 99.9% of cases was not life threatening. Oyster sales vanished after the press got hold of the story.

As a result many of the farmers are now bankrupt and the butt of every shellfish joke. Honest and dedicated farmers who would not intentionally put out a bad product have been devastated for doing all the right things.

The lesson here is that public perception will lead authorities and the buying public to come to a conclusion that is essentially not a true reflection of the facts.

There is more risk of getting Cryptosporidiosis from exchanging money than swimming, and eating Wallace Lake oysters is more likely to increase your libido than knock you off. Likewise the risk of getting terminally ill after using potting media is far less than being struck by lightning.

The garden industry has yet to come under any concerted media attack, but we should not be complacent. We should have in place a way to manage this situation if it arises.

The best approach is to be proactive. We as an industry need to be honest about the risks that are taken when people use potting media. We need to clarify those risks and to identify the safest way to use the potting media. We need to ensure that we set a good example and lead the way in safe handling of this basic product to our industry.

We also need to manage the (mis)information that is being distributed to ensure that the public is not lead to the conclusion that to garden is an unsafe and hazardous activity. If this is allowed to occur unchallenged nursery operators might end up in a similar situation to the Wallace Lake oyster farmers.

Being honest about the risks is what lead the manufacturers of bagged potting media to develop a label. They wanted the label to be clear, simple to read and not give a false impression. It was also essential that this label was national. Most manufacturers trade interstate and having a variety of labels would be confusing.

If the industry association had not moved quickly and efficiently on this issue then we could have had vastly different requirements from the respective state departments of health, some of whom entertained the idea of banning bagged potting media entirely. Getting all states to agree on anything is no mean feat.

The result was obtained by subtle lobbying and the backup from the industry funded research.

Being honest about the risks is also why we now have a Material Safety Data Sheet (MSDS) for potting media, composts, and other organic materials. You may not be aware that there is a MSDS for perlite and vermiculite as well. The MSDS clarifies the risk and gives ways in which you the propagator can use these products safely.

So the bottom line is we need to change. Managing the change is what is important here, It has been said that when faced with adversity people generally follow a four step process.

1) The first step is disbelief. "No, potting mix cannot be harmful in anyway. I have been using it for 20 years and I'm not sick. They could never enforce it anyway"
2) Next comes anger. "Why is the Nursery Industry Association (NIAA) doing this to me, can't they just leave me also to get on with my job?" or "It's another case of Government ruining our life."
3) After anger we get acceptance. "Oh well I suppose we are all in the same boat." "It is going to happen whether I like it or not so we may as well get used to the idea."
4) Only after these first three steps do we get people accepting that they must change.

Propagators can lead the change process. We can see that in the end there are benefits from having a safe work environment. We can move our workmates, employers, employees through the change process quickly.

We need to develop new handling procedures for potting mix and other organic compounds. This for some activities will mean the use of gloves, face masks, and goggles. But it is not necessary and a gross over reaction to think we all need to walk around in space suits just to work in a nursery. The key here is risk management.

Risk management is looking at conforming to the MSDS, that is having a safe workplace as well as being comfortable. It is about the management and workers in a nursery sitting down together to find ways to manage the risk. It is also about sharing good ideas with other propagators so that their health is also protected. Good ideas can include shields and covers on potting machines, water races, extractor fans, etc.

Already there are changes being made to potting machinery. Comet, a Queensland-based manufacturer of possibly the most popular potting machine have now installed a shield system and are working on an extraction system. Using this the risk of bioaerosols and dust is reduced considerably. The improvements can be retrofitted into existing setups.

We live in a country where litigation levels are increasing and approaching the rate of the U.S.A. When lawyers tout openly for workers compensation business, and where some aggrieved individuals see an opportunity to gain easy money, we will suffer the risk of being sued. To reduce that risk it will take vigilance and attention to detail. You will need to be aware of the risks and inform your staff to ensure that they follow the safety requirements.

In reality this is not a potting-mix issue. It is an Occupational Health & Safety (OH&S) issue that is being spearheaded by potting mix. We need to face the fact that there are many substances that are in our nurseries which are a potential health risk, and we need to closely manage the ways in which these are handled.

It is imperative that you are able to demonstrate, in a court if necessary, that the staff who handle these have been trained in their use and are competent to do so. Many nurseries also have operating procedures that could be altered to improve the health and safety of the work force. Again, this is about communicating with staff and management to ensure the best outcome.

Let's not leave out the buying public from changing their practices when using potting media or other organic compounds. We can be the source of reasoned information, whilst escaping being the focal point of the anger. It makes it harder for the public to form a false impression when the industry is at the forefront of factual and reasoned information and is prepared to make changes themselves.

It is incumbent on us to keep gardeners up to date with developments, so long as the facts of your information are correct. There is an opportunity for professional garden centres to show leadership here. Stonewalling and ignoring questions will only lead to misconceptions, mistrust, and fear created by those with an agenda to alarm. To assist, NIAA and AHC are putting together a three-fold brochure aimed at the gardening public which will be available shortly.

This is not the ideal forum to go into the new ways of handling potting media. They will differ according to the workplace layout and assessed risk. There are details of diseases to consider and the MSDS to be explained.

The nursery industry association has put together a short workshop on this and advise all of the industry to attend as soon as practical. The workshop will examine current information available and look at options that could be considered for dealing with this aspect of OH&S.

There are four things that you can do TODAY to ensure that potting media in your nursery is handled safely.

1) Decide to only purchase and sell potting media, bagged or bulk, that has the NIAA approved label attached. This label should also be accompanied by an MSDS.
2) Enroll to attend the Safe handling course as quickly as possible. It should be available within a few weeks. Also send your staff along.
3) Examine the work practices at your nursery, in conjunction with staff, owners, and others. Seek to reduce the risk of disease by conforming to the MSDS.
4) Advise your customers of the issue by:
   - Offering a MSDS when selling all potting media, composts, and other organic material;
   - Providing the three-fold pamphlet when it is available.

New information will be made available through Australian Nursery Manager and sent to State Associations.

The Benefits of *Trichoderma* and Mycorrhizas in Growing Media

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INTRODUCTION

Trichoderma and mycorrhizas have been present in natural plant ecosystems for millions of years. In its natural environment *Trichoderma* resides in the decaying plant litter and humus in the soil profile. McPherson and Hunt (1995) state: It acts as a mycoparasite or saprophyte to establish a niche for itself often at the expense of the fungi which it may use as an alternative source of nutrients. *Trichoderma* has been clearly demonstrated actively parasitising basidiomycete fungi including *Rhizoctonia solani, Armillaria mellea,* and *Chondrostereum purpureum*. Researchers in the U.S.A. have confirmed that *Trichoderma* does not interfere with either beneficial *Pseudomonas* soil bacteria nor does it upset the mycorrhizal fungi's assistance of nutrient uptake by plant roots.

Mycorrhiza is from Greek derivation "mycor" meaning fungus and "rhiza" meaning root, hence fungus - root (Jasper, 1997). Mycorrhizas form a very intimate association with plant roots of up to 80% of plant families (Brundrett, 1991) where they aid uptake of nutrients and in protection from some plant pathogens, the fungus in turn take sugars and other nutrients from the plant, the relationship is termed mycotrophy. There are wide selection of mycorrhizae, most common are either endomycorrhiza which enter the root cells to form structures known as vesicles and arbuscules. These are termed vesicular-arbuscular mycorrhizae (AM or VAM). The other common mycorrhizas are ectomycorrhiza (ECM) which form a mantle of fungal material around the root and a network of hyphae (referred to as the Hartig net) between the root cells. The growth of fungal hyphae from the colonised root increases the volume of soil from which nutrients can be absorbed for the benefit of the plant.

These beneficial properties of *Trichoderma* and mycorrhiza have led to the commercialisation of *Trichoderma*- and mycorrhiza-based formulations in several countries.

USING *TRICHODERMA* IN GROWING MEDIA

The critical things to consider when using *Trichoderma* in a commercial nursery situation are:

Formulation. The type of formulation intended for use in the medium, does it contain any type of nutriment to help enable the successful and long-term colonisation of the *Trichoderma*. Does the formulation require controlled atmosphere storage, how long is the shelf life?

Dose. The claimed activity of the commercial formulation at manufacture measured in colony-forming units (cfu) of *Trichoderma* per gram. The formulations available in Australia as soil conditioners vary from 5×10^7 to 10^8 cfu. Higher cfu measures would be expected to improve the chance of colonisation.

Application. The application needs to be targeted at the plant root zone, this may be possible with: a pellet formulation placed adjacent to the root or emerging root zone, as a granular form blended into the growing medium, or as a wettable powder used as a soil drench.

Timing. The *Trichoderma* should be applied as a preventative management treatment against soil and water-borne fungal pathogens. Addition to the growing medium after sterilisation will ensure that the *Trichoderma* will grow and occupy the vacant niche. For commercial growing media, that is not sterilised, addition before use will ensure that the *Trichoderma* becomes established. Evidence of activity may be noted as distinctive fuzzy white mycelium visible in the medium just days after application.

THE OPTIMUM GROWING-MEDIUM CONDITIONS FOR *TRICHODERMA*

Soil Temperature. Growing-media temperatures in the 5 to 27C range are required with 20 to 25C considered as ideal. At low temperatures, less than 10C growth is much slower.

Soil pH. *Trichoderma* occurs naturally in acidic soils within a pH range of 3.5 to 7.0.

Soil Water. Growing-medium moisture levels suitable for plant root growth should be appropriate for *Trichoderma* colonisation and growth.

Soil Organic Matter. Growing media should contain a component of organic material containing cellulose such as composted bark, sawdust, or peat to sustain the *Trichoderma*.

Fertilisers. Fertiliser levels applied to sustain plant growth should not be detrimental to *Trichoderma*. Fertilisers applied with a high alkaline content such as limestone, dolomite, or gypsum will discourage *Trichoderma*. Soluble fertilisers applied at high rates, causing high electrical conductivity levels, may also be detrimental.

Pesticides. Agrimm Technologies Ltd. in New Zealand have carried out numerous laboratory and field experiments testing the compatibility of various fungicides. Aerial sprays such as dinocap (Karathane), copper oxychloride, phosphoric acid, bitertanol (Baycor), and wettable sulphur are considered as compatible. Soil or growing medium drenches such as fosetyl-al (Aliette), triadimefon (Bayleton), metalaxyl (Ridomil), and phosphoric acid are considered compatible.

MYCORRHIZAS AND GROWING MEDIA

In general, mycorrhizal associations are absent in soilless growing media. The use of substrates like perlite, vermiculite, composted bark, and sterilised soilless media will not contain mycorrhizas and the adoption of the use of inorganic fertilisers and fungicidal chemicals in nurseries will deter the development of mycorrhizas. Mycorrhizas have specific soil pH requirements, they do not tolerate low light intensities or excess water and extreme temperatures in the root zone (St. John, 1994). The challenge will be to introduce them into nursery growing media and sustain their development and survival. As mentioned previously the endomycorrhiza (AMs or VAM) and the ECMs are the most common.

Hunter (1998) lists the following benefits of mycorrhizas in a nursery situation: greatly enhanced uptake of less mobile soil nutrients such as phosphorus and zinc,

particularly important where extractable nutrient levels are low; increased plant tolerance to the fungal pathogens *Phytophthora*, *Fusarium*, and *Pythium*; enhanced plant water relations; production of a glue-like exudate that stabilises the soil; and produce a network of fungal threads in the soil which provides a nutritious surface for the proliferation of a host of growth-promoting soil bacteria.

USING MYCORRHIZAS IN GROWING MEDIA

There are many similarities between the successful use of *Trichoderma* and mycorrhizas in growing media. The most significant aspects are:

Formulation. The type of inoculum formulation intended for use in the medium. If it is a commercial type, does it contain spores and mycelium, how stable is it with variation in temperature in storage, what is its shelf life, is it easily applied to the target area?

Activity. The claimed activity of the inoculum formulation to be used and the species present in the formulation will determine what plant types will be infected. Formulations containing several species of mycorrhiza are likely to be more successful infecting the target plant than those with only one.

Application. The application needs to be targeted at the plant root zone, this may be achieved by applying the mycorrhizas in a granular form directly adjacent to the root or emerging root zone or by blending directly into in the growing medium or as a wettable powder used as a soil drench. What rate of inoculum is required?

Timing. Application of the inoculum directly in the developing root zone at propagation would be ideal as relatively small amounts of inoculum would be required. Once the plant is infected the beneficial relationship will be continuous unless compromised by a change in environmental conditions. Addition to the growing medium after sterilisation will help ensure that the mycorrhiza germinates and infects the plant roots before any pathogenic fungi. For commercial growing media which are not sterilised, the addition by incorporation or direct placement at the time of use is possible.

CONCLUSION

If nurseries wish to take up the challenge of utilising *Trichoderma* and mycorrhizas in growing media situations they will have to consider more sympathetic management practices. These would encompass monitoring fertiliser inputs, soil pH, and chemical pesticides, as well as critical selection of media substrates. There are laboratories around Australia that are able to assess mycorrhizal infection in plant roots to reassure growers that inoculation has been successful.

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Low Pressure Fogging

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INTRODUCTION

Propagation is a very specialised area of growing plants. During this stage it is critical to have the right balance between temperature and moisture in the propagation medium. In climates with high temperature and low humidity, the propagator needs to take care in choosing equipment which will maintain optimum environmental conditions around the propagation bench. Some of the systems which apply and control moisture will be addressed in this paper.

OPTIMUM CONDITIONS FOR PROPAGATION

The optimum conditions during plant propagation will depend on plant species and type of cuttings used. During the first few days it is important not to stress the cuttings. Most stress will occur through evaporation of moisture from the tissue of the cuttings. This will occur when air temperature is too high and/or humidity too low. In the first few days the cuttings cannot transport moisture from the medium to the upper parts of the plant. It is important to keep humidity around the cuttings at 70% to 80% and the air temperature between 23 and 28C.

The right propagation mix needs to be selected to achieve the correct balance between air and water in the medium.

MISTERS

The most common method of water application to a propagating bench is by misters. Most misters operate at a pressure between 150 and 250 kpa. The flow rate per mister is between 20 to 40 litres h^{-1}. The misters are usually placed at 1-m spacing above the propagation bench. A good mister gives a fine droplet which will land on the cuttings, the evaporation of the droplets will give a cooling effect to the cuttings. Most evaporation will take place during the time that the misters are on, i.e., there is little residual effect. This can create a problem on a hot dry day when the misters are on more often, as the system struggles to maintain set temperature and humidity levels. A proportion of the water applied as mist will land on the propagation medium, if application exceeds evaporation from the medium saturation will occur and the cuttings may rot.

FOGGING SYSTEMS

More and more propagators are looking at fogging systems for propagation. This system does not give droplets but a fine fog. Air with low moisture levels will absorb fine fog very easily and humidity is increased very quickly. Most fogging systems operate at very high pressure (sometimes more than 3000 kpa). This high pressure requires copper or steel piping throughout the propagation area. Some systems even require air compressors to further pressurise the system.

LOW-PRESSURE FOGGERS

In contrast to conventional fogging systems, a low-pressure system works with a recommended operating pressure of 400 kpa (e.g., Dan Foggers^{TM}). All components

are manufactured of high quality plastic. The foggers and fittings are designed in such a way that they are easily installed and changed. Foggers can be pushed onto the fittings and pulled off by hand, no additional tools are required. There are various nozzles with different flow rates available and these are usually colour coded for ease of recognition.

Installation is very simple as the fogger nozzles can be installed by pushing the barb fitting directly into polypipe. The recommended nozzle spacing is one per 1 to 1.5 m^2. The recommended operating pressure of 400 kpa will give an average droplet size of 100 µm. Although 100 µm may not be a real "fog" — it is a good and cost-effective alternative to the high pressure systems. It provides perfect conditions for plant propagation by humidifying the air and also assisting with cooling of the propagation house.

A leakage prevention device can also be installed. This device prevents water dripping through the fogging nozzles onto the plants when the system is not in operation. It will keep the system under pressure which allows a simultaneous startup of all foggers when switched on.

CONCLUSION

With the cost very similar to a conventional misting system and performance close to that of a high-pressure fogging the system, the low-pressure fogging system is a very good alternative to apply moisture to a propagation bench. It also provides an ideal solution for cooling and humidifying production greenhouses.

Changes in Horticultural Training Delivery

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There are seven major changes that have impacted on horticultural training. Those of you who have either personally attended courses or have had staff members as apprentices, trainees, etc. during the past 10 years will be aware that there have been what seems like a never-ending stream of changes. We all know how difficult these can be to deal with. The bad news is that the changes haven't stopped yet. The good news is, and most of us would agree, that most of these changes have been for the better.

COMPETENCY-BASED TRAINING

The first seeds of dramatic change that took place 6 or 7 years ago for us was the change from "chalk and talk" classroom delivery to Competency-Based Training (CBT). We have moved out of the classroom and into workshops, practical field areas, and sometimes sheds to teach horticultural skills. The concept is that students should learn practical skills in a "hands on" environment and be assessed on what they can do as well as what they know. This meant a large outlay for equipment, so that students could use this themselves, rather than having only one piece as a demonstration model. And teachers needed to have better teaching skills — a good move.

RECOGNITION OF PRIOR LEARNING

Next came the recognition that many people acquired skills and knowledge at work, at home, through hobbies and interests and these should be able to be credited to a formal course of study, if appropriate. This is called Recognition of Prior Learning (RPL). An alternative term that is preferred in some areas is Recognition of Current Competencies (RCC), as this term suggests the person should have up-to-date knowledge and skills. This is now widely available, although it does tend to be a bit of a paper chase for the applicant because, as could be expected, there is a requirement that they provide proof of competence in the area they are claiming.

INDUSTRY INVOLVEMENT IN COURSE DEVELOPMENT

Industry is now steering horticultural development in Australia. Industry is involved in the determination of courses, subjects, industry-specific course streams, skills required, and the levels that students enter and exit courses — linked to employment positions. The teachers are no longer dictating what is being taught. Industry working groups for several years now have decided what people in their area of industry need to know and the standard they should attain. In many instances the industry groups have invited the participation of the training sector and this has proved a rewarding partnership.

COMPETENCY STANDARDS

The result of CBT, RPL, and industry involvement has been a set of competency standards for seven horticultural industry groups, over level 1 (basic level) to

advanced diploma (just below university entrance level). These seven groups are arboriculture, floriculture, gardening, nursery, landscaping, production, and turf. The first set of competency standards has subsequently been revised and we are now awaiting the final version.

NATIONAL HORTICULTURE CURRICULUM

The fruit of this work is what is known as the National Horticulture Curriculum. This is a set of courses and the syllabi for them, over six levels of training for seven horticulture industry sectors. The idea to standardise training levels and courses was seen as an advantage to both industry and the students, providing portability and cross recognition of qualifications from coast to coast. Most states adopted some or all of these courses at the beginning of the year.

HORTICULTURE TRAINING PACKAGE

The latest development, and one that leads us to the immediate future of horticultural training, is the Horticulture Training Package. It is based on the revised version of the competency standards which have been rewritten by industry groups.

The concept of a training package is not as easy to understand as the current system of courses, modules, and qualifications — and there is a completely new terminology to come to grips with.

It does however encompass the concepts developed and put into place over the past few years such as:

- Being national, so there will be consistency of qualifications across the country,
- Assessment for competency will be carried out by a qualified workplace assessor, and the assessment may be conducted in the workplace, if appropriate.
- The workplace assessor must also have competence in the area being assessed, i.e., have the appropriate industry experience, or work in partnership with someone who has.
- For training that is conducted away from the workplace, e.g., at TAFE, the assessment, and presumably the training, will be conducted in a closely simulated workplace situation.
- The old method of teaching to a syllabus, which is a very prescriptive guide to a particular subject or module that is tied to a number of hours of delivery, is no longer appropriate. The end result of the student gaining competence is more important than how long it took to achieve.

The Training Package for Horticulture is expected to be endorsed by the training ministers of each state in June 1998. After that it will be up to the training bodies, both government and private providers, to implement it. At this stage it would appear that the timing will differ considerably between states because of the differences in their readiness to change to a completely new system, e.g., getting the new computer systems, funding models, etc. changed to meet the new requirements.

This to will give the trainers a time frame for planning the implementation stage at the coal face. Communication to industry groups, employers, students, parents, and schools of the new system as to how these changes will effect them

is vitally important. Intuition tells me that I will be spending much of my time in the near future explaining how we at South Metro TAFE will be implementing the Horticulture Training Package.

The Training Package may not, however, have all the competencies in it that you require. It is up to industry groups to ensure that anything missing is added, otherwise the skill will not be taught or more importantly recognised. The one that concerns me in the area of plant propagation is that there are no competencies for seed collection or seed extraction methods. The current competencies are based on sowing clean seed. In WA we have a small number of professional seed collectors, people working in minesite rehabilitation, farming, and urban communities who are involved in bushland regeneration projects, who all need to know how to collect and extract seed. I am sure that other states will have similar groups. If you agree that there should be competencies developed for this area please get together and lobby to have them incorporated.

CHOICE OF TRAINING

The final change is "choice" in training. For several years now you have been able to choose who will provide your horticultural training needs. There are choices between TAFE and independent providers. Now that some recognised training takes place in the workplace, high schools are jumping at the opportunity to teach horticultural skills as part of their final-year programs.

There are choices between traineeships, new format apprenticeships and old format apprenticeships, and certificates of six levels in seven industry streams in horticulture. As well there are land care /land management courses which overlap horticulture in some areas.

How do you know which course suits your needs? The only answer is to work through the maze carefully; research, question, and compare. Just as with any major purchase, you don't just buy the first thing you see. Remember that you are the customer. Where the initial dollar commitment may not seem large compare the time spent in training related to your dollar, and always be mindful of the effects on your profit margin if the training has been good, or if the training has been poor.

CONCLUSION

We are ploughing through a period of rapid change in horticultural education and training, and it isn't over yet. We now have industry involvement in the development stages of training. We have training based on the skills required. We have recognition of prior learning and the development of a national standard for horticultural training. You as industry representatives have many choices to make. Not only in which areas of training you choose for your staff and yourselves, but who will deliver the training and also what the competencies gained through that training should be. No one expects change to be easy, but I'm sure that having input into ensuring the relevancy to your industry of the skills taught is a welcome one.

Production of Trees and Shrubs in Germany

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HISTORY OF NURSERY STOCK PRODUCTION IN GERMANY

The production of trees and shrubs in Germany goes back more than 200 years. Henne (1776) describes his experience in setting up a "large" nursery for fruit tree production — it covered approximately 2500 m^2. His nursery, in the Principality of Halberstadt, was one of the first private nurseries in Germany. All earlier nurseries belonged to the monasteries or to the rulers of that time. The industrial revolution led to a new bourgeois class. A businessman in Hamburg, Caspar Voght, employed James Booth, a Scotsman, to set up a nursery, which was to become the starting point of the biggest nursery stock growing area in the world — Pinneberg in Holstein (see Lösing, this volume).

At the end of the nineteenth century there were many large private nurseries. One of the biggest, in Berlin, was Späth which covered well over 100 ha. After World War II, nurseries were forced by the British authorities to reduce the area cultivated by each nursery by up to 95% and were required to grow vegetables. It is difficult to assess the effect of this decree but certainly nurserymen were pleased when things began to normalise in 1947 and indeed, in that year more than three times the normal amount of sowing was done (Alpen et al., 1994).

The 1950s and 1960s, were the decades of the German "Wirtschaftswunder", the economic miracle. The increasing affluence of the average citizen led to a huge increase in the demand for trees and shrubs. In 1971 there were about 14,000 ha of nurseries in the former Federal Republic of Germany (West Germany). Twenty-one years later in 1992 this area had increased to almost 23,000 ha. Now Germany, including the former East Germany, has about 27,000 ha (Table 1). In 1992-93 the total value of trees and shrubs produced in Germany was DM1610m (Table 2). There is, therefore, a much larger area under production in Germany than in Europe's most important tree and shrub exporting country, the Netherlands, which has approximately 12,000 ha of production.

The average size of nurseries is tending to increase. In 1986 the average nursery was 4.7 ha but by 1996 the average was 6.6 ha (Table 1). Business is becoming concentrated into the hands of a smaller number of larger nurseries and there are not so many smaller nurseries now as in previous decades, a situation that can also be seen in the Netherlands.

MARKETING, CROPS, AND PRODUCTION REGIONS

The expanding market lasted well into the 1980s in Germany. Until then weaker nurseries survived reasonably well. Most nurseries did not have to be particularly active in selling plants. Some growers even waited for the customers to come and buy plants. The average Dutch nursery sees its market as a European market and more than 50% of production is exported to other countries — in contrast, the average German nursery, until recently, saw its market only as a German market and only a relatively small quantity of plants was exported. For example, of the estimated DM1.6 bn worth of plants produced in 1992 only about DM85 m were exported. The

situation has changed rapidly in the 1990s. Nurseries are becoming more marketing orientated and are trying to satisfy the needs of customers. Many young and dynamic nursery people are developing new markets and export will in future be of more importance for them. Figure 1 shows the main nursery stock producing areas of Germany mentioned in this article.
The following trends can be observed in the German market for individual groups of plants:

Forest Nurseries. These have been having a difficult time in recent years because many forest nurseries were taken over in East Germany by West German nurseries after the reunification of Germany in 1990. The market was already getting difficult in the West but after reunification little public money was spent in reforestation. There has been a tendency to plant at wider spacings and in many cases the private forests have turned to natural regeneration because the price of wood was so low for a number of years. With rising wood prices, the need for more plants will increase again. Most of the forest seedlings in Germany are produced in Pinneberg, near Hamburg, and grown-on to a saleable size in other nurseries, in Bavaria for example. The biggest nurseries have halved production in the last few years to try and correct the price situation.

Seedlings of Ornamental Plants and Plants for Landscaping. These are grown mostly in Pinneberg, an area which includes some of the best nurseries in Europe. These nurseries are highly mechanised because of the high cost of labour. The demand for plants from native seed sources is increasing but earlier fears of some nurseries, that they would loose business to other regions as a consequence of that demand, have not materialised. The climatic advantages of the traditional nursery areas are more important for successful production of native plants. Nursery growers in Bavaria, for example, still want to have their native seed sown in areas such as Pinneberg.

Young Plants and Liners. These are produced from cuttings and grafting, propagation techniques now concentrated in a few major nurseries. Most growers now do very little propagating and prefer to buy in the young plants. The quality of young plants from specialised nurseries is excellent and these companies are also exporting quite a lot.

Rhododendrons and Other Evergreen Plants. These have traditionally been grown in the Oldenburg area of Germany and to a much lesser extent in Pinneberg and Dresden. Oldenburg is the biggest centre in Europe for the production of rhododendrons and other ericaceous plants. At least 10 million rhododendrons are grown there each year. Sales of these plants have been stimulated by the breeding and selection of a new rootstock that tolerates a high soil pH — the Inkarho rootstock.

Roses. They are grown in Pinneberg where some of the most important breeders of roses in the world are based, such as Kordes and Tantau. Many roses are also grown in Steinfurt near Frankfurt — a traditional rose growing area. The number of roses sold in Germany over the last few decades has dropped from about 40 to 20 million. The main reason is the perception of roses as being susceptible to pests and diseases and a change in fashions — beds of roses are no longer so common.

Fruit Trees. Nurseries producing fruit trees have been under pressure for many years in Germany. Competition from Dutch and Italian growers has been increasing and much innovation has come from outside Germany, especially from The Netherlands. A high percentage of trees for commercial fruit growers is imported. Important fruit tree producers are to be found in Pinneberg, Meckenheim, and Forchheim.

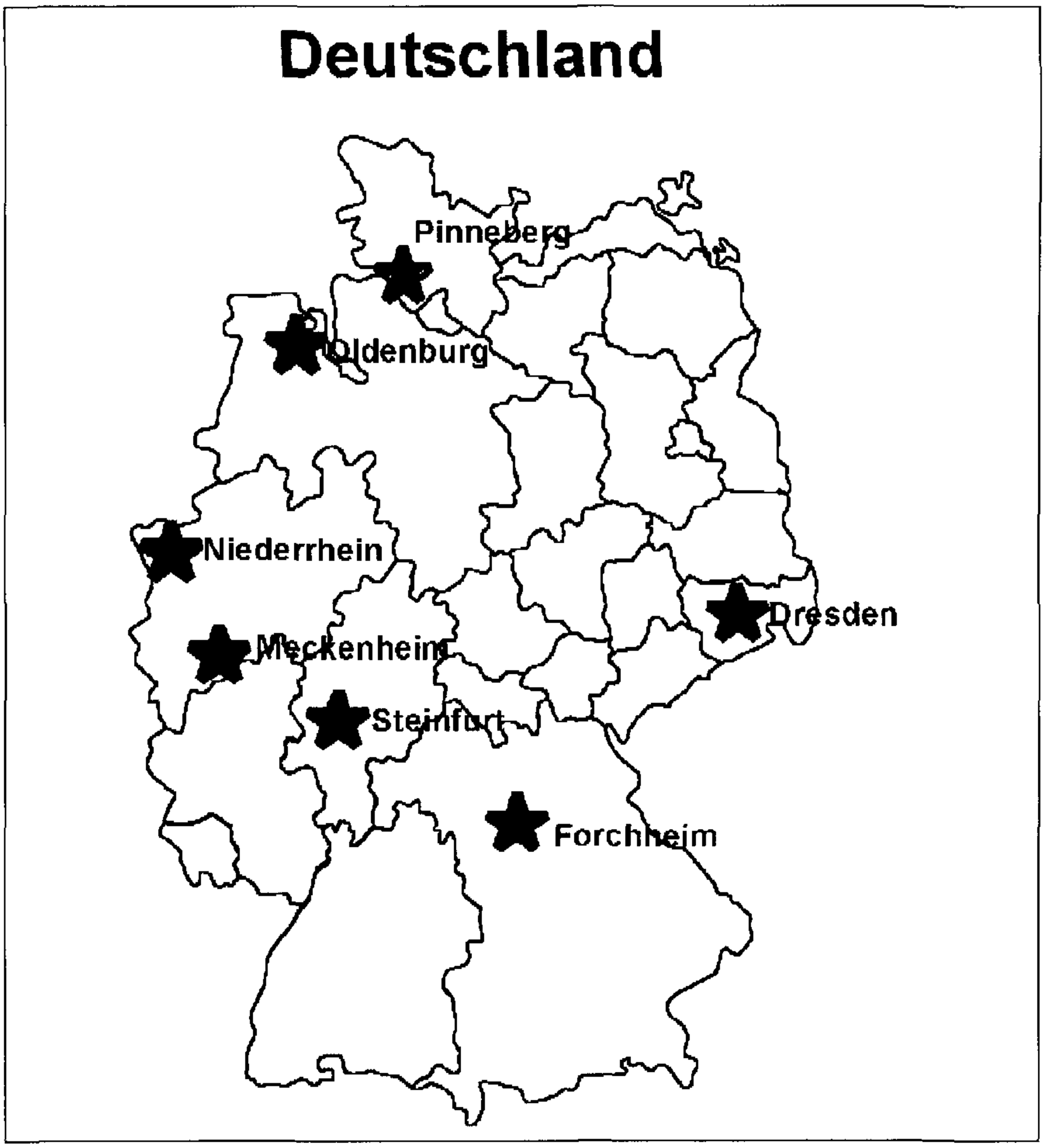

Figure 1. The main nursery stock producing areas of Germany mentioned in this article.

Trees. Ornamental trees for landscape and amenity planting are divided into two groups. In Europe, propagation and growing of general ornamental trees has been concentrating more and more in Dutch and Italian hands. However, the production of large trees is a specialty of a few German nurseries, for example Bruns (Oldenburg), v. Ehren (Hamburg), and Lappen (Niederrhein). When it comes to the largest or most prestigious European planting projects, such as Disneyland in Paris or Canary Wharf in England, one of these German nurseries is nearly always a main supplier of specimen trees and shrubs.

Table 1. Trends in nursery stock production in Germany*.

	Federal Republic of Germany (former)				East Germany	Germany (united)		
Year	1986	1988	1990	1992	1992	1992	1994	1996
Nurseries (number)	4129	4057	3927	3804	280	4084	4085	4101
Total nursery area (ha)	19430	20715	21381	22712	3014	25726	27133	27011
Breakdown:								
Fruit (ha)	1311	1336	1263	1324	341	1665	1699	1577
Ornamental plants (ha)	10817	11192	11499	12183	1033	13216	13942	13990
Forest plants (ha)	2713	2934	3205	3253	610	3863	4183	4073
Others (ha)	4589	5253	5414	5952	1030	6982	7309	7370
Average nursery (ha)	4.7	5.1	5.4	6	11	6.3	6.6	6.6

*Source: Federal statistics office.

Table 2. Total value of tree and shrub production in Germany (DM, millions)*.

Year	1988/89	1989/90	1990/91	1991/92	1992/93
Total Sales	1300	1350	1430	1440	1610

*Source: Federal Government reports

Ornamental Shrubs. These crops account for almost half of the area under nursery stock in Germany. The move to more container grown plants is quite evident. Of great importance for the further development of large nurseries is the change in the market situation in central Europe. Chain stores, DIY stores, garden centre chains, etc., need large quantities of good quality product. Nurseries with good logistics and service are doing good business. Smaller nurseries cannot generally compete in this market.

CONCLUSIONS

The traditional centres of nursery stock production in Germany are getting stronger while many smaller nurseries scattered throughout Germany are declining or developing into service centres for those customers wanting gardens designed and planted. The process of concentration not only in Germany but in the whole of the E.U. will rapidly increase in the coming years and will be hastened by the introduction of the new E.C. currency, the Euro.

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Nursery Production In Schleswig-Holstein, Northern Germany

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INTRODUCTION

The history of hardy ornamental nursery stock production in Schleswig-Holstein goes back 200 years, when a local land owner, Casper Voght, invited James Booth, a Scotsman, to come and start a nursery north of Hamburg.

The area is now the largest for nursery stock production in Europe. Five hundred and fifty-three nurseries, covering a total of 4918 ha, are producing a wide range of forest liners, potted liners, fruit trees, trees, shrubs, conifers, understocks, and perennials. Most nurseries nowadays are located around the town of Pinneberg, 20 km north of Hamburg, the heart of the growing region. The average size of a nursery is about 10 ha. Nearly all of them are family owned.

The climate of the area is mild in winter and cool during the summer season, with a high humidity and quite a lot of natural rainfall. Temperatures can go down to -25C once in every 8 to 10 years but frost damage outside can occur up to the middle of May so plants up to about hardiness Zone 6 do well in this region. The soils are sandy with a high portion of organic matter (3% to 5%) and a pH around 5 to 5.5, which makes them very good for growing seedlings.

Table 1. Nursery production in Schleswig-Holstein in numbers.

	Schleswig-Holstein	Germany
Number of nurseries	553	4085
Total area	4918 ha	27134 ha
Ornamentals	2085 ha	13990 ha
Fruit trees	122 ha	1577 ha
Forest plants	1384 ha	4073 ha

CROPPING PATTERNS

Forestry Stock. One of the most important products of the region is bareroot forest plants grown from seed of different German and international seed sources. Clonal selections of spruce and other species are available but not widely used yet. Since 1990 there has been a big change in production from conifers to broadleaf species. Before 1990 the production split was approximately 80% conifers — now it is 80% broadleaf. With this change new technology for seed treatment and storage, especially for beech and oak, was developed so that seedling production could be maintained even during poor seed-crop years.

Conifers are broadcast sown and transplanted the following year. Broadleaf species are mainly sown in rows with a distance of 25 cm between the rows, normally five rows in a bed. Summer transplanting is possible with conifers and broadleaf trees because of the humid climate. Nearly 100% of the production is shipped as bareroot material, sometimes in paper bags.

Roses. Roses continue to be propagated the traditional way by budding as a 2-year crop on a seed-grown understock. Selections of *Rosa canina*, such as 'Inermis', *R. multiflora* 'Koopmann 2', and — most commonly — *R. corymbifera* 'Laxa' are used to avoid suckering. Propagation by cuttings is becoming increasingly popular for groundcover roses. Bareroot accounts for 90% of rose production sold in the region.

Understocks. Clonal understocks, such as the Malling M types for apple, or 'Colt' and GISELA™ for cherries, are produced traditionally from stool layering but increasingly understocks are propagated by tissue culture. For other species, 1- or 2-year-old seedlings are used. Approximately 90% of total German production of rose understocks, nearly 28 million plants, are produced in the Pinneberg region annually.

Liners. Potted and bareroot liners are one of the specialities of the Pinneberg region. Hardwood cuttings are just planted in the field in spring without any further protection. Softwood cuttings are propagated during the growing season either under mist or fog systems. The standard pot size for liners is a 8- or 9-cm pot.

Trees. Shade, weeping, branched, flowering trees, and multiple-stemmed forms are grown from many species up to any size, but mainly 16 to 18, 18 to 20, 20 to 25, and 25 to 30 cm in calliper. Whips are bought in from other European countries, mainly the Netherlands.

Shrubs. Many species are grown as a 2-year crop, planted in spring, pruned sharply during the next winter season and grown on for another year. The result is a very well branched shrub with a nice root system.

Container Plants. Container production started about 30 years ago. Mainly 2-, 3-, 5-, and 7.5-litre plastic pots are being used. Plants are grown in peat, or in media which include other substances such as coir or bark, to reduce the amount of peat, together with controlled-release fertiliser. The whole range of ornamental plants, large ornamental landscape trees, and even forest plants are available for summer or spring and autumn shipping.

WHOLESALING

Because of the wide range of plants produced in the area it is easy for wholesale growers to quickly put together complete orders. A modern computerised purchasing system was established for local growers in 1997. About 167 growers around Pinneberg are linked together by a computer system which holds information on stocks of all plant material that is available during the season and it is able to automatically handle stock control on the participating nurseries.

Plants produced by the nurseries in the area are sold all over Europe but the Scandinavian market is traditionally important. There is also a big exchange market between Pinneberg and the other major German growing regions of Weser-Ems and Rheinland; and also with Europe's other major nursery stock areas of Boskoop and Zundert in The Netherlands, Pistoia in Italy, and Angers in France.

Work Organisation for Growers

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INTRODUCTION

The subject of work organisation has been around for many years as nursery growers have tried to improve their production efficiency. Various methods of study have been tried in order to obtain that competitive edge. Some of these techniques have been adopted from tried and tested systems, as used by other industries with some success.

Today, as never before, these techniques are invaluable in the quest for efficiency in order to stay competitive. Growers and propagators need to identify how to get more from the working hour. Close examination of the tasks carried out on the nursery can often reveal possible areas for improvement.

For example, just how much time does a worker spend walking to perform a task? This can be a large portion of time which is not entirely productive. Only by detailed examination and study of the task can a decision be made as to how it can be improved. All tasks need to be considered because the nature of nursery work involves the repeated handling of plants; from the taking of a cutting to the placing of the finished plant on the trolley for distribution.

The owner, manager, or supervisor needs to encourage their staff to consider the method of how the task is carried out. All staff need to develop an awareness of how they are carrying out a task to try and work as efficiently as possible to keep costs down. The continuing rise of labour costs and the increasing demands of customers has resulted in the need for even more stringent observation of how tasks are done. On the nursery there are many areas for the grower to study. Examples include:

- The collection of propagating material; cuttings, scions, buds;
- The sticking of cuttings; handling of plug trays;
- Potting up rooted cuttings;
- Potting on liners into their final pots;
- Setting/standing down potted plants;
- Caning and tying climbers;
- Trimming/pruning stock to obtain the desired shape/quality;
- Labelling;
- Spraying.

The list is considerable if the problem is to be resolved. It is important to consider all production, lifting, and preparation for despatch because all plants are handled.

WORK STUDY METHODS

The safety, well being, and comfort of workers is the concern of ergonomics, which is often referred to as "fitting the task to the worker". The subject demands a knowledge of medical disciplines so that ergonomists are able to design tasks to suit people.

Products and services may be designed to remove all the unnecessary parts, or simplified to retain only those which are necessary for functional, aesthetic, or prestige purposes. When these cost-reducing devices are built in at the design stage

the technique is known as value engineering, but the related technique of value analysis, may be used on existing services and products. Similar thinking can be applied not just to products and services but to the way tasks are done.

With all these approaches, there are two basic questions: "how should the task be done?" and "how long should it take?" The first of these must be tackled by a problem solving technique and the second by work measurement.

IMPROVING PRODUCTIVITY

The term "productivity improvement" has been used for many years. It means the productivity of goods and services with the minimum of resources, consistent with adequate quantity, quality, utilisation, and other requirements.

Productivity can be increased by raising production but using the same or fewer resources, or by maintaining the same productivity with fewer resources. These resources are materials, labour, services, and money. Productivity measurement poses problems because it is difficult to reduce all results to a common denominator. This makes comparisons between different companies difficult. It is a relative consideration: productivity may be measured before and after a change, and the two results compared to quantify the uplift in productivity. A common form of productivity measurement is operator performance in terms of time taken to do a job.

PROBLEM SOLVING

People are always solving problems and making decisions both in their private and working lives.

Type of Problem. Work study recognises four types of situation:

1) An improvement problem, in which there is a situation that needs improving in some way, such as an inefficient method.
2) A deviation problem, in which the actual situation differs from the planned approach.
3) A creative problem, in which one wishes to invent or design something, given terms of reference, or objectives to be achieved.
4) Problem avoidance, in which one tries to anticipate troubles or problems before they occur, and thinks up remedies in case they do occur.

Solution Strategy. There may be an infinite variety of problems but all can be approached using a common strategy. The general approach applies equally to method study, organisation and methods, operational research, or to any other technique.

Problem Definition. Clearly, before a problem can be tackled the true problem, as opposed to the apparent problem, must be defined.

Data Collection. All the facts about the situation must be assembled before any solution can be attempted.

Examination. The facts must be critically examined in either a logical way, or in some cases, using a completely illogical approach.

From the results of this examination can follow:

Development of a Solution. Examination will show up the deficiencies and point the way to a solution. This is now developed and tested during a "dry-run" period.

Installation. When the proposed solution is as perfect as it can be, it is introduced to the situation.

Maintenance. Continuing monitoring and up-dating is necessary as the situation develops in the future.

Methods for Problem Solving. Problem solving methods can be separated into "logical" and "illogical". A logical, step-by-step method is traditional critical examination which asks "what is done?", "when?", "by whom?", "where?", "how?", "are the targets achieved?", and, to all this, "why?" Often tasks need not be changed or simplified, but can in fact be abandoned altogether as unnecessary.

An illogical approach is to use analogies to describe a situation, thereby making a complex one more easily understood by equating it to similar circumstances with which the observer is more familiar. The Kepner-Tregoe approach is to list all things about what the situation is and what it is not. From the lists, the causes of deviation from the desired condition are highlighted.

Another nonlogical method of collecting ideas is brainstorming. This requires participants to throw in ideas as they occur to them in an uninhibited way, with no criticism. This method avoids stereotyped ideas and often generates novel and even way-out ideas. Trial and error is often used, each trial being improved upon until the optimum solution is achieved.

IMPROVEMENT OF WORKING METHODS

Problem solving may be applicable to all situations, but method study capitalises widely on the techniques. In the production of plants, organisation and method is the principal tool for increasing effectiveness and productivity. The investigator may wish to improve the layout, using a flow diagram as the basis, even using three-dimensional models, which can be moved around to find the best configuration.

Using In Vitro Propagation to Rejuvenate Difficult-to-Root Woody Plants

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INTRODUCTION

Juvenility of stockplants is one of the most important factors affecting rooting success in cutting propagation. Especially in difficult-to-root woody plant species, the ease of adventitious root formation declines with the age of the stockplant, resulting in a propagation problem. In that context, in vitro propagation has been used to overcome this problem by producing stock plants with juvenile-like characteristics (Hartmann et al., 1990).

At Humboldt University, various studies have been carried out during the last 10 years on in vitro propagation and the further growth and development of woody plants propagated by this technique. Initially the aims included methods and procedures for in vitro propagation, studies of physiological reactions of different genotypes in vitro and the development of a suitable transfer and acclimatisation system. Later, the use of the apparently changed juvenility status of in vitro-propagated plant species to improve cutting propagation has been investigated.

It is well known that most in vitro-propagated woody plants have a better potential for adventitious root formation (Hackett, 1988; Howard et al., 1988; Howard et al., 1989; Franclet, 1991). During in vitro culture the microcuttings obviously go through a rejuvenation process and this could be of great importance in the production of stock plants to provide cuttings for the propagation of difficult-to-root plant species. Cuttings of several deciduous shrubs and trees from in vitro and conventionally propagated stock plants have been compared for their rooting potential in Berlin (Plietzsch, 1996). Further work with these species has shown that in-vitro-propagated plants had some further differences from conventionally propagated plants. The apparent rejuvenation effect caused a more vigorous growth, increased branching at basal parts, and some more varied morphological characteristics during the first seasons after in vitro propagation. To obtain more detailed information about the value of such plants for garden and landscape use, a supplementary long-term evaluation with *Prunus* from different propagation origins was established in 1994.

PROCEDURE FOR ACCLIMATISATION AND TRANSFER OF MICROCUTTINGS

The following difficult-to-root plants have been successfully propagated in vitro. Currently most of them are still propagated by grafting in German nurseries: *Amelanchier* ×*grandiflora* 'Ballerina' (syn. *A. lamarckii* 'Ballerina'), *Hamamelis* ×*intermedia* 'Feuerzauber' (syn. 'Magic Fire'), *P. cerasifera* 'Nigra', *P.* 'Kanzan', *P. tenella* 'Fire Hill', *P. triloba*, *Sorbus* hybrids (*S. aria* × *S. aucuparia*) from Hungary, *S.* ×*thuringiaca* 'Fastigiata', *Syringa vulgaris* cultivars, and *Tilia cordata* cultivars.

The most difficult stages in micropropagation were acclimatisation after in vitro rooting and transfer to horticultural substrates. Thus it was necessary to develop an effective and comprehensive transfer system for weaning of microcuttings. Currently the rooted and unrooted microcuttings are weaned under fog then transferred to open ground beds sheltered by a low polythene tunnel. A period from the end of April to mid June has proved to be the best time for weaning in this way. The most suitable plant size is 4 to 6 cm. Removing the shelter in August, the plants are hardened off under shade and can be overwintered in open ground or harvested for transplanting. During that period the plants grow to very uniform quality—and reach a size of about 80 to 100 cm in *S. vulgaris* cultivars and about 60 to 80 cm in *P.* 'Kanzan' (Jacob et al., 1991). In contrast to the small potted plants leaving some commercial micropropagation laboratories, such a plant quality is most suitable for further field production in the nurseries.

TRIALS ON REJUVENATION EFFECTS IN ADVENTITIOUS ROOTING

Use of plants propagated in vitro as stockplants has often been reported to promote adventitious rooting in cuttings (Hartmann et al., 1990). Similar results were observed for various difficult-to-root species in our trials.

Hardwood Cuttings. Winter hardwood cuttings of *S. vulgaris* cultivars and *P.* 'Kanzan' from stockplants of different propagation origins and with different ages were compared. The best rooting performance was obtained from the youngest in-vitro-propagated stockplants (Table 1).

Table 1. Rooting percent of *Syringa vulgaris* (1993) and *Prunus* 'Kanzan' (1994) using hardwood cuttings from different stockplants.

Species and stock plant source (with propagation date)	Rooting percentage Without hormone	Rooting percentage With 1% IBA
Syringa vulgaris		
Conventional stockplant (1992)	0	10
In vitro stockplant (1990)	5	15
In vitro stockplant (1991)	30	35
In vitro stockplant (1992)	85	80
Prunus 'Kanzan'		
Conventional stockplant (1992)	0	0
In vitro stockplant (1990)	0	2.5
In vitro stockplant (1993)	80	90

In 1996 further *S. vulgaris* cultivars gave similar good results using hardwood cuttings from 1-year-old, in-vitro-propagated stockplants (e.g., 'Katherine Havemeyer', 76%; 'Madame Lemoine', 86%; and 'Madame Stepman', 72%).

From these results it appears that successful rooting of difficult-to-root woody plants by hardwood cuttings may be accomplished using 1-year-old, in-vitro-propagated stockplants but that the usefulness of such plants wears off very quickly. The influence of juvenility proved a much stronger effect than applications of rooting hormones.

Softwood Cuttings. Further investigations covered the rooting performance of softwood cuttings from different stockplants. For this trial, stockplants were propagated in vitro or by grafting and were pruned back annually in winter. Cuttings from in vitro stockplants often showed an increased rooting rate. In addition, significant differences could also be demonstrated in rooting quality (number of roots, root fresh weight) and in subsequent growth compared with cuttings from conventional stock plants (see Tables 2 and 3). Rooting hormones were not used in these trials.

Table 2. Rooting percentage and shoot growth rate of *Syringa vulgaris* 'Katherine Havemeyer' softwood cuttings (1994) from stockplants of different origins.

Stockplant source (with propagation date)	Rooting (%)	Shoot growth rate (%)
Conventional (1989)	83	3
In vitro (1990)	95	0
In vitro (1991)	93	8
In vitro (1992)	98	46
In vitro (1993)	100	88

Table 3. Rooting percent and rooting quality of *Amelanchier ×grandiflora* 'Ballerina' softwood cuttings (1997) from stockplants of different origins.

Stockplant source (with propagation date)	Rooting (%)	Roots (number)	Root fresh weight (g)
Conventional (1990)	27.1	2	0.3
In vitro (1996)	93.8	5	1.4

Rooting Potential and Stress. A further trial was designed to provide information about the interaction between stress tolerance and rooting potential of softwood cuttings from stockplants of different propagation origins. Unrooted softwood cuttings of *P.* 'Accolade' were stored in plastic bags at 5C before inserting them in the propagation medium (without using rooting hormone). The duration of storage was varied from 0 to 16 days. Four weeks after sticking the cuttings were evaluated for rooting success.

Rooting quality was strongly correlated with duration of storage (Table 4). Even after 16 days of storage all cuttings showed 100% rooting. But cuttings from in-vitro-propagated stockplants showed a significantly better rooting quality (measured in terms of number of roots) compared with cuttings from conventional stock plants (Plietzsch, 1997).

Table 4. Influence of storage stress, to unrooted cuttings of *Prunus* 'Accolade' (1995) from different sources, on rooting success.

Storage duration	Cuttings from in vitro stockplants (1993)		Cuttings from conventional stockplants (1989)	
(days)	Rooting (%)	Root number	Rooting (%)	Root number
0	100	10	100	8
2	100	9	100	7
4	100	8	100	5
8	100	8	96	5
16	100	6	100	4

Softwood cuttings from juvenile in vitro stockplants produced a better rooting quality (increased number of roots and increased fresh weight of roots — data not shown) and even after the stress of short-time storage they maintained their rooting advantage.

These findings suggest that cuttings from in-vitro-propagated stockplants should mainly be used for difficult-to-root woody species or for less—difficult species likely to be propagated under unfavourable conditions. Further research is dealing with overwintering problems of rooted cuttings in relation to their juvenility status.

LONG-TERM EVALUATION OF IN-VITRO-PROPAGATED WOODY PLANTS

Apart from adventitious rooting the apparent rejuvenation effect also had a clear influence on morphological growth characteristics of in-vitro-propagated plants. In order to study this, a long-term evaluation has been established since 1994 using *P. glandulosa* 'Alba Plena' and *P. nipponica* var. *kurilensis* 'Brillant' from different propagation origins with 40 plants per treatment. First results after a period of 3 years suggest that significant differences exist between plants of the same genotype depending upon propagation method (Tables 5 to 7).

Table 5. Comparison of plant volume growth (m^3) of *Prunus nipponica* var. *kurilensis* 'Brillant' propagated in 1992 by different propagation methods.

Source	1994	1995	1996	1997
In vitro propagated plants	0.18a*	0.69a	1.65a	1.96a
Cuttings from in vitro stockplants	0.04b	0.22b	0.95c	1.12b
Cuttings from conventional stockplants	0.03b	0.33b	1.28b	1.41b
Grafted plants	0.06b	0.24b	0.77c	1.08b

*Within columns, results with the same letter are not significantly different.

Table 6. Number of flowers per plant and shoot length (cm) in 1997 of *Prunus nipponica* var. *kurilensis* 'Brillant' propagated in 1992 from different sources (measured in 1997).

Source	Flowers (number)	Shoot length	Flowers per cm
In-vitro-propagated plants	12,440	3836	3.2
Cuttings from in vitro stockplants	8869	2824	3.1
Cuttings from conventional stockplants	8585	2904	3.0
Grafted plants	6683	2169	3.1

Table 7. Area of shrub base (cm^2) and sucker formation of *Prunus glandulosa* 'Alba Plena' propagated in 1992 from different sources (measured in 1997).

		Sucker formation	
Source	Base area (cm^2)	Plants with (%)	Suckers (number)
In-vitro-propagated plants	693a*	60a	3.5a
Cuttings from in vitro stockplants	446b	20b	1.5b
Cuttings from conventional stockplants	429b	17b	1.4b

*Within columns, results with the same letter are not significantly different.

In vitro-propagated plants showed particularly significant advantages in terms of morphological growth characteristics such as plant size and volume, shoot length, and sucker formation. These plants had a more vigorous growth than conventionally propagated plants, even in comparison with those grown from cuttings obtained from in vitro stockplants. No differences were found in size of flowers or flower density, growing and flowering periods, susceptibility to pests and diseases, and frost hardiness.

CONCLUSIONS

Young in vitro-propagated plants have a changed juvenility status. That effect may be used to improve the results of commercial cutting propagation in certain circumstances. Using in vitro stockplants as the cuttings source improves adventitious rooting in softwood and hardwood cuttings of many difficult-to-root woody species. Combined with pruning and hedging of stockplants, the rejuvenation effect continued in softwood cuttings for several years. For hardwood cuttings of difficult-to-root species the rejuvenation affect is apparent only in cuttings from 1-year-old in vitro stockplants.

Generally, it is assumed that the observed differences between plant propagation origins had been caused by a different juvenility status. However, there is a trend suggesting that early differences will decrease with increasing age of the plants and this will be investigated during future research.

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Rooting Regulators and Managed Cuttings Production

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INTRODUCTION

There is an increasing demand for plants of better quality and uniformity with customers demanding large consignments of uniform, visually attractive, and high-quality plants. Such requirements can only be met by growers who start out with high-quality raw materials — and the raw materials include cuttings. However, many growers encounter problems during rooting and growing-on that are a result of using poor quality cuttings. From my experience as a technical adviser I would say that more than 50% of the growing problems growers experience come from poor uniformity and poorly rooted cuttings.

It is of incalculable value for growers to have confidence in their raw materials. This reliability applies, of course, to pots, growing media, fertilisers, greenhouses, climate-control systems, heating, and so on. These items are well organised at most nurseries and, probably because they have traditionally been supplied by third parties, and in a competitive market, quality and price regulate themselves. The only raw material usually produced within the nursery itself is the cuttings so market forces have had less of an impact on quality and cost.

IMPORTANCE OF STOCK PLANTS

The starting point for high-quality cuttings has to be the parent plant or stock plant. Good quality cuttings cannot be obtained from plants growing in a strip of public landscaping along the highway or in a cemetery. Neither can they be obtained from the old plants or hedges growing around the nursery.

Top-quality stock plants need to be grown in a greenhouse especially devoted to their needs where the grower can regulate the growing conditions to provide the best possible environment for the production of cuttings.

The stock plants themselves should be grown from cuttings especially selected for the purpose, with this selection being based on rooting ability, vigour, susceptibility to disease, ornamental value, and so on. Such selection can be an ongoing process so that the stockplants are continually refined as new material becomes available. Your stockplants are, if you like, your "secret weapon" of production.

Another option is to start every year, or production season, with newly selected material that has been propagated by means of tissue culture.

Although outside our own industry, Dutch chrysanthemum (*Dendranthema*) propagation and selection nurseries are a good example of what can be achieved when appropriate attention is paid to stock plants. These nurseries are specialised in propagation from cuttings, each one producing hundreds of millions of cuttings on a year-round basis. In that industry, chrysanthemum parent plants are harvested twice a week to keep the cuttings uniform. If the cuttings are not needed, they are either stored temporarily or destroyed. For many cultivars, cooling and brief storage has a beneficial effect on rooting. The chrysanthemum parent plant ages quickly, and produces cuttings for only 17 weeks.

But is the Dutch way of growing cuttings really affordable? Well, for chrysanthemum cultivation, the price for a rooted cutting has been fairly constant for more than 25 years: between 10 and 15 Dutch cents. Yet the quality of the cuttings has continually improved.

When all the factors are accounted for, a properly produced cutting should not cost more than 10 to 15 cents unrooted. The advantage of improved rooting, faster growth, less susceptibility to disease, and less wastage makes it cost effective for every grower.

THE ROOTING PROCESS

Even a superior quality cutting produced as outlined above will have received only a limited supply of energy from the stock plant. Once separated from the parent plant, the energy required for basic respiration, plus the energy required for rooting, makes demands on the energy reserves stored in the cutting, together with whatever energy it can obtain through photosynthesis. The propagator's job is to provide the right conditions so that as much energy as possible goes into rapid root formation.

If subjected to variable or unfavourable conditions, the cutting will lose much of its valuable reserves in simply staying alive and have less energy available for rooting.

Important Factors for Rooting. The following factors need to be optimised to keep cutting stress to a minimum: temperature, oxygen, water, humidity, carbon dioxide, light, and rooting hormones.

Temperature. Soil temperature has an immediate effect on how fast the cutting roots. The higher the temperature, the faster the rooting, but a safe temperature is 20 to 25C. The temperature of the air may be 5C lower than the soil temperature during root induction. This reduces the activity taking place in the plant's aerial parts and makes all the energy available for the rooting process. It is also advantageous to lower the temperature 5C for 6 to 8 h at night. This reduces the respiration rate during the period when the plant cannot restore its energy levels through photosynthesis.

Oxygen. Oxygen is necessary for the cell division process at the base of the cutting during root formation. This means that propagators have to use a rooting medium with sufficient aeration to allow a constant supply of oxygen to support this cell division process. Sphagnum peat, particularly Finnish peat, is an example.

Water. Water is needed for the transport of minerals from the growing medium into the cutting; for the movement of assimilates of photosynthesis and plant hormones around the plant; for maintaining cell turgor; for temperature regulation; and as a raw material of photosynthesis. The availability of water is thus essential for root formation. A dry cutting substrate causes cell death and encourages black rot and excessive callus growth. The moisture must also be easily available since the cutting still lacks roots to absorb the water.

Humidity. Maintaining a high humidity prevents the cutting from losing moisture. It also allows the leaf stomata to remain open for maximum photosynthesis.

Carbon Dioxide. Carbon dioxide is the second raw material for photosynthesis and thus must be provided in measured amounts in the enclosed space being used for rooting activity. In general, a concentration of 500 to 800 ppm is sufficient.

Light. Light is essential to provide the energy for photosynthesis but light has a by-product, warmth. The propagator wants to maintain an air temperature of between 15 and 20C so it is important to screen out excess light during the day. However, as the optimal day length is 16 to 18 h, it will be necessary to use supplementary lighting.

Rooting Hormones. Using rooting hormones will quicken and improve rooting and will produce a more uniform rooted cutting.Uniform rooting is extremely important, as the propagator can then determine exactly when all cuttings are rooted. It also means the environment can be adjusted to time the crop.

Quick rooting is necessary because the cutting only has a very limited amount of energy.

Better rooting means more roots around the base of the cutting. The more stem vascular bundles that have their own root, the better the plant can develop.

NEW DEVELOPMENTS

To obtain more knowledge about the best possible conditions for the growth of plants, it's necessary to be able to take exact measurements and record them accurately. There are recording instruments and data loggers available that can measure and record every conceivable process going on, in, and around the plant. This information can be compared and interpreted in computer models. With this information, we can develop growth models to use for more efficiency in rooting and growing plants.

CONCLUSION

In the coming decades, the underdeveloped fields of cutting quality, and of rooting of cuttings, will have to be the focus of more attention. The lack of high-quality cuttings and good rooting environments are underestimated factors. New developments, however, are making it technically and economically feasible to construct environments where the best possible rooting of cuttings can take place.

Lime Tolerance in Rhododendron

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INTRODUCTION

High content of lime or bicarbonate (HCO_3^-) in the soil inhibits plant growth in many economically important members of Ericaceae family including *Rhododendron*. Difficulties in cultivation could be reduced by selection of lime-tolerant genotypes. Such plants could increase the market for rhododendrons and have the environmental benefit of reducing the amount of peat used by the horticulture industry for commercial production of these plants.

For the cultivation of large-flowered rhododendron hybrids (elepidote rhododendrons), lime-tolerant rootstocks have been selected at the Institute for Ornamental Plant Breeding in Ahrensburg, Germany (Preil and Ebbinghaus, 1994). For the small-leaved rhododendrons (lepidote rhododendrons) cultivation problems exist still on lime soil. This paper summaries experiments at The Institute for Ornamental Plant Breeding, Ahrensburg, on the development of lime-tolerant rhododendrons, including investigation of the variability of lime tolerance in the genus *Rhododendron* and the selection of genotypes for breeding lime-tolerant rhododendrons with different flower colours.

MATERIALS AND METHODS

Seed from open pollination of 200 rhododendron species and cultivars was collected from a number of botanical gardens and from the natural growing regions (a complete list of tested rhododendron species can be obtained from the author). Seeds were germinated in the greenhouse directly on a peat substrate supplemented with 1 g (control), 5 g or 10 g $CaCO_3$ $litre^{-1}$, respectively, resulting in pH ($CaCl_2$) levels of 4.2, 6.4, and 7.1, respectively (Table 1). In further experiments 10 g $CaCO_3$ $litre^{-1}$ was found to be a toxic level for most rhododendrons (Chaanin and Preil, 1996). Tests were carried out in boxes 20 cm × 15 cm × 5 cm deep. To avoid loss of bicarbonate (HCO_3^-) arising by dissociation of $CaCO_3$ in water during the experiments, these boxes were placed inside water-tight containers. Loss of $CaCO_3$ or HCO_3^- was prevented by the closed culture system used. Each treatment was replicated three times.

For estimating the amount of bicarbonate (HCO_3^-) in the substrates 50 g of the substrate was shaken with 250 ml of distilled water for 15 min. After filtration HCO_3^- was determined by titration with 0.01 M HCl using a pH electrode at pH 4.3 (modified after Boxma, 1972). Measurements of pH were carried out by suspending the substrate in 0.01 M $CaCl_2$ (1 : 2.5, v/v).

Table 1. $CaCO_3$,HCO_3^- ,and pH ($CaCl_2$) of the substrate at the start of lime tolerance screening.

Treatment	$CaCO_3$ (g $litre^{-1}$)	pH (in 0.01 M $CaCl_2$)	HCO_3^- (mg $litre^{-1}$)
Minimum lime	1	4.2	32
Medium lime	5	6.4	814
High lime	10	7.1	1554

RESULTS

As expected the control (minimum lime) plants, growing in a medium with just 1 g $CaCO_3$ $litre^{-1}$, were healthy and grew vigorously. The majority of those growing in 5 g $CaCO_3$ $litre^{-1}$ (medium lime) were stunted in growth beyond the second month with iron chlorosis symptoms in the youngest leaves of most taxa in the trial. On the high lime (10 g $CaCO_3$) substrate, all plants died after 4 months except one progeny of *R. micranthum* and few seedlings of *R. schlippenbachii* and *R. occidentale*.

All seedlings on the minimum lime substrate had roots longer than 5 cm after 4 months. The root growth of most seedlings in the medium lime substrate was stunted, reaching a maximum of 2.4 cm while the roots of most seedlings in the high lime substrate reached a maximum of just 1.7 cm. Roots of lime-stressed seedlings were untypically branched and coloured dark brown.

Rhododendron micranthum was the exception to the above results. In the high-lime substrate the roots of these seedlings grew to 4.2 cm (Table. 2). These roots were healthy, light in colour, and did not show growth deformations. Iron-chlorosis symptoms were not observed on the leaves of these seedlings during the duration of the trial. Shoot growth was not significantly stunted in this species on the medium- nor high-lime substrates.

Table 2. Comparison of root and shoot growth (length, in mm) of a selection of the taxa screened for lime tolerance, after 4 months.

	Minimum lime		Medium lime		High lime	
Taxa	Shoot	Root	Shoot	Root	Shoot	Root
canadense	56	50+	2	9	1	2
cumberlandense	33	50+	4	30	1	12
hormophorum	20	50+	4	14	2	15
micranthum	35	50+	15	42	11	42
ponticum	48	50+	3	6	1	2
pseudoyanthinum	25	50+	4	17	1	6
smirnowii	18	50+	2	24	1	5
'Cunningham's White'	25	50+	2	6	1	2
'Gibraltar'	30	50+	4	16	2	9
'Klondyke'	33	50+	5	19	2	5

In a further trial, selected plants of *R. micranthum* were grown in 12-cm plastic pots in substrates containing lime at four different concentrations: 1, 5, 10, or 20 g $CaCO_3$ $litre^{-1}$. In all concentrations the plants grew normally with no signs of damage. Even after 8 months there was no difference between the plants growing in 1 g $CaCO_3$ $litre^{-1}$ and those in 20 g $CaCO_3$ $litre^{-1}$. In the substrate with the highest lime concentration (20 g $CaCO_3$ $litre^{-1}$) the bicarbonate concentration was approximately 3000 mg HCO_3^- $litre^{-1}$ and the pH ($CaCl_2$) was 7.1.

In order to breed lime-tolerant dwarf or small-leaved rhododendrons, crosses were carried out from *R. micranthum* with 53 species or hybrids. Most of these crosses failed to set seed. From the interspecific crosses, few combinations resulted in viable seedlings. One seedling resulted from the cross *R. micranthum* × 'Blaumeise',

11 from *R. micranthum* × *R. impeditum*, and several hundred each from *R. hirsutum* × *R. micranthum* and *R. ferrugineum* × *R. micranthum*. These will be screened for lime tolerance.

DISCUSSION

Rootstocks already selected at the Institute for Ornamental Plant Breeding in Ahrensburg, in cooperation with the INKARHO, can tolerate lime concentrations in soil up to about 400 mg HCO_3^- kg^{-1} soil. However the growth of these plants was strongly inhibited at 600 HCO_3^- (Chaanin and Preil, 1996).

In the trials described in this paper, seedlings of *R. micranthum* were able to tolerate bicarbonate concentrations up to nearly 3000 HCO_3^- $litre^{-1}$ substrate. These plants, therefore, represent a valuable gene source for interspecific crosses for breeding lime-tolerant small-leaved rhododendrons.

There are some disadvantages of this species as a breeding parent. It has small white flowers. It does not hybridize well with other rhododendrons and there are no known hybrids.

Current knowledge about the heredity of lime tolerance in rhododendrons is limited and looking for lime-tolerant seedlings still requires the testing of large populations. Our experience of crossing *R. micranthum* with other rhododendrons has resulted in only limited success. Only in the combinations *R. hirsutum* × *R. micranthum* and *R. ferrugineum* × *R. micranthum* could worthwhile quantities of seedlings be produced. Further screening of these progeny will yield more information about the genetics of lime tolerance in rhododendrons.

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The Use of Jet 5 in Propagation

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INTRODUCTION

The importance of good hygiene in reducing disease spread around the nursery, and particularly for propagation, is well established.

Jet 5 was introduced in 1993 and has become one of the leading disinfectants for use in the U.K. on and in glasshouse structures, benches, pots, trays, irrigation lines, capillary matting, sand beds, and equipment. A number of qualities make Jet 5 particularly suitable for use in nursery stock production. It is an equilibrated, stabilised formulation of peracetic acid. It is a highly effective disinfectant with broad spectrum activity against viruses, bacteria, fungi, yeast, algae, and their spores. It also has some reported activity against nematodes.

The activity against plant pathogens has been well established by various research workers including Loschenkohl et al. (1990), Kleinhempel et al. (1987), *Secor* (1988), *Meier* (1990), *Linfield* (1991), and *Horticulture Research International Bulb Seminar* (1996).

Under normal conditions a contact time of 10 min will give complete disease control. This period should be extended when heavy soiling is present on the surface being cleaned.

Jet 5 decomposes rapidly after use to form the harmless by-products oxygen and water, with traces of acetic acid. Jet 5 does not adsorb onto surfaces. These properties make it an ideal disinfectant for use in propagation, where even traces of chemicals can disrupt the rooting process. At recommended rates it has been used for seed surface disinfection in cress and mung beans, which have shown improved rates of germination.

Many plant pathogens are spread by water-borne spores and the propagation area provides an ideal environment for disease development. The principal fungal diseases spread via water are *Pythium*, *Phytophthora*, *Thielaviopsis*, and *Fusarium*.

Recent research has focussed on disinfection of water, the activity of Jet 5 against these water-borne pathogens, and plant safety, particularly through overhead irrigation lines. This paper reports the results of recent trials and grower experiences with Jet 5 and highlights areas for further development.

MATERIALS AND METHODS

In all trials Jet 5 (5% peracetic acid, 27% hydrogen peroxide, mixed with surfactants and stabilisers), was tested under laboratory and field conditions.

Efficacy Tests in Vitro. In trials, conducted at HRI Efford by Tim Petit, Jet 5 was tested, at concentrations of 0.2 ppm and above peracetic acid (PAA), on irrigation water collected from drainage ditches or ponds from five nurseries. Dilutions of PAA were established using Merckoquant 1001 test steps. The efficacy of known concentrations of PAA against the mobility and germination of zoospores was tested against a zoospore suspension prepared by the method of Petit and Regg (1991).

These suspensions were mixed 1 : 1 (v/v) in Petri dishes and incubated overnight at 20C. Assessment by microscope was made once after mixing and again the following morning. The efficacy of PAA as Jet 5 was also tested against the germination and viability of spores of *Fusarium oxysporum* and *Thielaviopsis basicola*. Spore solutions of 103 spores were mixed with various concentrations of Jet 5 solution. These were incubated overnight at 24C. These were then sampled and grown on PDA plates until countable colonies appeared in the zero PAA control.

Efficacy Tests in Vivo. At HRI Efford, four concentrations of Jet 5 were tested on four different plant species to test for crop safety. Application was by overhead irrigation at rates of 0, 250, 500, and 1000 ppm PAA in a recirculatory system. The plant species were chosen because of their known sensitivity to chlorine-treated water: *Berberis* ×*ottawensis* f. *purpurea*, *Calluna vulgaris* 'Sunrise', *Chamaecyparis lawsoniana* 'Ellwood's Gold', and *Pyracantha coccinea* 'Red Column'. The plants were grown in 2-litre containers in a standard growing medium and assessed on four occasions for phytotoxic effects on leaves and effects on overall height.

In Holland, ProAgro has tested Jet 5, at concentrations of 1% and above, on 67 plant species and culitvars to evaluate both plant safety and the effectiveness of controlling moss, algae, and liverwort. All these trials were conducted on commercial holdings, on plants in their final container.

RESULTS

Efficacy in Vitro. At HRI Efford, Jet 5 applied to recirculated water containing a natural infection of *Phytophthora* zoospores caused immediate encystment. Complete mortality of zoospores and cysts occurred at concentrations of 20 ppm PAA and above.

Table 1. Effects of Jet 5 on germinating *Phytophthora cryptogea* in irrigation water.

Source of water	Assessment type	Concentration of peracetic acid (ppm)				
		0	0.2	2.0	20	50
1	D	52	68	46	2	0
	C	48	32	54	96*	100*
2	D	52	60	6	0	0
	C	42	12	50	100*	100*
3	D	32	-	28	0	0
	C	68	-	72	100*	100*
4	D	0	0	0	0	0
	C	100	100	100	100*	100*
5	D	45	15	5	0	0
	C	55	85	95	100*	100*

D = direct germination (% germination of zoospores), C = cyst formation (% of zoospores encysting)
* Nonviable cysts.

Table 2. Effects of peracetic acid on the viability of colony forming units (cfu) on *Fusarium oxysporum* and *Thielaviopsis basicola* in irrigation water.

Fusarium oxysporum				
PAA conc. (mg litre^{-1})	0	2.5	25	50
% cfu plate^{-1} (% of max. value)	100	82	23	0
Thielaviopsis basicola				
PAA conc. (mg litre^{-1})	0	2.5	25	50
% cfu plate^{-1} (% of max. value)	84	94	26	0

[a]The actual mean maximum number of cfu plate^{-1} for *F. oxysporum* was 69.3.
[b]The actual mean maximum number of cfu plate^{-1} for *T. basicola* was 97.5.

Efficacy in Vivo and Jet 5 Effect on Nursery Stock Foliage. Treatments of up to 250 ppm PAA as Jet 5 produced no adverse effects on the four species tested. *Berberis* showed a statistically significant reduction in height but this would have had no commercial significance. A reduction in the levels of moss and liverwort was also noted in trials where Jet 5 had been applied at concentrations of 125 ppm PAA and above.

Table 3. Assessments of percentage foliar damage (scorch) in four nursery stock species after application of Jet-5-treated water via overhead irrigation.

	PAA concentration (mg litre^{-1})			
	0		25	
	Assessment date		Assessment date	
Taxa	29 July	27 Sept.	29 July	27 Sept.
Chamaecyparis	0.53[a]	0	0.47	0.13
Berberis	0	0	0	0
Pyracantha	0	0	0	0
Calluna	-	0	-	0

[a]Mean scores of fifteen plants for percent foliar scorch severity.

Table 4. Assessments of percentage foliar damage (scorch) in four nursery stock species after application of Jet-5-treated water via overhead irrigation.

	PAA concentration (mg litre^{-1})			
	0		125	
	Assessment date		Assessment date	
Taxa	31-Sept.-96	16-April-97	31-Sept.-96	16-April-97
Chamaecyparis	0	1.0	0	0.9
Berberis	0	0	0	0
Pyracantha	0	3.2	0	2.3
Calluna	0	78.5	0	69.2

Table 5. Assessments of plant height (cm) in four nursery stock species after application of Jet-5-treated water via overhead irrigation.

Taxa	PAA concentration (mg litre^{-1}) 0	25	Statistical significance[b]
Chamaecyparis	6.8[a]	5.7	NS
Berberis	26.7	13.4	Sig. P = 0.05
Pyracantha	22.9	19.9	NS
Calluna	-	-	-

[a]Values presented are the means of fifteen replicate plants and are the differences between individual plant heights recorded at two sample times (7/29/96 and 9/27/96).
[b]Treatments were compared by simple analysis of variance.

In Holland, ProAgro carried out field trials using Jet 5 at concentrations of 1.0% to 2.5% (500 to 1250 ppm) PAA for the control of algae, moss, and liverwort, as a single application. At 1% concentration no crop damage was seen on plants in their final containers. At 2.5% concentration slight damage was seen on *Gaultheria mucronata* (syn. *Pernettya mucronata*), *Cytisus nigricans* 'Cyni', *Gultheria* spp., *Hydrangea macrophylla* 'Maculata' (syn. *H. variegata*), and *Lavandula* ×*intermedia* 'Grappehall'.

Results Derived From Other Sources. In the U.K., various nursery stock growers have been experimenting with Jet 5 to reduce disease spread via irrigation water. Hillier Nurseries has treated three forms of laurels, *Prunus laurocerasus* 'Rotundifolia', 'Otto Luyken', and 'Zabeliana', to reduce the spread of the fungal syndrome known as "shothole" (*Stigmina carpophila*, *Trochila carpophila*, etc). Since adopting this strategy Hillier reports high levels of completely clean crops. Isis Nursery reports similarly good results when using Jet 5 in propagation. When treating *Caryopteris*, *Garrya elliptica*, and other plants during rooting, this nursery found reductions in botrytis and improved rooting. Leaf spots, believed to be of bacterial origin, were also reduced (Dr. P. Orton at Askham Bryan College, York). He has discovered that Jet 5 as a 1% dip for 5 min was extremely effective in the preparation of roses for micropropagation and was found to be totally safe on semiripe and softwood *Rosa* plant material. Jet 5 also "rescued" a *Hosta* culture contaminated with bacteria. A significant number of in vitro growing plantlets tolerated the treatment. Where damage occurred it was transitory and plantlets eventually recovered. In unreported trials by Geoff White of HRI Wellsbourne, various disinfectants were compared for their ability to reduce the spread of pythium. The tests were designed to assess the chemicals under severe conditions. The most effective treatment was Jet 5.

DISCUSSION AND CONCLUSION

Phytophthora spores (zoospores and cysts) and *Fusarium* spores were effectively killed in vitro by use of Jet 5 at 50 ppm PAA and above. The source of the water in the trial had little effect on disease control results. A PAA concentration of 100 ppm was required for total kill of *Thielaviopsis*.

Applications of Jet 5 to four species known to be sensitive to chlorine damage showed no foliar phytotoxicity at concentrations of up to 125 ppm PAA. (This crop safety work has been confirmed in trials on vines, potatoes, and lettuce).

In laboratory tests on irrigation water, PAA as Jet 5 controlled *Phytophthora, Fusarium, Thielaviopsis*, and *Pythium*. Overhead applications to a wide range of nursery stock species have shown good reductions in disease spread with no phytotoxicity at up to 125 ppm PAA. A reduction in the spread of bacterial diseases has been achieved by commercial applications of Jet 5 as a water disinfectant. Bacterial control has been achieved on plants in propagation.

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Micropropagation of Decorative Plants in Bulgaria

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INTRODUCTION

The use of micropropagation for clonal multiplication of ornamental species in Bulgaria began about 25 years ago. The earliest research explored the seasonal regenerative ability of isolated meristem tissues from *Dianthus* (Izvorska and Kacharmazov, 1977) and the obtaining of haploid plants from *Anemone hepatica* (Georgiev and Chavdarov, 1974). The in vitro propagation of ornamental tree species started later, with the first successful cloning of *Betula pendula* through callus cultures, introduced from apical and leaf segments (Iliev and Chavdarov, 1988).

By the 1990s laboratories were being built and equipped for in vitro propagation of ornamental, forest, and agricultural species and by the middle of the decade there were six large-scale laboratories in different research institutes and two on farms. Each of them has a considerable industrial capacity; they were designed to satisfy not only Bulgarian needs, but those of countries of the former Soviet Union and other eastern European countries. With its total of 19 laboratories, Bulgaria has the 12th largest micropropagation capacity in Europe (Riordain, 1997). The main purpose of the work in these laboratories is the investigation of propagation technologies of economically valuable plants.

In particular, methods have been developed and applied to cloning and multiplication of *Dianthus* (Yantcheva et al., 1997a), *Dahlia* (Nencheva and Protich, 1996), *Rosa* (Kornova and Angeliev, 1996; Uzunova, 1996), *Lilium* (Chavdarov and Denkova, 1994), *Hippeastrum* (Denkova et al., 1995), *Rhododendron* (Haralampieva and Gyuleva, 1996), *Betula* (Iliev and Chavdarov, 1988a), *Quercus* (Tsvetkov and Atanassov, 1992), *Populus* (Gyuleva and Atanassov, 1992), *Sequoiadendron* (Iliev and Iliev, 1996), *Sequoia* (Iliev and Trifonov, 1996b), *Metasequoia* (Iliev and Tsvetkov, 1995), *Albizia* (Iliev et al., 1993), *Robinia* (Iliev and Ganchev, 1991), *Paulownia* (Gyuleva and Garelkova, 1993), *Platanus* (Gyuleva and Atanassov, 1994), and others.

Bulgarian researchers, like those elsewhere, have two goals for their work on micropropagation techniques: multiplication of existing taxa and creation of genetic variability.

MULTIPLICATION OF EXISTING TAXA

Micropropagation to increase existing taxa is carried out by: (1) direct organogenesis; (2) adventitious bud-formation; and (3) somatic embryogenesis.

The most often used explants for inducing direct organogenesis are segments with axillary and/or apical buds. When obtained from tree and shrubs species they are taken from dormant specimens but juvenile (Iliev and Ganchev, 1991; Tsvetkov and Atanassov, 1992; Iliev et al., 1993; Iliev and Tsvetkov, 1995) or mature (Gyuleva and Atanassov, 1994) donors can be used. Micropropagation has also been used to effectively rejuvenate propagation material to improve speed and quality of production, for example *B. pendula*, *Sequoia sempervirens*, *Sequoiadendron giganteum* (Iliev, 1996; Iliev and Trifonov, 1996; Iliev and Iliev, 1996). The technique shows promise for the production of stockplants that will result in high yields of difficult-to-propagate plants produced by conventional vegetative propagation techniques.

Apical, nodal (Iliev, 1991, 1996a; Haralampieva and Gyuleva, 1994; Chavdarov and Denkova, 1994; Uzunova, 1996) or leaf segments (*B. pendula* cultivars Tristis, Youngii, Laciniata (syn. 'Dalecarlica); *P. tremuloides*) (Iliev, 1988, 1996, Iliev et.al., 1998; Gyuleva and Atanassov, 1992) have all been used successfully as initial explants for inducing adventitious bud formation. It was established that younger leaves have higher morphogenetic potential, which also depends on their position on the shoot. Induction of adventitious bud formation and the rate and extent of multiplication are determined to a great extent by the genotype, which imposes the use of different nutrient media and phytohormones.

Somatic embryogenesis has by far the highest multiplication coefficient of any of the micropropagation methods used in Bulgaria. Experiments are under way to study the effect of combinations of various hormones on induction of the process in immature embryos of common oak (*Quercus robur* L.) (Tsvetkov, 1998).

An essential stage in the production cycle of the in-vitro-cloned plants is their acclimatization to greenhouse and field conditions. Trials here have shown that basic factors that aid successful acclimatization are the preliminary washing of the plantlets' roots; high soil moisture content and atmospheric humidity, and the temperature of the greenhouses. Based on these results, techniques for industrial acclimatization have been elaborated for a number of species of *Gerbera, Dendranthema*(syn.*Chrysanthemum), Phillodendron, Rosa, Gypsophila, Cordyline*, and others. Trial plantations have been established from in-vitro-cloned plants from *B. pendula* at an altitude of 900 m above the sea level.

Micropropagation is currently being exploited in Bulgaria for the large-scale production of flowers. The need to obtain large quantities of virus-free planting material has seen the routine use of meristem culture coupled with contemporary methods for virus indexing, such as ELISA (Jankulova et al., 1983; Eskenazy, et al., 1983; Denkova et al., 1993; Denkova and Chavdarov, 1994) and ISEM (Kajtazova, 1983).

CREATION OF GENETIC VARIABILITY

Genetic engineering is one of the possible methods for obtaining new forms of plants with desirable ornamental features. At the present stage this technique is generally only being developed for agricultural species, for example by the Institute of Genetic Engineering, Kostinbrod.

Transgenic techniques, using transformation with *Agrobacterium tumefaciens*, have been used to produce new ornamental cultivars (Lena, Scania, Yanita, Regina, Nasslada, and Line 84) from *Dianthus caryophyllus* (Yantcheva et al., 1997b).

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Management of Seed Dormancy in *Fagus sylvatica, Fraxinus excelsior,* and *Prunus avium*

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INTRODUCTION

This paper reviews results from one element of a 3-year European Union (EU) funded project, *A multidisciplinary approach to the understanding and efficient handling of seed dormancy in tree species* (October 1993 to October 1996). It included work in Denmark (coordinator, four research groups), Great Britain (two research groups), The Netherlands, France (five research groups), Spain, and Germany. It was divided into two groups. One group worked with applied technology and biology with regard to harvest, dormancy breaking treatments, and storage of pretreated seeds. The other studied the physiological and biochemical processes involved in seed dormancy. This review covers the main results of the applied group on the species *Fagus sylvatica, Fraxinus excelsior*, and *Prunus avium.*

Some 60% of the tree species from the temperate region, particularly hardwood species, have seeds which can be regarded as deeply dormant. This prevents germination until the dormancy has been released. It is known that the seed is dormant at maturity, but the timing of the onset of dormancy and the factors influencing it are still under research. There are different kinds and combinations of dormancy. Embryo dormancy is the most common kind in tree seeds from the temperate regions (Bewley and Black, 1994).

Embryo dormancy can be released by stratification treatment at low temperature and at high moisture content, a well known procedure used successfully for many years. The term "stratification" today also includes all treatments, not just cold, to release seed dormancy. There are however problems with management of stratification methods used on nurseries. For example, depending on environmental conditions the optimum cold stratification period varies from year to year. Stratification requirement can also vary within a seed lot. Another problem is that seeds can germinate at the stratification treatment temperature and in some cases up to 20% of the seeds in a batch may germinate during stratification. Existing stratification methods for tree seeds are time consuming, inflexible, and unreliable. At least 30% of the potentially productive seeds in a batch fail to germinate due to ineffective stratification methods.

The objectives of the applied element of the EU funded work were, therefore:

- To obtain a better understanding of the seed dormancy process including all phases from dormancy induction to release, combining basic and applied seed research for an overall view.
- To improve seed handling procedures for dormant tree seeds with particular emphasis on the development of more efficient and versatile stratification methods.
- To improve viability tests of dormant seeds and investigate whether it will be possible to determine the level and state of dormancy.

The project was divided into seven connected tasks:

1) Optimal seed collection and handling with regard to dormancy level, pretreatment, and storage (studied on *Fagus sylvatica*, *Fraxinus excelsior*, *Prunus avium*, *Sorbus mougeotii*, *Malus sargentii*, and *M. sieboldii*).
2) The effects of pretreatment conditions on the efficiency of dormancy breaking and laboratory assessment of dormant tree seeds (studied on *F. sylvatica*, *F. excelsior*, *P. avium*, *Pseudotsuga menziesii*, *Acer platanoides*, and *A. pseudoplatanus*).
3) Dormancy breaking by exogenous application of hormones (studied on *F. sylvatica* and *P. menziesii*).
4) Redrying and storage of pretreated seeds (studied on *F. sylvatica, F. excelsior, P. avium,* and *P. menziesii*).
5) Endogenous hormones involved in seed dormancy (studied on *F. sylvatica* and *P. menziesii*).
6) Molecular changes during dormancy induction and dormancy breaking (studied on *F. sylvatica* and *P. menziesii*).
7) Production of a tree seed dormancy database.

COMMON BEECH (*Fagus sylvatica* L.).

Beechnuts have a very deep and heterogenous dormancy. The dormancy varies from year to year, from seedlot to seedlot, and among seeds within the same seed lot. The seeds are dormant at collection and thus fail to germinate in conditions under which nondormant seeds germinate rapidly.

Optimal Seed Collection and Handling.

Collection. Seeds were harvested from two provenances on three occasions (Weeks 35, 38, and 44) during 1993. The seeds started to shed about week 38. The first two collections were made from the trees, the last from the ground (Thomsen, 1997). Both seed sources were fully germinable at the first harvest. One provenance had more mature seeds than the other, indicated by a lower moisture content (44% and 40% respectively, fresh weight basis). Seeds harvested early in development could germinate, but only at low temperatures. The more mature the seeds were, the faster they germinated. The mean germination time (MGT) was about 22 weeks for the first harvest, about 18 weeks for the second, and about 13 to 14 weeks for the last harvest. These results indicate that the seeds are "born" dormant and it is not possible to overcome dormancy by collecting the seeds before maturity. However, if the seeds are left too long on the ground they may deteriorate. The optimal time of collection is therefore as soon after natural shedding as possible. In this investigation, the optimal collection time was Week 38 for the provenance with the lowest moisture content (more mature seeds) at the first harvest. For the second provenance the optimal collection time was Week 44 (Thomsen, 1997).

Handling. Beechnuts from all three collections were dried at three different rates: (1) at 15C and 15% relative humidity (RH) to about 8% moisture content (fresh weight basis); (B) at 20C and 15% RH 4 h day to 8% moisture content; (C) at 20C and 15% RH 8 h day to 20%, 16%, 12%, and 8% moisture content.

Germination tests were performed before and after drying and after 10 and 16 months subsequent storage at 5C (Thomsen, 1997). Drying to 8% moisture content reduced the mean germination time (MGT) by about 3 weeks. In beechnuts, drying can, therefore, substitute for part of the cold stratification. Drying rates had no effect on the speed of germination. However, there seems to be a relationship between moisture content and MGT: drier seeds germinated more rapidly than moister seeds (Thomsen, 1997). There was no significant difference in survival following drying to 8% moisture content under the different drying rates except in the first harvest of one provenance. Here the faster rates resulted in more damage (Thomsen, 1997). Beechnuts dried to 8% moisture content stored well at 5C, with only slight decreases in germination capacity. The best short- and long-time survival was obtained by drying the seeds at 15C and 15% RH. When comparing the two drying treatments at 20C it was found that the faster rate was more damaging than the slower (Thomsen, 1997).

Pretreatment Conditions. In beechnuts cold stratification breaks both embryo dormancy and seed-coat-imposed dormancy and allows the seeds to germinate at a wider range of temperatures and increases the germination rate (Derkx and Joustra, 1997).

Beechnuts from three provenances (The Netherlands, Poland, and Denmark), with a moisture content of 30%, were stratified at 3C for varying periods from 4 to 60 weeks. Germination at a range of temperatures was tested after the pretreatment. No germination occurred during stratification. Freshly harvested seeds hardly germinated at 10C or above. Stratification for between 16 to 20 weeks increased the range of temperatures over which germination occurred, so that the seeds could germinate between temperatures of 0 to 20C. Stratification for up to 24 weeks decreased the mean germination time, but stratification for longer periods increased MGT (Derkx and Joustra, 1997). The optimum cold stratification period for fresh beechnuts from the three provenances tested was 16 to 20 weeks (Derkx and Joustra, 1997) with 20 weeks generally giving optimal dormancy breakage, although shorter durations may give good emergence in the field (Derkx, 1996). Increasing the temperature range of germination has the important implication that temperature conditions at the time of sowing in spring become much less critical (Derkx and Joustra, 1997). For practical purposes the optimal duration of stratification for dormancy breakage coincides with that for increasing the germination temperature range (Derkx and Joustra, 1997). Premature germination during a dormancy releasing treatment can be prevented by controlling the moisture content. The moisture content of beechnuts should be a maximum of 32% (based on fresh weight).

Redrying and Storage of Pretreated Seeds. After 8, 12, and 16 weeks pretreatment, portions of the seeds from all three provenances from the trial described above were transferred to storage conditions. They were either stored without drying or dried to moisture contents of 9% or 16%. The moisture content of 9% was obtained by drying for 7 days at 17C and 45% RH. The moisture content of 16% was obtained by drying for 7 days at 17C and 75% RH. The seeds were stored at -2 or +3C in perforated bags. Germination was tested in the dark at a range of temperatures of 3, 10, 15, 17, 20, 25, and 30C (Derkx and Joustra, 1997).

Seeds stratified for 8 weeks and stored undried at -2C for a further 8 weeks showed a remarkable increase in germination. A positive effect on germination

was also observed when undried, 8-week-stratified seeds were stored at 3C (Derkx and Joustra, 1997).

Dutch seeds stratified for 12 weeks and stored with moisture contents of 9% or 16% at -2C for 8 weeks showed a large reduction in germination capacity at germination temperatures above 20C. Storage at 3C of seeds from the same pretreatment length and drying regime reduced germination even more and under these conditions the drier seeds suffered more. Seeds from the Polish and Danish sources were even more affected by these treatments (Derkx and Joustra, 1997).

The effects of dehydration and dry storage depended on the duration of the dormancy-breaking pretreatment. Increasing the duration of pretreatment from 8 weeks to 12 or 16 weeks reduced desiccation tolerance and storability of the seeds. It may be hypothesised that dormancy breakage is complete after a certain period of pretreatment, and following this, early germinative events preparing the seeds for radicle protrusion may start, since the moisture content of the seeds (30%) during stratification allows metabolic activity. A proposal is that seeds that are dehydrated during the phase of dormancy breakage withstand dehydration and dry storage, whereas dehydration during the phase of early germination events causes irreparable damage (Derkx and Joustra, 1997).

It follows that if the seeds are to be redried and stored, the pretreatment duration should be shortened. After pretreatment of 7 to 10 weeks the seeds can be dried to a moisture content of 8% to 10% and be stored at -2C for at least 6 months without loss of germinability. The dormancy breaking and germination temperature effects of the pretreatment are maintained during storage (Derkx, 1996).

Application of Hormones. Pretreatment duration can be reduced by application of gibberellins on naked *F. sylvatica* seeds. Application of gibberellin on whole seeds had limited effect (Corbineau et al., 1995).

Seeds treated with ethylene showed a distinct increase in the endogenous gibberellins GA_3 and GA_{19}. Possibly the promoting effect of ethylene on dormancy breaking is through increasing gibberellin concentrations. The ethylene-releasing compound ethephon is normally used to apply ethylene conveniently. Treatment with ethephon on whole seeds showed a distinct increase in germination. By combining cold treatment and ethephon treatment, the duration of pretreatment could be reduced by 50% (Corbineau et al., 1995; Falleri et al., 1997).

Conclusions.

- The optimal collection time of *F. sylvatica* seeds is as soon after seed shed as possible.
- Cold stratification at about 5C for 16 to 24 weeks gives optimal dormancy breakage for northern Europe provenances.
- Cold stratification of 16 to 24 weeks widens the germination temperature range so that seeds germinate between 0 and 20C.
- Premature germination during stratification can be prevented by controlling the moisture content and adjusting it to maximum 32%.
- For storage of stratified seeds the stratification period should be shortened to 7 to 10 weeks.
- For storage the seeds can be dried to a moisture content of 8% to 10% and be stored at -2C for at least 6 months without loss of germinability.

COMMON ASH (*Fraxinus excelsior* L.)

Ash fruits have an underdeveloped embryo when the fruits fall from the tree in autumn. For full development of the embryo a warm treatment is needed. For dormancy release a cold treatment is needed. The warm treatment usually precedes the cold.

Optimal Seed Collection and Handling.

Optimal Seed Collection. Ash fruits from six different trees in the U.K. were collected on five occasions. The fruits were pretreated in a peat and sand (1 : 1, v:v) medium for 16 weeks at 15C followed by 16 weeks at 4C. Embryo development and optimum germination temperatures were examined. The seeds were germinated at a range of constant temperatures from 3.5 to 25C and at the alternating temperatures of 5/15 and 5/25C (12h/12h) (Jones and Gosling, 1996).

The collection date did not influence the rate of embryo growth during stratification. Significant differences between the trees were found concerning the embryo lengths. The optimum germination temperature was between 3.5 and 10C. At higher temperatures germination decreased, probably because of the induction of secondary dormancy. For batches in which dormancy had not been completely broken, germination was better under alternating temperatures (Jones and Gosling, 1996).

Pretreatment Conditions. During the warm phase of pretreatment full development of the embryo appears to depend on the presence of some kind of medium around the seeds. The rate of embryo growth was influenced by the composition of the medium, with peat-based media performing better than vermiculite and sand. Pericarp degradation was much greater in fruits stratified in a medium suggesting that embryo growth is inhibited by the pericarp (Derkx, 1996).

Washing the fruits in running water for 48 h before pretreatment effectively improved embryo growth whether or not the pretreatment occurred in the presence of a medium. The washing probably removed a soluble growth inhibitor in the fruits. Washing the fruits, followed by pre-treatment including 4 to 8 weeks of warm period without medium, increased germination compared with unwashed seeds pretreated in the presence of a medium.

Stratification of washed ash fruits without any medium offers more flexibility in dormancy breakage procedures. The warm phase could be shortened to 4 weeks, but 8 weeks ensures consistently better germination (Jones and Gosling, 1996).

The optimum temperature for embryo elongation in the warm stratification phase was 15C, though 10C or 20C also were suitable. However, seeds pretreated at 20C were less likely to germinate during the following cold phase than those pretreated at 15C. Embryos did not elongate during cold treatment at 5C unless they had received a warm stratification phase first; however, embryos do continue to grow at 5C once they have received at least 4 weeks warm stratification. The duration of the cold phase had a clear effect on the MGT. The stratification should consist of 4 months at 15 to 20C and be followed by at least 16 weeks of cold treatment at 3C. A period of 24 weeks of cold treatment gave significantly more germination (Derkx, 1996).

Embryo growth was unaffected by fruit moisture contents between 45% to 60% (fresh weight basis). However, at 60% moisture content, germination was reduced.

Germination was not affected by moisture contents between 45% and 55%. Moisture content between 50% to 55% turned out to be too high to prevent premature germination during the cold phase. A moisture content of 45% is ideal (Derkx 1996).

Redrying and Storage of Pretreated Seeds. Full stratification of freshly harvested fruits in a medium, followed by redrying and storage for 3 months, resulted in only a small reduction of germination capacity. Drying after the warm phase only caused large decreases in germination capacity (Derkx, 1996).

Conclusions.

- The collection date (after shedding) does not influence the rate of embryo growth.
- Embryo growth inhibitors in the pericarp can be overcome either by warm stratification in a substrate or by washing the fruits in running tap water for 48 h. Washing reduces the warm pretreatment requirement by about 6 weeks.
- The optimum temperature of the warm phase is 15C.
- The optimum duration of the warm phase is 16 weeks.
- The duration of the cold phase had a clear effect on the mean germination time. The cold phase should last at least 16 weeks.
- The moisture content of the fruits during the warm phase should be 45% to 55%, during the cold phase 45% (to prevent premature germination).
- Drying after harvest or after stratification gives only small reductions in germination capacity.

WILD CHERRY (*Prunus avium* L.)

Wild cherry seeds need both warm and cold stratification.

Optimal Seed Collection and Handling. Fruits of wild cherry were harvested in three successional years at weekly intervals from 6 weeks before full maturity up to full maturity. Dry weight, desiccation tolerance, and the level of dormancy (measured by mean germination time) of the seeds increased during maturation while moisture content decreased (Jensen, 1996). Sugars (glucose, fructose, and sucrose) increased during maturation (Nowag et al., 1997). All these results indicate that optimal seed quality is provided at full maturity. The maturation phase is delayed by cold springs and summers and hastened by warm springs and summers (Jensen, 1996).

Wild cherry seeds are able to germinate from about 5 to 6 weeks before full maturity, but only with about 40% germination and survival. Fully matured seeds may reach a germination capacity of more than 80%. Because the seeds acquire the ability to germinate late in their development, and since fully mature seeds produce the most vigorous seedlings, premature harvest cannot be recommended (Jensen, 1996).

Pretreatment Conditions. Wild cherry seeds, harvested from 5 different provenances in 1992, 1994, and 1995, were stratified at -5C at a moisture content of approximately 10%, after 2 months or 1, 2, or 3 years storage. Five different stratification treatments were also compared:

1) 2 weeks at 20C, 2 weeks 3C, 2 weeks 20C, 12 to 16 weeks 3C (until germination).

2) 2 weeks at 20C, 6 weeks at 3 to 5C, 2 weeks at 20C, 2 weeks at 3 to 5C, 2 weeks at 20C, and 12 to 16 weeks at 3 to 5C (until germination).
3) Same as Treatment 1 but with an addition of a compost activator from start of stratification.
4) Same as Treatment 2 but with an addition of a compost activator from start of stratification.
5) Same as Treatment 2 but with an addition of a compost activator when 50% of the stones had cracked.

Treatment 2 resulted in the largest number of seedlings in each case — between 2500 and 3000 seedlings per kg (at 30% moisture content) of seeds. It is important that the last cold period is sufficiently long, at least 12 weeks, to reduce the risk of inducing secondary dormancy at temperatures of 20C or more, which easily can happen at spring-time sowing (Nowag et al., 1997).

Currently it is not possible to determine the quantitative requirement for cold stratification. One investigation therefore looked to see if changes in fat, glucose, fructose, sucrose, and starch content could be related to dormancy release and used as markers for evaluating the release of dormancy. However, no correlation between the changes in reserve compound contents and the release of dormancy could be found. (Nowag et al., 1997).

The moisture content of the seeds during stratification should be about three percentage points below the fully hydrated moisture content (fresh weight basis). The full hydration level has to be determined for each seed lot each year, but usually lies around 38%. By aiming for a moisture content of some 35%, dormancy is released effectively, cracking of stones is avoided, and no premature germination occurs (Jensen, 1997).

The testa plays an important role in controlling the elongation and growth of the radicle during warm and cold stratification. In dormant seeds without testa the radicle will start to grow immediately when the temperature reaches 20C. At 4C radicle growth is delayed and will begin after about 20 weeks. In seeds with testa (but without exocarp) radicle growth is restricted at 20C and when such seeds are stratified at 4C they behave in the same way as whole stones (Nowag et al., 1997).

Drying generally leads to cracking of stones in a proportion of the seed lot. The faster the drying and the lower the final moisture content, the larger the proportion of cracked stones. Slow drying at low temperatures (4C) and high relative humidities (30% RH) showed a tendency to reduce germination compared to faster drying at lower RH (Jensen, 1996). Wild cherry seeds should be dried at temperatures between 15 and 20C with a RH of 20%.

Storage of dry (moisture content of 8% to 10%) nonstratified seeds at -5C is possible for up to 3 years without loss of viability and germinability (Nowag et al., 1997).

Redrying and Storage of Pretreated Seeds. After a shortened stratification under the conditions outlined above wild cherry seeds can be dried to a moisture content of about 12% (fresh weight basis) and be stored at 3C for 8 weeks, resulting in only slightly reduced germination capacity. The temperature for storage of pretreated seeds should not be below -3C because large decreases in germination have been observed in seeds stored below this temperature. However if dormancy

is released at higher moisture contents (i.e., fully hydrated rather than at 3 percentage points below full hydration) germination capacity is reduced significantly after drying. Drying the seeds reduces the need for cold treatment, but also induces sensitivity to low germination temperatures (Jensen, 1997).

Conclusions.

- Optimal seed quality is provided at full maturity when germination capacity is 80% or more.
- Optimum stratification is 2 weeks +20C, 6 weeks +5C, 2 weeks +20C, 2 weeks +5C, 2 weeks +20C, and 12 to 16 weeks +5C.
- Optimum moisture content of the stone during stratification is three percentage points below full hydration.
- The seeds should be dried at 15 to 20C and 20% RH.
- Nonstratified seeds with a moisture content of 8% to 10% can be stored at -5C for at least 3 years without loss of germinability.
- Storage of pretreated seeds has not been successful.

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Factors Affecting Rooting of Difficult-to-Root Plants

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INTRODUCTION

Millions of plants of easy-to-root species or cultivars are propagated by nurseries. Each nursery operates its own propagation environment, but all root the plants successfully. This indicates that for easy-to-root species the precise coordination of plant and culture factors is not necessary. A wide range of easy-to-root taxa can be rooted in the same propagation system with the same substrate and the same hormone treatment, often over a long period in the year.

In contrast, difficult-to-root plants need very precise coordination of plant and culture parameters. This is a problem because the whole environment in which cuttings are propagated involves up to 50 factors or conditions that could be altered, including cutting length, setting time, growth hormones, substrate, humidification, light, fertilisation, temperature, and so on. Many of these factors are interdependent (Spethmann, 1990). So it would be necessary to make hundreds of investigations with tens of thousands of plants to develop an optimised propagation method. With forest trees it was possible to undertake complex investigations over many years often with more than 100,000 cuttings and to develop optimised cutting propagation systems, e.g., for *Picea abies* (Kleinschmit et al., 1973), *Quercus robur* and *Q. petraea* (Spethmann, 1986), and some other trees like *Tilia cordata* or *Prunus avium* (Spethmann, 1982; 1990). But this is not practical with rare or expensive difficult-to-root species, such as *Hamamelis*, some *Rhododendron* taxa, or *Kalmia*.

To reduce the number and size of trials needed, it is necessary to be able to rank the relevant plant and culture factors. The most important of these factors can then be optimised while the other factors only modify the result and can be optimised later on. At the same time other factors, the importance of which may have been over-estimated, can also be identified.

RANKING OF PLANT AND PRODUCTION FACTORS

Investigations by The Author over 20 years have cleared up the importance of many propagation factors. The most important factors for cutting propagation success (Table. 1), especially in difficult-to-root species, are:

- Effective age stage;
- Sticking date;
- Humidification method;
- Method of overwintering.

Effective age stage means the combination of effects such as treatments to stimulate juvenility, age of the stockplant, height of the collecting position on the stockplant, and so on.

When factors such as effective age, physiological condition of the cuttings (e.g., degree of stress), and cultural conditions are below optimum, it leads to the following changes in propagation success (Spethmann 1997, Fig. 1, 2):

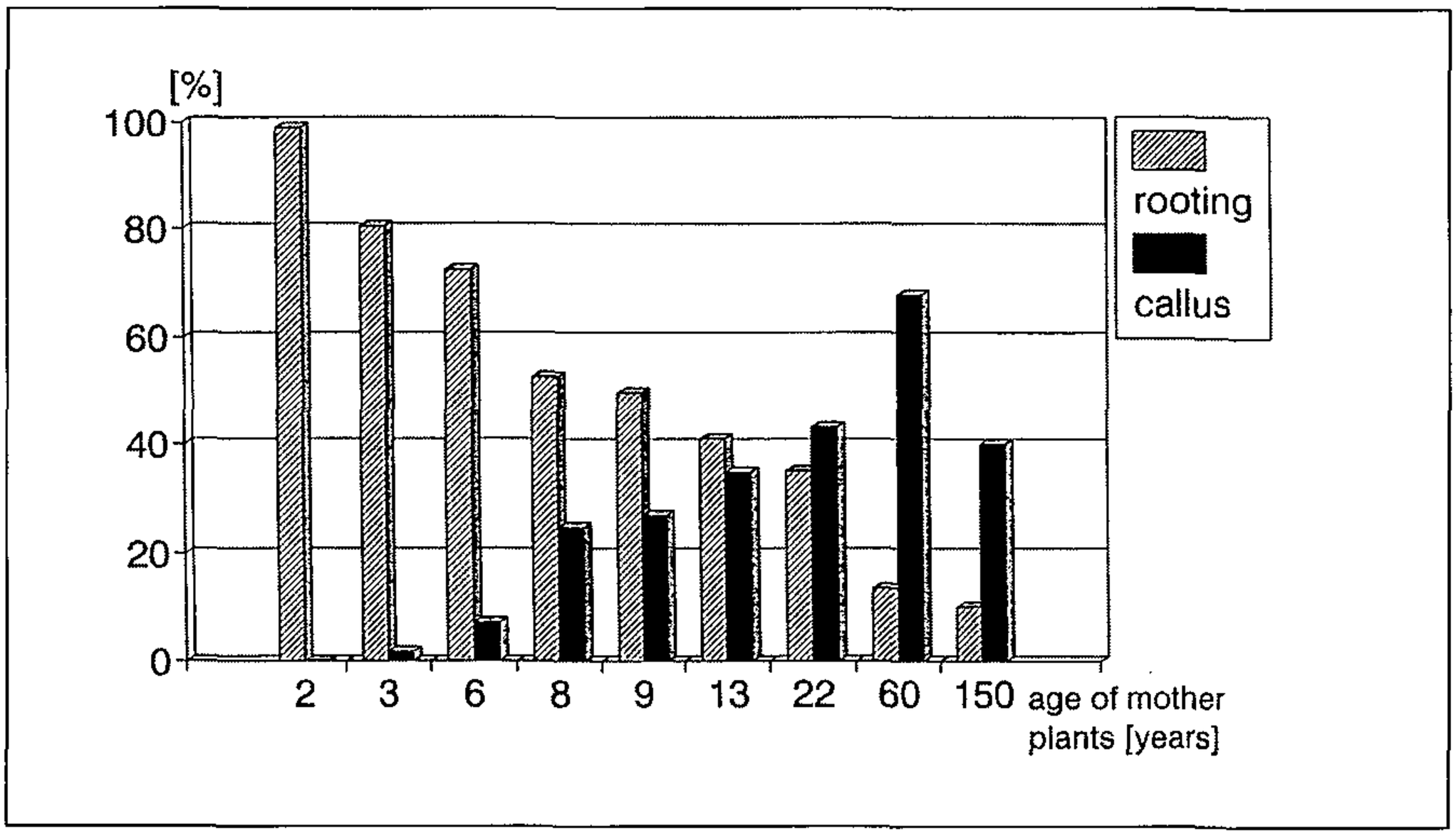

Figure 1. Mean rooting and callus formation of oak cuttings of different aged mother trees.

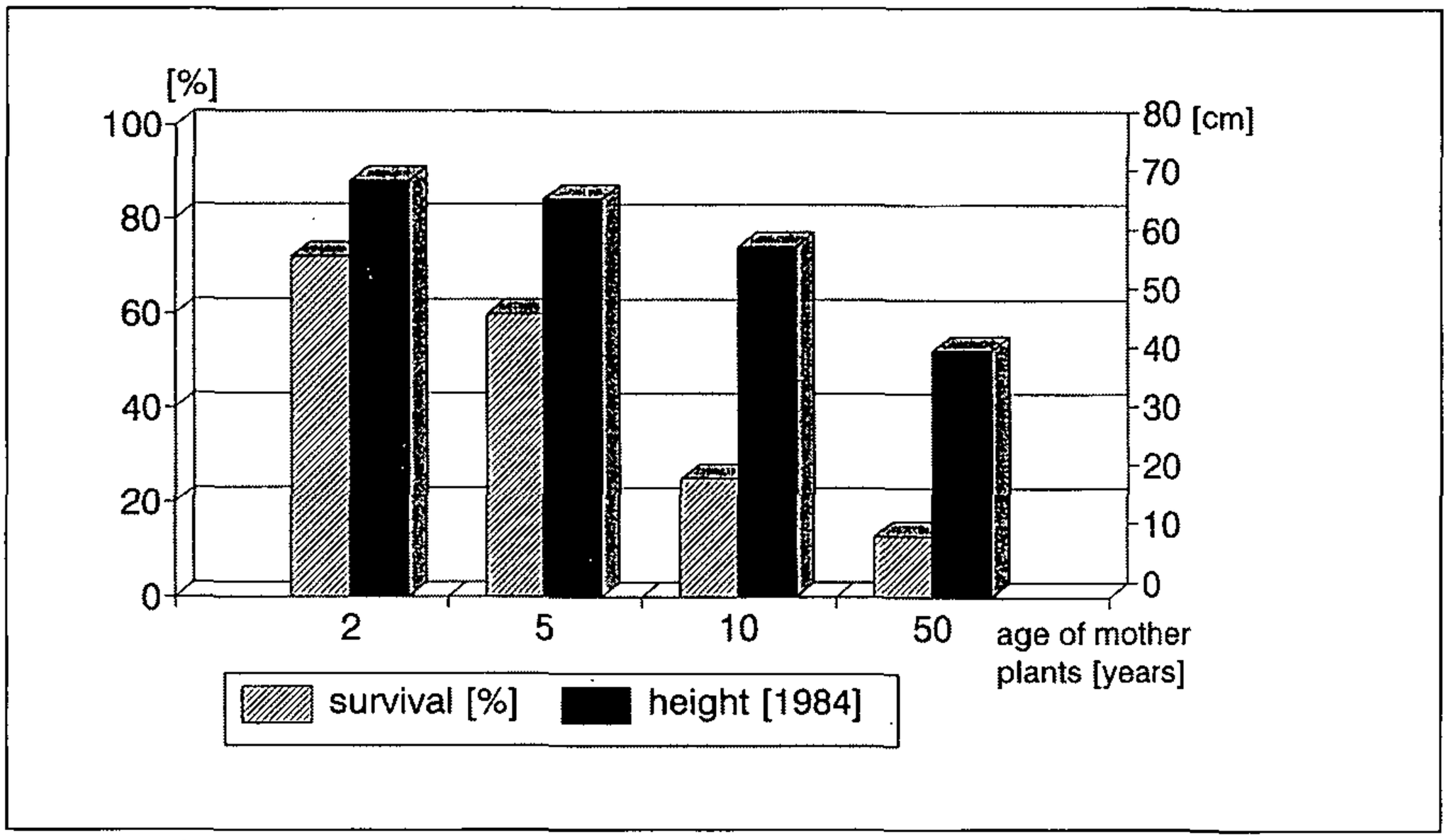

Figure 2. Survival after the first winter and mean height after 3 years of cuttings 1981 of *Betula pendula* as influenced by age of mother plants.

- Decrease in rooting percentage;
- Increase of callus formation;
- Decrease of the main root number;
- Origin of roots at the cutting turned from lateral, acrobasal to basal;
- Decrease of survival after the first winter and in the following years;
- Decrease in total vitality;
- Increase of plagiotropic growth habit especially in conifer cuttings;
- Decrease of the mean shoot growth in the following years.

The optimum time window for sticking is often very short (e.g., 3 weeks in *Quercus*). Trials involving sticking batches of cuttings every month through the year, will determine the optimum period. This shows, in some cases, unexpected results, e.g., *Prunus* (end of June and then again in November), *Fraxinus excelsior* (directly before and then directly after flushing), and *Phyllostachys* (December).

The most intensive and successful humidification system is fog, followed by mist system. Polythene used as a low or contact cover can be used successfully only for easy-to-root plants.

Cutting propagation can only be judged successful after overwintering and resumption of growth. Some tree species, such as oak, cherry, and birch should not be potted in autumn as this can lead to losses up to 80% over winter. Keeping them in the rooting bed in an unheated plastic greenhouse until next spring results in only a few losses and strong hardy rooted cuttings (Spethmann, 1986).

Table 1. Effect of unsuitable plant and culture factors on the success of cutting propagation.

Juvenility	Sticking date	Humidification	Overwintering	Result
juvenile	correct	suited	adapted	best success
adult	correct	suited	adapted	rooting not poss.
juvenile	wrong	suited	adapted	rooting not poss.
juvenile	correct	unsuitable	adapted	no rooting/poor plant quality
juvenile	correct	suited	not adapted	rooting but no survival

QUALITY AND FURTHER GROWTH OF THE CUTTINGS

Important factors influencing the quality of establishment and further growth of the cuttings are: sufficient volume for root development, fertilisation of the substrate, an adapted pH of the substrate (Mlasowsky, 1996), and, in some cases, use of growth hormones.

Ideally the cuttings, especially those of tree-like species, should be set in beds rather than trays or containers to allow plenty of space for root growth. These plants could be transplanted with bare roots to the field after overwintering. Shoot growth after rooting in these conditions is better than that of cuttings set in pots, especially those in cell trays. Fertilisation with 2 kg m^{-3} of medium of Osmocote Plus (3-4 months) tends to stimulate shoot growth effectively, and this results in shorter production time. In our trials we have produced oak from cuttings stuck in June that were more than 1 m tall by October (Spethmann and Harms, 1993).

More recent trials have revealed a significant effect of substrate pH. Surprisingly, the best pH for oak propagation is between pH 3.2 and 4.5 (Mlasowsky, 1996). With increasing pH, rooting percentage decreases, callus formation increases and new shoot growth decreases (Figs. 3 and 4). At pH 6 to 7 cuttings begin to suffer from chlorosis caused by unavailability of nitrogen, iron, and manganese (Table 2). In *Prunus*, pH of 4.5 is the optimum.

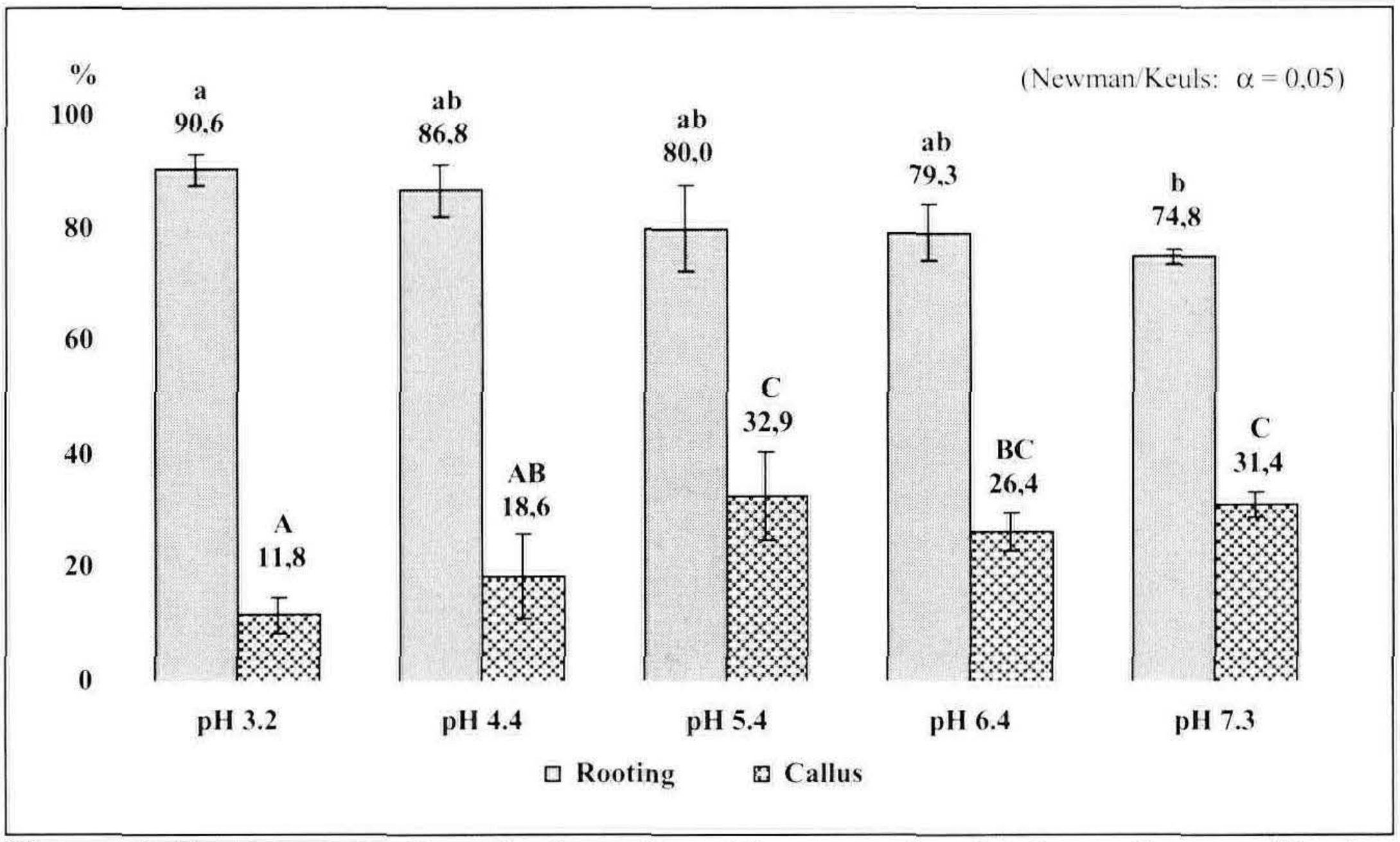

Figure 3. Rooting and callus of oak cuttings (*Quercus robur* L.) depending on pH value (Mlasowsky, 1996).

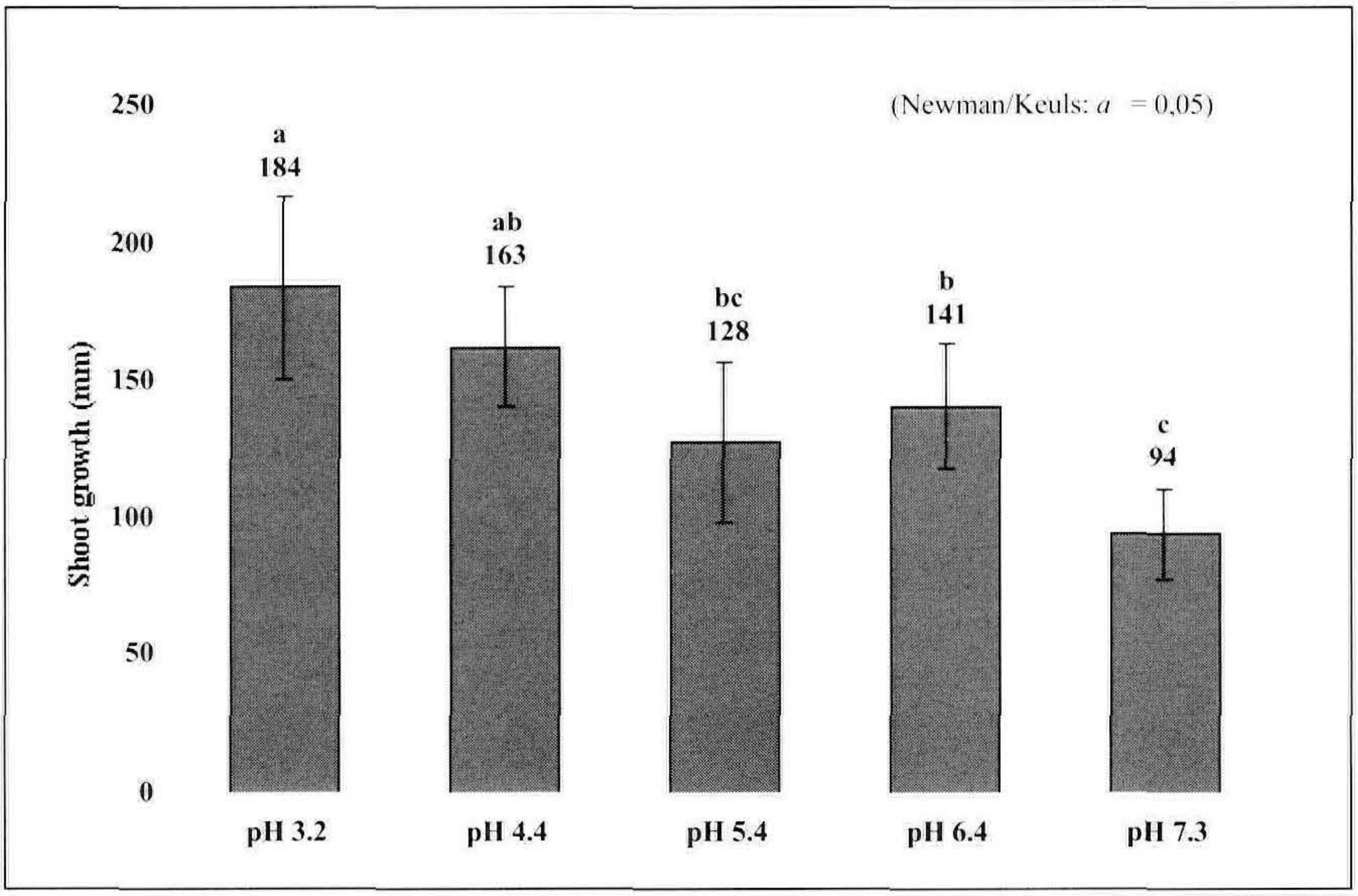

Figure 4. Average shoot growth of oak cuttings (*Quercus robur* L.) depending on pH value (Mlasowsky, 1996).

Rooting is promoted by growth hormones, these are especially effective in reducing rooting time and promoting root quality (root number, rooting position) but do not have much effect on rooting percentage.

Table 2. Nutrient content in dry matter of leaves from oak cuttings rooted in media of different pH (measurements made 23 Oct.).

pH	N (%)	Ca (%)	Mn (ppm)	Fe (ppm)
3.2	1.99	0.88	69	111
4.4	1.88	1.26	60	116
5.4	1.64	1.36	54	80
6.4	1.63	1.6	38	84
7.3	1.56	1.65	39	44
Limiting value	1.65	0.3	35	50

Limiting values based on Bergmann, 1986 and Lyr et al., 1992).

OVERESTIMATED PRODUCTION FACTORS

Some overestimated factors are temperature, light, substrate, a correct cut or wounding of the cutting base, and callus formation.

In particular, a wide range of substrates can be used as long as the key factors described in the previous section are optimised. So, for example, oaks could be rooted in pure peat, different peat mixtures, perlite, or gravel (3 to 8 mm). Even rhododendrons can be rooted with nearly equal success in a peat and sand mix or pure gravel. It is important, however, that the substrate is adapted to the humidification system (Spethmann, 1997).

Wounding of the cutting base often has a negative effect, so that rooting only takes place at the unwounded side, callus formation occurs at the wounded side. In addition, an important commercial consideration is that wounding is an additional handling stage with a cost, which has to be balanced against the likely rooting improvement, which in many cases is less than 5%.

INTERPRETATION OF PROPAGATION TRIALS

To interpret the effect of different propagation regimes it is important to choose the most relevant characters to measure and compare. For years the following characters have been used successfully: rooting success (% of rooted and survived cuttings), lack of callus, position of roots at the cutting, main root number, and shoot growth until autumn. As mentioned earlier, successful propagation can only be judged after the rooted cuttings have overwintered. Often species such as *Fagus* or *Hamamelis* root successfully but the rooted cuttings fail to overwinter.

Callus formation has been regarded as a precursor of root formation by some nurserymen. But in fact callus formation is totally independent from root formation. Cuttings from juvenile stockplants never show callus formation, but it is observed on cuttings from aged motherplants or those stuck in suboptimal culture conditions. Shoot growth of cuttings with root and callus formation is less than that of cuttings which develop roots without callus (Mlasowsky, 1996). In most cases where it looks as if roots have grown from the callus, microscopic study reveals that the roots have in fact developed at the base of the cutting and grown through the callus.

A better type of rooting than basal rooting is acrobasal rooting (over the lower 1 to 3 cm of the cutting) or laterally (along the full depth of the part of the cutting in the substrate). This type of rooting is promoted by the use of rooting hormones with IBA giving better results than IAA (Spethmann and Hamzah, 1987). Cuttings of aged stockplants are likely to root basally under the same conditions that produce acrobasal rooting in cuttings from more juvenile sources (*Quercus, Prunus, Fagus, Tilia, Thuja*, and others). In many species, however (e.g., *Picea*) only basal rooting occurs, despite optimising all conditions.

The number of main roots on a cutting is another important factor in comparing the results of different propagation treatments. After roots have emerged from the cutting bark, the number of main roots of the finished cutting is determined. Juvenile cuttings and optimised propagation systems result in the highest number of main roots. The number of roots is independent of the time you allow before evaluation. The root length, however, depends on evaluation time, substrate, and fertilisation — and the long roots are not necessarily the best roots. Root length of more than 15 or 20 cm hinders nursery handling operations such as potting or transplanting. Therefore root length should not be used as a root quality factor (Spethmann and Hamzah, 1987).

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Clematis Production In Poland

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INTRODUCTION

The first clematis species to be grown in Poland were *Clematis vitalba*, *C. recta*, and *C. alpina*, which are all Polish native plants. Other species and cultivars have been produced in Poland since the 19th century.

Two Polish breeders working since the mid 1960s, Wladyslaw Noll and Brother Stefan Franczak, have bred more than 50 valuable cultivars of clematis, of which more than 20 have gained wide recognition internationally (a list at the end of this paper details the most valuable of their cultivars).

Despite the international success of these plants, the clematis was never very popular in Poland and it was not widely grown commercially. By the late 1980s, less than 100,000 clematis were produced annually, and only some 20 or 30 cultivars grown.

With the political and economic changes that have taken place in Poland since the early 1990s, nursery production has developed dramatically, and clematis production has increased. Currently, more than 100 species and cultivars of clematis are grown commercially. Approximately 800,000 clematis plants are sold annually, of these about half are container grown and the rest are rooted cuttings for export. More than 60% of all Polish clematis are produced at the Clematis Container Nursery in Pruszkow, 20 km from Warsaw, the rest are produced by several nurseries scattered across Poland, growing between 5 and 15 thousand plants a year each.

MARKETING

Clematis Container Nursery has carried out a wide-scale promotion of these plants, including illustrated magazine articles, television show appearances, distribution of colourful catalogues, posters, and information leaflets, the aim being to make information available to garden lovers so that they will learn about the different kinds of clematis and the many ways to cultivate them. This has greatly increased the interest in these plants and people have begun to ask for particular cultivars.

The most popular sellers are the large-flowered clematis, which include both the standard type, for example: 'The President', 'Doctor Ruppel', 'Rouge Cardinal', 'Ernest Markham', 'Gipsy Queen', 'Marie Boisselot' (syn. 'Madame le Coultre'), and 'Jackmanii', as well as the Polish cultivars. But the so-called "botanical cultivars", with smaller flowers, are becoming increasingly popular, for example *C. alpina* 'Frances Rivis', 'Pamela Jackman', and 'Ruby'; and *C. macropetala* 'Jan Lindmark', and 'Markham's Pink'. All can withstand frost in the Polish climate just like the *C. viticella* and *C. texensis* cultivars. *Clematis montana* cultivars are also produced in Poland, but they can be raised only in regions with a temperate climate. In colder winters they freeze to the level of the snow and will not bloom the following spring.

Recently there has been increased interest in perennial clematis, for example *C. integrifolia* and cultivars, and *C.* 'Arabella' and 'Aljonushka'. These clematis, which are characterised by small flowers, make up approximately 10% of production in Poland.

PROPAGATION AND CULTIVATION

Only *C. vitalba* and, in some nurseries, *C. viticella*, *C. recta*, and *C. tangutica*, are propagated from seeds. The basic method of propagation for all species and cultivars in Poland is softwood cuttings. Grafting — the dominant method of production 30 years ago — is no longer used.

At the Clematis Container Nursery clematis cuttings are stuck from the beginning of May to the first half of August and placed in polytunnels for rooting. In May and the beginning of June the cuttings are taken from stock plants growing in tunnels, later, from plants growing outside.

Single-node cuttings, with the base treated with hormone rooting powder (0.1% NAA) are used. They are placed in plastic cases measuring 40 cm × 60 cm × 12 cm, filled with a mixture of peat moss and perlite (1 : 1, v/v) layered on the surface with a 2-mm layer of sand. Once they are watered, the cases with the cuttings are sealed with a milky plastic film wrap (0.02 mm thickness). When the cuttings root, they are hardened off with the film removed. The cuttings are kept in the tunnels until November, then removed, cleaned, graded, and tied up in bundles of 25. The bundles are gently sprinkled with moist peat moss, placed in plastic cases and put in a cold store at a temperature between +2C and -2C.

Potting begins in March. The stronger cuttings, which have the most (more than 3) or thickest roots are planted in 2-litre pots (14 cm). Weaker cuttings are planted in 0.5-litre pots (9 cm). The medium is mixed on the nursery and consists of peat moss, bark, styrofoam, and sand (5 : 3 : 1 : 1, by volume) with an added 2 kg of dolomitic limestone, 2 kg of chalk, and 2 kg of Osmocote 5-6M per m^3. The 2-litre-potted plants are placed outside, with 90-cm bamboo canes. When newly grown shoots reach between 40 to 90 cm, they are cut at the second node. From the buds grow 2 or 3 shoots, which are tied 2 to 4 times to the cane, growing in the course of 6 weeks to the height of 90 cm. They are then ready for sale, with colour labels with the picture of the plant and the name of the cultivar, packaged into wooden cases of 25 plants (cases measure 40 cm × 60 cm × 25 cm). Approximately 60% of container-grown clematis are sold during summer and autumn. The rest of the plants are overwintered and sold in the spring.

Throughout the winter the majority of the plants are kept in double-skinned tunnels. Preparation for overwintering begins in November. Plants which will be overwintered in unheated tunnels receive a 2-cm mulch of pine bark sprinkled onto the surface of the growing medium in the containers. More sensitive cultivars are overwintered in tunnels heated by gas burners. These plants are not mulched. In the heated tunnels the temperature is maintained at a minimum -4C. Clematis which cannot be placed in the tunnels, because of lack of space, are overwintered outside on a well drained, sheltered field, with a 5-cm layer of pine bark mulch covering the containers.

Clematis in 0.5-litre containers are prepared in the same manner but using shorter bamboo canes, 40 cm long and sold packaged in plastic bags with large colourful tags, or in colourful cardboard packages, or as a set of 24 plants in 6 colours in one box.

Table 1. The most important recent Polish clematis cultivars.

'Niobe' (deep ruby red flowers)
'Général Sikorski' (blue flowers)
'Błękitny Anioeł' (flowers light blue with very fine silky texture, ruffled sepals with curled edges, very freely blooming)
'Kardynal Wyszyński' (glowing crimson flowers, very freely blooming)
'Warszawska Nike' (flowers dark red velvet violet with gold stamens)
'Polish Spirit' (viticella group, velvety flowers, rich purple-blue, extremely freely blooming, nice, small, dark green leaves)
'Jan Pawel II' (flowers creamy white with pink trails, long blooming time, a strong growing culitvar)
'Fryderyk Chopin' (flowers steel blue with ruffled sepals)
'Kacper' (very large, intensive violet flowers)
'Monte Cassino' (wine red velvet flowers)
'Westerplatte' (rich red almost fluorescent flowers)
'Matka Urszula Ledochowska' (flowers pearly, bright, white with a translucent satin sheen on the surface, one of the earliest blooming cultivars)
'Emilia Plater' (a member of the viticella group, very healthy, strong growing and freely blooming)

Developments in Magnolia Propagation

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At Prenor Nurseries we were not obtaining a satisfactory yield of magnolias propagated by softwood cuttings (e.g., *Magnolia* x*soulangiana* 'Alexandrina', *M. liliiflora* 'Nigra'). A number of different treatments were tried on both the mother plants and the cuttings. The first trial involved girdling the mother plants with plastic bands or metal wires but this did not result in yield improvements. The second trial compared different concentrations of rooting hormone treatments and different sticking times. This showed that yields were improved when cuttings were taken as early as possible, then left in the plugs after rooting and not potted until the next spring. The plants are overwintered in greenhouses, and new shoots are used as cuttings, since most of them have to be removed at this time anyway. The rooting percentage of cuttings treated in this way was 95%.

INTRODUCTION

Magnolia hybrids and cultivars are propagated vegetatively. Methods such as grafting and layering are still in use, but most nurseries now propagate them by cuttings (Tomayer, 1992). But with such difficult-to-root plants the results are not always satisfactory and many plant propagators have undertaken trials on various pretreatments of the mother plants (Maynard and Bassuk, 1988; Schmidt, 1982). Magnolias do not transplant well (Callaway, 1995), and are difficult to overwinter, so the potting time of the rooted material is also a key issue.

The aim of the trials described in this paper was to find a method involving either mother plant pretreatment or timing of cuttings, which Prenor Nurseries could use to improve the yield of its magnolia propagation.

MATERIALS AND METHODS

In 1995 and 1996 the trials were carried out at Prenor Nurseries in Szombathely, Hungary, on two taxa: *Magnolia* ×*soulangiana* 'Alexandrina' and *M. liliiflora* 'Nigra'.

Two trials were based on the following treatments:

Girdling of the Mother Plants as a Pretreatment. In the first year plastic bands were used to girdle the plants; metal wires were used in the second year. Four girdling times were compared and the cuttings were taken at either 3 or 5 weeks after the treatments.

Comparison of IBA Concentrations. Concentrations compared were 0.6%, 0.8%, 1.0%, and 1.2% in the first year, and 0.6%, 1.0%, 1.4 % in the second. The concentrations in the second year were chosen because it was felt they would be likely to show more clearly the differences between high and low doses.

Comparison of Sticking Times. Cuttings were stuck at 14-day intervals from 20 June until 9 Aug.

In 1997 the trials were undertaken at the Humboldt University, Berlin, Germany, on two different taxa: *M.*'Susan' (*M. stellata* 'Rosea' × *M. liliiflora* 'Nigra'); and *M. ×loebneri* 'Merrill'

The aim of this part of the research was to use microscopy to make anatomical observations on the process of rooting in the cuttings. In addition a practical trial was also undertaken, comparing the effect of two different solvents (ethanol and acetone) for the IBA on rooting yield. The IBA concentration was 1.0% in both solvents, and results were compared with a control batch of cuttings which were not treated with rooting hormone. Cuttings were all stuck on 12 July.

In all trials the cuttings were stuck in plug trays, and rooted under mist irrigation, then overwintered in greenhouses and potted on after 15 May the following year. Before potting the plants were pruned back, and the cuttings used for further propagation. All trials were evaluated after overwintering because this is such a crucial stage in the propagation of these plants.

RESULTS

Table 1. Effect of girdling, IBA concentration, and sticking date on yield (measured as percentage of cuttings rooted and surviving over winter) of *Magnolia ×soulangiana* 'Alexandrina' and *M. liliiflora* 'Nigra', propagated from cuttings in Summer 1995.

		IBA concentration				
		0.6	0.8	1.0	1.2	Control (0.8)
		Yield Rooted				
Date girdled (weeks before sticking)	Date stuck	(%)	(%)	(%)	(%)	(%)
M. ×soulangiana						
3	20 Jun	34	44	49	35	57
5	5 Jul	12	17	28	20	-
3	6 Jul	20	32	21	38	33
5	18 Jul	28	33	52	47	27
3	19 Jul	65	40	64	61	-
5	1 Aug	27	15	25	30	9
3	2 Aug	23	42	30	47	-
5	9 Aug12	9	22	21	6	
M. liliiflora						
3	21 Jun	67	81	74	73	
5	5 Jul	20	26	8	20	
3	6 Jul	34	62	54	55	
5	18 Jul	42	43	44	45	
3	19 Jul	48	42	53	48	
5	1 Aug	37	18	25	20	
3	2 Aug	17	20	19	23	
4	9 Aug	4	15	6	2	

Table 2. Effect of IBA concentration on rooting percentage and average number of roots per cutting, after survival over winter, of *Magnolia* ×*soulangiana* 'Alexandrina' cuttings at different sticking times in 1996.

	IBA concentration					
	0.6		1.0		1.4	
Date Stuck	Root (%)	No. roots	Root (%)	No. roots	Root (%)	No.roots
5 June	34	6	56	6	54	6
20 June	53	9	40	9	61	8
4 July	21	5	18	6	18	6
23 July	38	4	21	6	33	6

Effect of Rooting Hormone Solvent. The highest rooting percentage was achieved with ethanol solution (with which the rooting percentage was 58.8%), and the lowest was with the acetone solution (0% rooting for *M.* ×*loebneri* 'Merrill', and 12.5% with *M.* 'Susan'). Cuttings not treated with rooting hormone gave surprisingly high yields in this trial (e.g., 51% rooting of *M.* 'Susan').

DISCUSSION

Girdling had no beneficial influence on the rooting percentage of the cuttings. Sticking time proved to be the most important tool for the nursery, with the best results coming from cuttings taken as early in the season as possible. Early sticking means the plants have a longer period of growth and establishment which leads to better survival over winter. The rooting percentage before overwintering is always around 95%.

A rooting hormone concentration above 0.8 % in ethanol gave the best results.

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Experiences With Recycling in Germany

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INTRODUCTION

Waste problems do not arise either in nature, nor in traditional rural human lifestyles as in both these situations all substances are more or less "recycled". Only industrialisation results in the creation of large quantities of waste materials for which there is no immediate use. Rising economic output has been accompanied by an increased consumption of materials and a constant growth of waste volumes. Up to the 1970s sufficient dump space was available to deal with these wastes. But the increasing volume of "garbage heaps", the shortage of resources, the risks, and harmful effects of inappropriately created landfills in connection with an increasing environmental awareness has pushed the waste problem into the centre of public interest.

At the start of the 1970s, waste policy in Germany was geared to environmentally compatible disposal. But from 1986 the Waste Management Act legally defined the order of priorities for dealing with waste as: (1) avoidance; (2) recycling, and [only when the first two are not possible] (3) disposal. Later the Packaging Ordinance (1991), and the Closed Substance Cycle and Waste Management Act (1996), also aimed to reverse the trend of growing waste volumes. Recycling has ever since become an important objective in German waste policy.

DEFINITIONS

Waste. The Closed Substance Cycle and Waste Management Act defines waste as "movable things which the owner wants to or has to get rid of". The act differentiates between "waste for recovery", which should be recycled or reused as secondary raw materials or fuels, and "waste for disposal", which cannot be recycled and should be disposed of. A third category of waste deals with the so-called "special waste". Special waste requires extra supervision, because it could cause hazards to health or contaminate air or water.

Recycling. Recycling means the recovery of raw materials and their return to the substance cycle, or processing into new products. Recycling technologies are used to preserve resources and to reduce waste volumes. Good results in recycling are achieved especially in waste paper, glass, aluminium, and tin plate. Recycling includes the biological, chemical, or energetical transformation of waste.

FUNDAMENTALS OF GERMAN LEGISLATION

Closed Substance Cycle and Waste Management Act 1996. This is the core legislation dealing with waste. It is based on a fundamental waste management concept of extending the producer's responsibility to the entire life cycle of a product. Special attention is paid to the development and the manufacturing of low-wastage products. The producer, as well as the consumer, must ensure that unavoidable residues are fed back into the cycle as secondary raw materials. Only waste which

cannot be recycled may be disposed of in a manner that causes no hazards to the environment or to human health. This newly defined concept of "waste" thus also includes residual materials and commodities, which were formerly beyond the government's influence sphere.

The special emphasis on waste avoidance before recycling and disposal is defined in Section 4 of this law. The imperative of recycling is only necessary if it is technically feasible and economically reasonable. Substance recycling and energy recycling have equal status, the more environmentally compatible method should be given priority.

Packaging Ordinance 1991, Amended 1998. This measure is seen as a major step to closed substance cycles. It requires manufacturers and retailers to accept returned packaging and to recycle it in an extra waste-collecting system outside the public one. Producers and retailers are freed from the obligation to accept returned packaging if they participate in a system for collection and recycling of sale-packaging, which is paid for by the manufacturers. So the "Duales System Deutschland GmbH" was founded to collect and recycle such material. The DSD has to meet certain collecting and recycling quotas.

It also requires producers and retailers to accept packaging containing hazardous residues.

Sewage Sludge Ordinance 1992. This lays down requirements for the utilisation of sewage sludge in agriculture, horticulture, and forestry. It regulates the spreading of sewage sludge on soils. Spreading sewage sludge is prohibited in forestry areas and on areas used for cultivating fruits and vegetables and heavy metal content is limited. The maximum quantity of sewage sludge which can be spread is limited to 1.6 t dry weight per hectare per year.

Biological Waste Ordinance 1998. This new legislation regulates collecting, processing, and utilisation of biowaste as well as the yield on horticultural and agricultural soils. Biowaste is defined as waste from food processing, kitchen waste, and gardening. Quality requirements for compost are specified and maximum yield quantities and limits for heavy metals and pollutant analysis are determined.

Technical Instruction on Waste from Human Settlements 1993. This regulates the handling and disposal of municipal waste, which must be treated in such a way that the proportion of organic matter is below 5% before disposal. At present this can only be achieved by incineration. Until 2005 organic substances are to be collected separately.

WASTE AND RECYCLING

The quantity of waste in Germany should be reduced drastically by the legal regulations detailed above. According to Ministry of Environment statistics, between 1990 and 1993 waste volume decreased about 10% to 337 million tonnes. At the same time the recycling ratio increased to 25%. In industry 59% of waste is recycled. The DSD collects about 5.4 million tonnes of packing waste from a total amount of 6.4 million tonnes. With a recycling level of approx. 77% (4.9 million tonnes) the legal standards are currently being met.

New technologies have been developed for substance recycling, for example the application of plastics as a reducing agent in steel production. However, there are limits to recycling. Thus the most valuable materials are collected, even though capacity or technology is not currently available to process all of them or markets are not yet ready for the recycled product. The latter is the case, for example, with sludge and biocomposts. This waste is often stored for long periods. In some areas only the admixture of small proportions of secondary raw materials is possible for the production of high-quality products.

RECYCLING AND NURSERIES

Organic Waste. Approximately 80% to 90% of the waste volume arising in nurseries is organic waste. Usually it is composted on the nurseries and used as fertilisers or for soil improvement.

Pasteboard and Paper. Pasteboard and paper usually originate from packaging materials. But even office paper is collected separately and recycled as secondary raw material. Very dirty and soaked papers can also be composted.

Plastics. Approximately 1% of the waste arising from nurseries consists of plastics. This waste stems from pots and containers, packing materials, foils, fleeces, and fabrics. Depending upon the degree of contamination and the ability of the nursery to separate different types of plastic, this waste can be recycled to high-quality raw materials or into new products, e.g., pallets, buckets, pots, and foils. Already 50% of all plastic pots are made from recycled plastics. The fuel value of waste plastic corresponds to heating oil.

Wood. Crates, pallets, and used tree stakes are sources of the waste wood. Only untreated materials are recyclable. They can either be composted or converted by the woodworking industry.

Pesticides Packaging. Only a small proportion of waste is due to pesticides packaging. According to the "Packaging Ordinance" pesticide packaging has to be collected separately. The pesticide producing industry introduced a collection system to recycle pesticide packaging chemically.

USE OF RECYCLED PRODUCTS ON NURSERIES

Recycled products are already in use in many areas of horticulture. On nurseries, substrates are currently being tested which are enriched with bio-compost, wood fibres, or bark.

Recycled paper products are used for packing and as pots. Plastic pots are made partially of recycled material, as are pallets, plastic stakes, and fleeces.

Waste avoidance is possible by using multi-use packaging such as "C-C carts", multi-use plastic crates, multi-use pallets or "bigbags" for substrates, and by using biodegradable materials, such as paper pots, degradable fabrics and binding-material, and wooden crates.

Water Recycling in Container Plant Production

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INTRODUCTION

Irrigation is no longer a matter of simply applying enough water to the crop. Modern nursery-stock growers have to be aware of the increasing amount of legislation and restrictions enacted to avoid pollution of the environment and to protect natural resources, such as soil and water. Nevertheless, to remain competitive in the market, growers have to produce plants of a high quality and at the lowest possible costs. Irrigation of container-grown plants now means the management of several interacting factors which range from the selection of water of the right quality for growing plants, to the safe and appropriate disposal or use of surplus water.

IRRIGATION REQUIREMENTS

There are three factors which now need to be taken into account when choosing and managing irrigation systems.

- **Irrigation requirements for environmentally sound plant production.** This includes, for example, collection of the right amount of rain water, recirculation of runoff water, closed irrigation cycles instead of more-or-less water recycling, water-saving irrigation techniques, and minimised production of waste material.
- **Irrigation requirements for good quality.** This includes factors such as mineral content, contamination with disease organisms, availability of the right quantity of water at the appropriate times and locations, and bed construction.
- **Irrigation requirements for low cost.** Here the grower needs to consider procedures which will result in savings on items such as technical devices, labour, water, fertiliser, energy, side-effects, follow-up care of plants, etc.

Since some of these requirements are contradictory, no irrigation system can fulfil them all completely. However, the progressive nurseryman will see that the traditional system of well or borehole water only, overhead sprinklers, and vast quantities of surplus water running off site, will meet none of these requirements and is not beneficial in the long run.

WATER RECYCLING

The best combination of characteristics, which will meet most of the criteria discussed above, is provided by an optimised recirculating system. Such a system consists of four components.

1) **Sealed but Perfectly Drained Beds.** These beds collect rain water and all surplus irrigation water and deliver it completely to collection ditches. This requires a durable compacted bed base covering an appropriate area. It needs to be well tailored to the kind of water supply and to the amount of rain water that is required for

irrigation. Rain water is eminently suitable for irrigation in terms of quality and economy of placement. It is very difficult, for example, to tailor a fixed point overhead sprinkler system for nursery stock. One reason is the difficulty of determining the appropriate size of sprinkler. Erratic wind drift and severe water losses by evaporation have also to be taken into consideration, as well as the enormous water output required to make up for losses and missed areas. Use of a gantry system to deliver overhead irrigation makes it much easier to determine the area the system will cover and hence tailor the delivery system to suit. Drip irrigation or some kind of subirrigation is even better because the potential for losses and missed areas is even further reduced. It is important to realise that if individual beds are too large they will collect more rain water than can be used for irrigation, and this water then has to be used differently or disposed of in a way which will not contaminate the ground or natural water courses with possible fertiliser or pesticide runoff residue.

2) **Sealed Collection Channels.** These intercept the water running off the beds and divert it to a containment pond, using gravity wherever possible to avoid the expense of installing and running pumps. The channels must be designed to cope with maximum expected volumes of water in order to avoid floods and prevent compost, leaves, silt, etc. from flowing into the pond. A settlement pit or pond before the main containment pond is a good idea to prevent the main pond silting up.
3) **Containment Ponds.** Such a reservoir, in form of a pond or tank, collects the runoff water and keeps it for recirculation. It must, therefore, be on an appropriate site, and of an appropriate construction type and capacity. These factors depend on the local situation, the amount of rainwater to be used as a substitute for well or mains water, and the local possibilities of surplus water disposal. It is necessary to monitor the actual volume of water stored in the pond, which may vary depending on seasonal variations in natural precipitation. It might be necessary to collect a large volume of rainwater during the winter, and there should always be sufficient room to store the runoff water after a heavy rainfall. It is desirable to install a means of controlling the flow of pure rain water into the pond. Integration of the reservoir with a disinfection device would also be wise. It is possible to install a slow filtration tank just before the water intake of the irrigation pump, for example in a pit at the bottom of the containment pool.
4) **Modern Irrigation Techniques.** Sprinklers are hard to control automatically, and often their operation time is limited to only a few hours in the evening. This means the whole system has to be "over-designed" so that it can supply unnecessarily vast quantities of water during a short period of time. More modern systems are designed both to save water and keep the amount of circulating

water low. It is important to use techniques which diminish wind drift and evaporation water losses, and which distribute the water uniformly and at the right time. This can be achieved by drip irrigation for large- or medium-sized containers, and with subirrigation such as a capillary matting system or ebb and flood tables for medium or small containers. Automatic controls, e.g., by tensiometers or a similar device, also improve the system. For some crops a gantry system is a good solution. The somewhat greater costs for constructing an optimised recirculating system are offset by stronger plant growth, more uniform crops, labour savings, and saved costs for water, fertiliser, energy, smaller pumps and pipes, etc.

WATER QUALITY

Water recycling brings with it a risk of plant damage resulting from the quality of the recirculating water, which may contain spores of disease organisms, salts, residues of chemical treatments, organic matter, and so on. However, this problem can be minimised by some simple measures as part of the overall management programme.

Disease. Avoid the risk of spreading diseases throughout the crop by:

- Permanent hygiene throughout the production process.
- Stop using overhead irrigation.
- Dilution of spores by large water circuits and big ponds, natural biological control of disease organisms by their antagonists within biologically active ditches and ponds.
- Use of slow filtration technique, if susceptible crops are grown.

Chemical Contamination. Diminish the risk of the accumulation of fertilisers and plant protection chemicals by:

- Use of adequate fertilising programs and fertilisers, control by EC meter.
- Avoid treatments with persistent herbicides, use integrated pest management approach.
- Dilution of residues by large water circuits and big ponds.

Blockages. Reduce the risk of algae, silt and/or salts, etc. blocking irrigation lines by:

- Storage of cleaner water, minimised leaching of fertilisers, and planted collection ditches.
- Correctly placed water intake, if installed through a slow-sand or rockwool filter.
- Use of filters with a self-controlled back flush.
- Use of appropriate distribution equipment, such as bigger emitters.
- Regular inspection and cleaning of drippers, emitters, and valves.

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Use of Green Waste Composts in Media for Hardy Nursery Stock

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INTRODUCTION

For more than 10 years, the Horticultural Research Institute Bad Zwischenahn has been conducting research on the use of green-waste composts in substrates for container plants. There are a number of advantages in using green-waste compost as an additive to peat substrates. These include: buffering of nutrients and pH, improvement of ecological image by reduction of organic waste, conservation of peat and, usually, a low price.

However, there are also some potential disadvantages, including: high pH, high salt content, decreased water capacity of the substrate, high volume weight, and increased transportation costs.

Great care is needed with the use of green waste composts in container substrates. It is absolutely necessary to analyse the compost before use and to keep the quality to a defined level. In Germany this is the nationally recognised "Gütebestimmungen für Substratkompost" (quality control for substrate-compost). Otherwise, plant damage — through nitrogen deficiency caused by fixation in the compost, salt and chloride toxicity, or other factors — is possible. Even with a high quality compost, the advantages and disadvantages need to be evaluated before deciding to use the material in container-plant cultivation.

GREEN WASTE COMPOST FOR NURSERIES

The production of green waste composts is increasing each year and they are increasingly being offered to nurseries in Germany, often for a very low price. At the same time, the container-plant sector has become interested in substitutes for peat as a container medium because of the bad ecological image of peat usage.

In recent years, the Horticultural Research Institute Bad Zwischenahn, in close cooperation with substrate producers, the extension service, Horticultural Research Institute Hannover-Ahlem, and the College for Horticulture Fachhochschule Osnabrück, has conducted research in the use of different composts in substrates for hardy nursery stock. Plants used in trials with these substrates were *Buddleja* (high nutrient demand), *Ribes* (chloride sensitive), and *Hypericum* (salt sensitive). The aim of the trials was to learn about the qualities of green-waste composts and to find limits for the different chemical contents.

DIFFERENT GRADES OF COMPOST

German standards distinguish between different types of compost. "Biokompost" contains a high proportion of organic kitchen waste and so has high levels of salt, and often chloride, and is not usable for container substrates; "Grünkompost" is made exclusively of plant material from parks and gardens. In reality, however,

composts offered to growers are often mixtures — basically Biokompost with Grünkompost mixed in to improve quality. So in practice, the terms "Biokompost" and "Grünkompost" are of little help in characterizing the quality of a compost.

A group of researchers, under the leadership of Horticultural Research Institute Hannover-Ahlem, developed the alternative compost descriptions "Substratkompost Type 1" and "Substratkompost Type 2". These terms are not defined by the origin of the composted materials but by their quality and their nutrient content (Table 1.)

Table 1. Characteristics of "Gütesicherung Substratkomposte".

	Type 1	Type 2
Maximum proportion of compost in substrate	20%	40%
Salinity (as mg litre^{-1} KCl)	<5000	<2500
N (mg litre^{-1})	<600	<300
P_2O_5 (mg litre^{-1})	<2400	<1200
K_2O (mg litre^{-1})	<4000	<2000
Cl (mg litre^{-1})	<1000	<500
Na (mg litre^{-1})	<500	<250
Zn (mg kg^{-1})	<300	<300

(Other factors including absence of N fixation and growth inhibition are being tested by incubation test, with indicator plants and by other means.)

SUBSTRATE STRUCTURE

In a trial with *Buddleja*, root development was normal on plants grown in a substrate containing 40% compost, but roots were poorly developed on plants growing in a substrate of pure compost.

Waste-derived composts have a higher organic mater content than peat and their dry volume weight is much higher than peat. As a result the transportation weight of container plants with a compost/peat mix substrate is higher than those with peat only substrates, especially when the plant itself is comparatively small (e.g., groundcovers). If the composts are wet, there is little difference in weight between peat and compost because of the high water-holding capacity of peat. On the other hand, it is easier to moisten a dry compost and peat substrate than pure peat. But the water capacity is reduced, so compost and peat mixes may need more frequent watering.

SALT AND CHLORIDE

Composts, especially "Biokompost", have high salt levels. In trials with *Ribes* and *Hypericum*, symptoms of salt damage (necrosis or chlorosis at the leaf margin) occurred when the plants grew in compost mixes with salinity levels of more than 2000 mg KCl litre^{-1}. In nurseries, it is possible to observe the same damage symptoms in groundcover crops at even lower salinity levels.

Chloride levels in compost are especially important. In trials, damage to *Ribes* and *Hypericum* was found at chloride levels above 400 mg litre^{-1}. In our tests, this level

of chloride could be found in compost/peat mixtures containing 25% or more compost. When evaluating potential for chloride injury, other sources of Cl stress, including irrigation water, fertilizers, or other soil amendments (e.g., coco-material) should be considered.

Each compost has to be analysed and if its chemical parameters don't fall within the limits of the "Gütesicherung Substratkomposte", they should not be used in substrates.

NITROGEN DEFICIENCY

Another problem that repeatedly occurred in the trials was nitrogen fixation. By early summer, crops, especially those that were potted into coarse-structured green-waste compost, showed nitrogen deficiency symptoms. These symptoms were caused by microorganisms using the nitrogen applied as fertiliser to decompose organic materials in the compost. This experience shows the importance of testing the compost before use to see if it is still fixing high amounts of nitrogen. There is a test, named "Brutversuch" (incubation test), that has been developed to measure the amount of nitrogen being fixed.

There are some composts — especially "Biokompost" that are capable of releasing large amounts of nitrogen. At certain times, for example after potting, when the plant does not demand much nitrogen, such releases could leach out and cause pollution.

NECESSITY OF PHOSPHATE AND POTASSIUM FERTILISATION

Phosphate and potassium contents of composted waste are very high, so it appeared that growers might get away with only having to apply nitrogen fertiliser. In one of our trials, the growth of plants growing in a medium containing Osmocote 39-0-0 (coated urea) was compared with those fertilized with Osmocote 5-6M (balanced NPK). Osmocote 39-0-0 supplied the plants with nitrogen much more slowly than Osmocote 5-6M, so nitrogen deficiency could occur. Trials at another research station showed that plants grown in waste-derived compost without added potassium suffered retarded growth. The current recommendation, therefore, is that even in waste-derived composts potassium and phosphate have to be supplied, although the amounts can possibly be reduced compared with those applied to peat-based composts.

ALKALINITY

A waste-derived compost usually has a high pH. This has to be considered when calculating the amount of lime added to the peat in substrate mixtures. In our trials, we were able to reduce the amount of lime from 4 g to 1 g litre^{-1} in substrates containing 20% "Biokompost" (pH 7.6-8.2 in $CaCl_2$). The amount of lime needed depends not only on the pH of the compost but also on its buffering capacity.

The high pH of waste-derived composts may cause problems for some plant species. With Ericaceae, for example, mixtures containing high proportions of compost are usually not desirable. On the other hand, plant species that prefer high pH, such as *Taxus* and *Buxus*, might grow better given the buffering capacity of waste-derived composts rather than the decreasing pH that occurs frequently under liquid feeding with soft water.

CONCLUSION

Growers need a substrate which will not present a risk of damaging the crop. Waste-derived composts offer advantages and disadvantages that have to be considered. If a waste-derived compost is to be mixed into a substrate, it is absolutely necessary to test the material before use. The German "Gütesicherung Substratkomposte" (quality control for substrate compost) gives guidelines where the important qualities and nutrient contents are measured so that the risk of crop damage is reduced to a minimum if such a quality compost is used. But composts are still not used widely in German container nurseries and there are many things to learn about using composts in container substrates.

Table Systems for Indoor and Outdoor Crops

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INTRODUCTION

Anglia Alpines grows not only alpines and herbs but a wide range of other hardy and nonhardy ornamentals, including poinsettias as a cash crop for Christmas. We grow under glass, outside in the open, and under polythene. The majority of our pots are 9 cm and 13 cm, normally placed pot thick.

On Anglia Alpines' original site, plants were grown mainly outside and under polythene but after an exceptionally hard winter one year a decision was made to try a secondhand glasshouse which could be used to provide frost protection if necessary. The excellent quality and the speed of growth which resulted were amazing. Indeed, growth had to be controlled by ventilation or by moving the plants outside once the first plants were big enough.

By this time the increasing cost of labour — rising at a much greater rate than inflation — was also becoming a concern. A 25-m walk, carrying 2 trays of 18 plants of 9 cm, was costing about 0.25p per plant. To move 1 million plants only once would at that rate cost £2,500 ($4075 U.S.A.) — and remember the plants need to be moved many times during the growing cycle.

REASONS FOR SELECTING A TABLE HANDLING SYSTEM

When the nursery expanded by developing a green-field site in 1989 the plan included a much greater area under glass and polythene as well as a larger outdoor growing area. A tour was made of nurseries in Denmark, Holland, and Germany for ideas. The mobile benching systems which were widely used for both growing and handling, under glass and outside, were most impressive. Note was also taken of other handling systems, such as computer guided cranes which could select a full table from the middle of a glasshouse, and specially designed lorries to load, transport, and unload tables of plants from the growing area to the order processing area.

It was realised that such systems would help Anglia Alpines to minimise the cost of moving plants about, especially from one growing environment to another. In addition, such table-based systems were sufficiently adaptable for use for a whole range of crops which would allow for future changes in the product mix.

DESIGN AND LAYOUT

This is the most critical factor and a good deal of attention must be paid to design and layout before installation begins as it is very difficult, if not impossible, to correct mistakes later.

Points to consider include: the position and frequency of the transit lines; the width and length of the tables and the fit with your pots and trays; the working height in relation to your own staff; the crop mix and how it might evolve; storage of empty tables and how to clean and feed these in and out of the system.

Finance must also be considered. Mobile benching is not cheap — tables cost about £500 ($815 U.S.A.) each and transit lines a similar amount though rail is quite cheap.

ADVANTAGES AND DISADVANTAGES

Disadvantages. It is slow to change from the rails to the transit lines and back again, although it is possible to motorise this operation. Both full and empty tables can be blown along the rails by even mild winds. Plants outside will also suffer more cold weather damage perched on tables than on the ground. Finally climbing over the rails is a real nuisance — and this is necessary when inspecting the plants, weeding, pinching, and staking, and for order selection.

Advantages. The advantages are in both production and handling. In production there is an increase of up to 50% in cropping area because you need less space for paths. The tables are isolated for pest, disease, and weed control, and can be easily moved elsewhere if necessary. Many different kinds of irrigation regimes can be used, including ebb and flood, irrigation booms, capillary matting, and hand watering.

In handling terms it is possible to put pots directly from a potting machine onto the table automatically at very high densities. It is remarkably easy to move plants about into different environments — hotter, cooler, under lights, and in shade, etc. Three people can move half a million 9-cm plants in a morning from one glasshouse block to another. And in straight lines it is perfectly easy to push 20,000 9-cm pots at walking speed. Plants can easily be moved from under glass to outside, and vice versa which is very useful for hardening off, and also for controlling growing speed and appearance. It is possible, for example, to root rapidly under glass and then finish off outside.

Having the crop at bench height also cuts down on backache, with plants easy to see at convenient working heights.

CONCLUSION

The combination of glass and mobile benches definitely improves plant quality and this author would certainly make the same investment again.

The Use of Paper Pots in Plant Production

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INTRODUCTION

The nursery stock industry has some 35 years of practical experience of growing woody plants in plastic pots. Research to develop alternative pots, made of biodegradable material, started approximately 15 years ago in response to: the increasing problem of waste disposal in industrialised countries; a growing ecological awareness; a rise in prices for plastic; and the possible technical advantages such pots might have for growers. From the many materials examined (paper, plant fibres from flax or coconut, wood fibres mixed with peat, laminated wood, biodegradable plastic), only a few satisfy the necessary requirements: sufficient durability; ability to be used in potting machines; and rotting ability after planting. This last point is particularly important for large volume pots. Two trials were undertaken to test the performance of 10-litre pots made of waste paper.

MATERIALS AND METHODS

Comparison of Container Material.

Trial 1: Comparison of Containers. Trial species were *Malus domestica* 'Cox Orange Pippin' and *Salix caprea* 'Weeping Sally' (syn. 'Pendula'). They were potted into four different 10-litre containers: Kitty-plast bio container "grey" (durability 2 to 4 years), Kitty-plast bio container "red" (durability 8 to 12 months), KEF pot, and plastic container (PP). The substrate consisted of peat, bark humus, wood fibre, clay, and green compost (48 : 30 : 10 : 7 : 5, by volume), fertilised with the controlled-release fertiliser Plantacote Depot 8M at 4 kg m^{-3}, and irrigated by drip irrigation. At the end of the trial growth parameters such as plant height, stem diameter, and shoot size were recorded. Subsequently the trial plants were planted into the field. Plastic pots were removed but degradable pots were left in position. Speed of establishment and quality of subsequent growth were measured.

Trial 2: Comparison of Substrate and Irrigation Method. Trial species were *Betula pendula* 'Youngii' and *S. cinerea*. They were potted into two types of 10-litre container: plastic container (PP) and KEF-pot. Four different substrates were compared: peat (100%); peat, wood fibre, bio compost, clay, and gravel (50 : 30 : 10 : 5 : 5, by volume); peat, wood fibre, and gravel (40 : 55: 5, by volume); and wood fibre and coconut pith (4 : 1, v/v). All substrates were fertilised with the controlled-release fertiliser, Osmocote Plus 8-9M, at 4 kg m^{-3}. Two different irrigation procedures were also compared for each combination of pot type and substrate: drip irrigation and capillary mat.

RESULTS

Comparison of Container Material. The container material had no influence on the plant height nor the stem diameter of *M. domestica* 'Cox Orange Pippin' (Table 1). With *S. caprea* 'Weeping Sally', pot material appeared to have a small influence on the number of long pendulous branches and on stem diameter (Table 2).

Table 1. Effect of pot type on growth of *Malus domestica* 'Cox Orange Pippin'.

Type of pot	Plant height (cm)	Stem diameter (mm)
Kitty-plast "grey"	188.48	17.4
Kitty-plast "red"	188.63	17.6
KEF pot	185.56	18.5
Plastic pot	183.32	18.5

Table 2. Effect of pot type on growth of *Salix caprea* 'Weeping Sally'.

Type of pot	Pendulous branches (no. of long)	Stem diameter (mm)
Kitty-plast "grey"	7.5	18.9
Kitty-plast "red"	11	20.0
KEF pot	8	19.2
Plastic pot	10	19.2

Root growth was more strongly influenced than shoot growth by pot type, with root circling appearing on plants grown in plastic pots but not in paper pots. The roots grew through the pot wall of Kitty-plast bio containers. When the roots emerged they were air-pruned which promoted growth of a better, more fibrous root system within the pot. With KEF pots roots were unable to grow through the side wall but did grow through the bottom of the pots. After planting out, plants in Kitty-plast bio containers showed comparable growth to those planted without pots in the first year because the roots were able to penetrate the pot wall. In contrast the pot wall of the KEF pot remained impenetrable and plant growth was reduced because of lack of water and nutrients (Table 3).

Table 3. Comparison of pot type on growth of *Salix caprea* "Weeping Sally' after planting out.

Type of pot	Pendulous branches (no. of long)	Stem diameter (mm)
Kitty plast "grey"*	30	24.0
Kitty plast "red"*	25	24.0
KEF pot*	16	20.0
Plastic pot**	29	25.0

*Planted with pot
**Pot removed before planting

Comparison of Substrate and Irrigation Method. The differences between the different substrates and the two-pot types were quite small when drip irrigation was used. *Betula pendula* 'Youngii' grew more strongly in substrates containing wood fibre than in peat (Table 4).

Table 4. Effect of substrate and pot type on stem diameter (mm) of *Betula pendula* 'Youngii' (drip-irrigation).

Type of substrate	Plastic pot	KEF pot
Peat 100%	12.6	12.9
Peat, wood fibre, bio compost, clay, and gravel (55 : 30 : 10 : 5 : 5, by volume)	13.7	13.4
Wood fibre, peat, and gravel (55 : 40 : 5, by volume)	14.5	13.9
Wood fibre and coconut pith (4 : 1, v/v)	13.9	14.1

Clear growth differences between the potting substrates occurred with *S. cinerea* grown on capillary mat. The strongest plants were produced in pure peat and reducing the proportion of peat in the substrate resulted in poorer growth. Here the differences between both container types were small. Plants grown in paper pots produced a slightly increased shoot fresh weight but the results for compost comparison were independent of the type of container (Table 5).

Table 5. Effect of substrate and pot type on shoot fresh weight (g) of *Salix cinerea* (capillary mat).

Type of substrate	Plastic pot	KEF pot
Peat 100%	563.1	600.3
Peat, wood fibre, bio compost, clay, and gravel (55 : 30 : 10 : 5 : 5, by volume)	420.0	475.0
Wood fibre, peat, and gravel (55 : 40 : 5, by volume)	550.6	487.9
Wood fibre and coconut pith (4 : 1, v/v)	350.0	406.9

The cause of the differences in growth between the different substrates was the amount of nutrient or salinity in the containers, and the effects were enhanced in nonpeat media and on capillary mat (Table 6 shows the example of potassium).

Table 6. Amount of potassium (mg litre^{-1}) in the different substrates at the beginning and end of the trial (capillary mat).

Type of substrate	Initial amount in substrate	Final amount (plastic pot)	Final amount (KEF pot)
Peat 100%	17	19	17
Peat, wood fibre, bio compost, clay and gravel (50 : 30 : 10 : 5 : 5, by volume)	166	128	104
Wood fibre, peat, and gravel (55 : 40 : 5, by volume)	47	69	39
Wood fibre and coconut pith (4 : 1, v/v)	315	137	224

There were clear differences in water consumption between the plastic pot and the paper pots. On capillary mat, four times as much water was used by the crop in paper pots as the crop in plastic pots, as regulated by tensiometers.

CONCLUSION

It is possible to produce nursery stock in 10-litre degradable paper pots to an equivalent quality and using the same growing regimes as for production in plastic pots. Peat-reduced substrates can be used. The use of capillary mat irrigation is possible, if good, low-salt substrates are used. A particular advantage of paper pots is that no root circling occurs and a compact, fibrous, self-pruned rootball is able to develop. The KEF pot is a durable container with an acceptable appearance but it does not degrade quickly enough when planted. The Kitty-plast bio containers allow a good rooting through after planting in the soil, but durability during cultivation and shipping is not as good as the KEF pot. In the current market it is not possible to pass the higher cost of the pot and higher production costs on to the customer.

Paper Pots in Liner Production: Experiences with the Humulus Pot

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INTRODUCTION

Humulus pots are produced from the same material as egg packaging which is 100% recycled paper. The measurements are 9 cm × 9 cm × 8 cm, the volume is 365 ml, and it is food-grade material.

At Kordes Jungpflanzen, trials were undertaken of all available biodegradable and recycled pots before selecting Humulus pots for the production of young plants in large quantities in 1992. Since then more than 12 million young plants grown in Humulus pots have been delivered to customers.

The reasons for choosing the Humulus pot were:

- It is pressed twice for strength;
- It runs well in the magazines of potting machines;
- Its costs are reasonable.

When the new pot was introduced customers were deliberately not informed. This was so that they would receive an order in which some plants would be in Humulus pots and others in plastic pots which enabled them to see that growth was equally good in both cases.

CULTIVATION AND TRANSPORT

For cultivation and transport of the Humulus pots Kordes Jungpflanzen uses a tray system. The tray contains 15 pots, measures 53 cm × 31 cm, and fits well into CC-Containers. The pot stands very stable in the tray, making bed frames unnecessary. Plants in partly filled trays remain stable and do not fall over. Handling and transport are easy with this system. In one mechanised operation the trays can be laid down, pots placed in the tray, pots filled with growing medium, and planting holes drilled. Plants are potted by hand.

Pot spacing in the tray is designed to give every plant a growing space of 10 cm × 10 cm but pot placing can be staggered for plants such as groundcovers or roses which need more space.

Humulus pots are suitable for cultivation in other types of holders, transport systems, or pot trays. The only point to watch is the length of time plants are allowed to stand close together because they are able to root through the pot walls and into one another. However, the tray system used at Kordes Jungpflanzen allows for growing up to 2 years.

During production Kordes Jungpflanzen treats the Humulus pots like plastic pots. In dry summers a little more water is needed than with plastic pots and Humulus pots require a little more nitrogen due to the decomposition of the pot. With the same amount of fertiliser the plants grow just a little bit less than in plastic pots.

Root growth is better in Humulus pots because plants root through quickly and there is no root circling.

In humid and wet periods the drainage is a lot better in Humulus pots compared with plastic and problems with *Phytophthora* are reduced. Humulus-grown plants are hardier in the winter because the range of temperature in the medium is not as high as with plastic pots.

ECONOMIC CONSIDERATIONS

The Humulus pot is not only ecological it is also economical. It costs 1.5 Pfg. (ca. 0.8¢ U.S.A.) more than an equivalent-size plastic pot. But the extra cost is recovered because with the Humulus pot there are no costs associated with pot removal at potting on or planting out. Unsold plants and plants not reaching specified quality standards can be composted along with the pot.

In Germany an additional advantage is that there are no costs associated with waste disposal with the Humulus pot as there are with plastic pots. These considerations will be important in other European Community (EC) countries as waste legislation becomes more widespread.

There are also economic advantages for the customer:

- Less time, and therefore cost, for removing pots;
- Planting and potting is faster, hence cheaper;
- Saves picking up and disposing of pots;
- Costs for transport and waste disposal are lower.

Paper pots are especially cost saving for garden and landscape companies.

CONCLUSION

From the experience of Kordes Jungpflanzen, biodegradable paper pots such as the Humulus Pot have many potential advantages:

- The pot saves money;
- It performs better with respect to forthcoming environmental laws;
- It has reduced waste disposal costs;
- It improves the image of the nursery;
- It can win new customers.

Kordes Jungpflanzen would be happy to do its whole production in the Humulus pot. Customers who have used them are increasing the proportion of the plants they grow in Humulus pots.

Self-Steering Systems for Tractors and Other Cultivation Machinery

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INTRODUCTION

Most field-grown horticultural crops are planted in rows. Cultivation is necessary both between the rows and in the rows for weed control. On large nurseries cultivation is mechanised to a greater or lesser extent to keep labour costs as low as possible but in most cases cultivation relies on human input to steer the cultivation machinery. Existing mechanical aids to steering use feelers. The feeler often uses the crop plants themselves to provide a fixed reference point for the rows. Such feelers can only be used if the crop plants are robust as damage to stems may occur. However, feelers are used in fruit and vegetable production and also in hardy nursery stock production. Feeler-based systems are costly to purchase because they are produced in relatively low numbers. They also bear high maintenance costs. Steering guidance using satellite global positioning systems (GPS) (Fig. 1) is a more sophisticated option for the future. However, the level of accuracy is at present only to the nearest metre, and therefore not exact enough for horticultural cultivation.

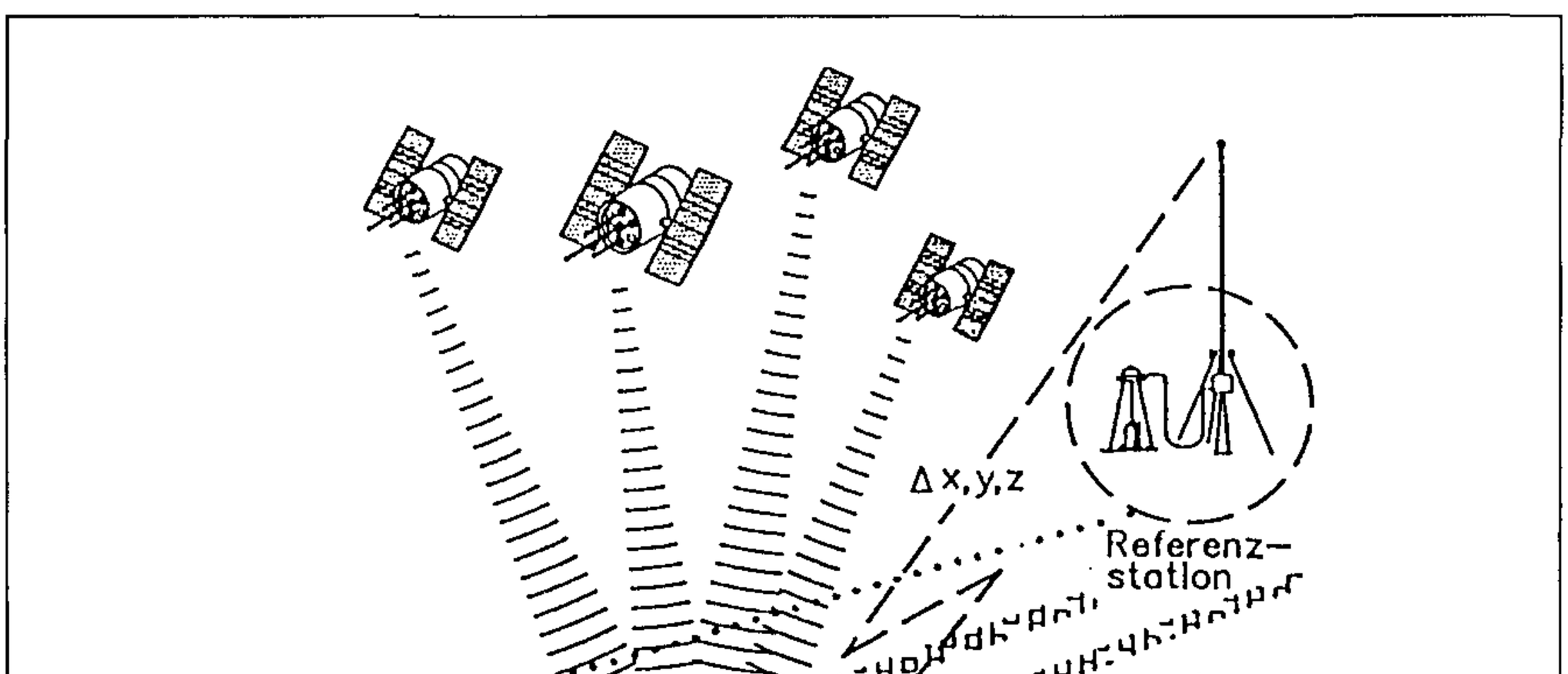

Figure 1. Steering with satellites.

DEVELOPING AUTOMATIC STEERING SYSTEMS

Other special measuring systems and radar equipment are being investigated. These systems use one or more fixed points in the field for navigation. These can operate effectively with a maximum distance of 1500 m between the fixed reference point and the cultivator. The accuracy is higher than with GPS but the working speed is very slow. Fully automatic guidance must be able to undertake the following processes:

1) The identification of the plants or detection of rows or other guide lines.
2) Output of a steering signal.
3) Reception and conversion of the signal by the electronic steering.

Signalling Systems. Mechanical vibrations and electromagnetic waves are identical in the rate of transmission and reflection. The direction of these waves and their reflection is the basis for steering system signalling mechanisms. Mechanical vibrations and electromagnetic waves will be referred to simply as "waves". Wave transmission between transmitter and receiver is demonstrated in Fig. 2.

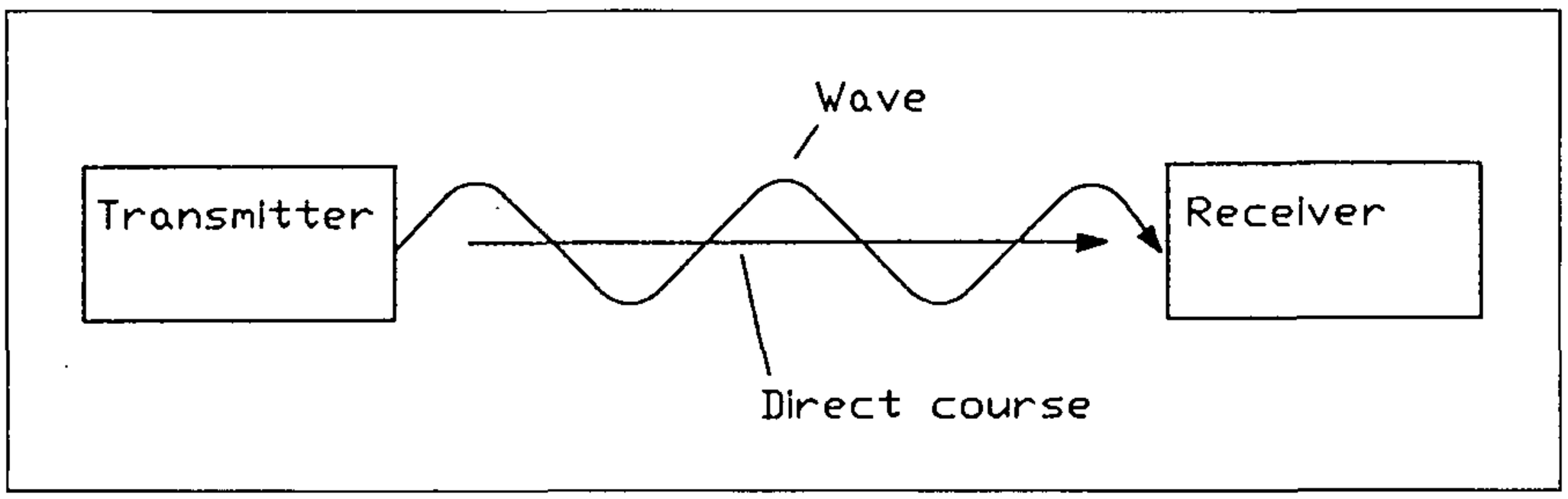

Figure 2. Wave transmission between transmitter and receiver.

In most cases, transmitter and receiver are placed in the tractor. The signal is sent to a fixed point from where it is reflected back to the receiver. The difference in position between the transmitter/receiver, a "black box", measures the difference in position of the sent and received signal, thus giving a measurement of the tractor's position (Fig. 3). The receiver can detect objects in the receiver area and calculate the exact distance from the sensor to the object.

The following systems can be used for steering machines in nursery.

- Ultrasound (mechanical vibrations)
- Infrared light (electromagnetic waves).
- Laser light (electromagnetic waves).

Ultrasound. Ultrasound waves are spread and be can reflected. These waves work with a frequency of 20 kilo Hz to 1 giga Hz. The waves are reflected from the surfaces of objects, including plants, in different ways according to the type of surface. The reflected waves are evaluated by the receiver. The steering system identifies objects in the adjustable receiver area and calculates the distance between the sensor and the objects (Fig. 4).

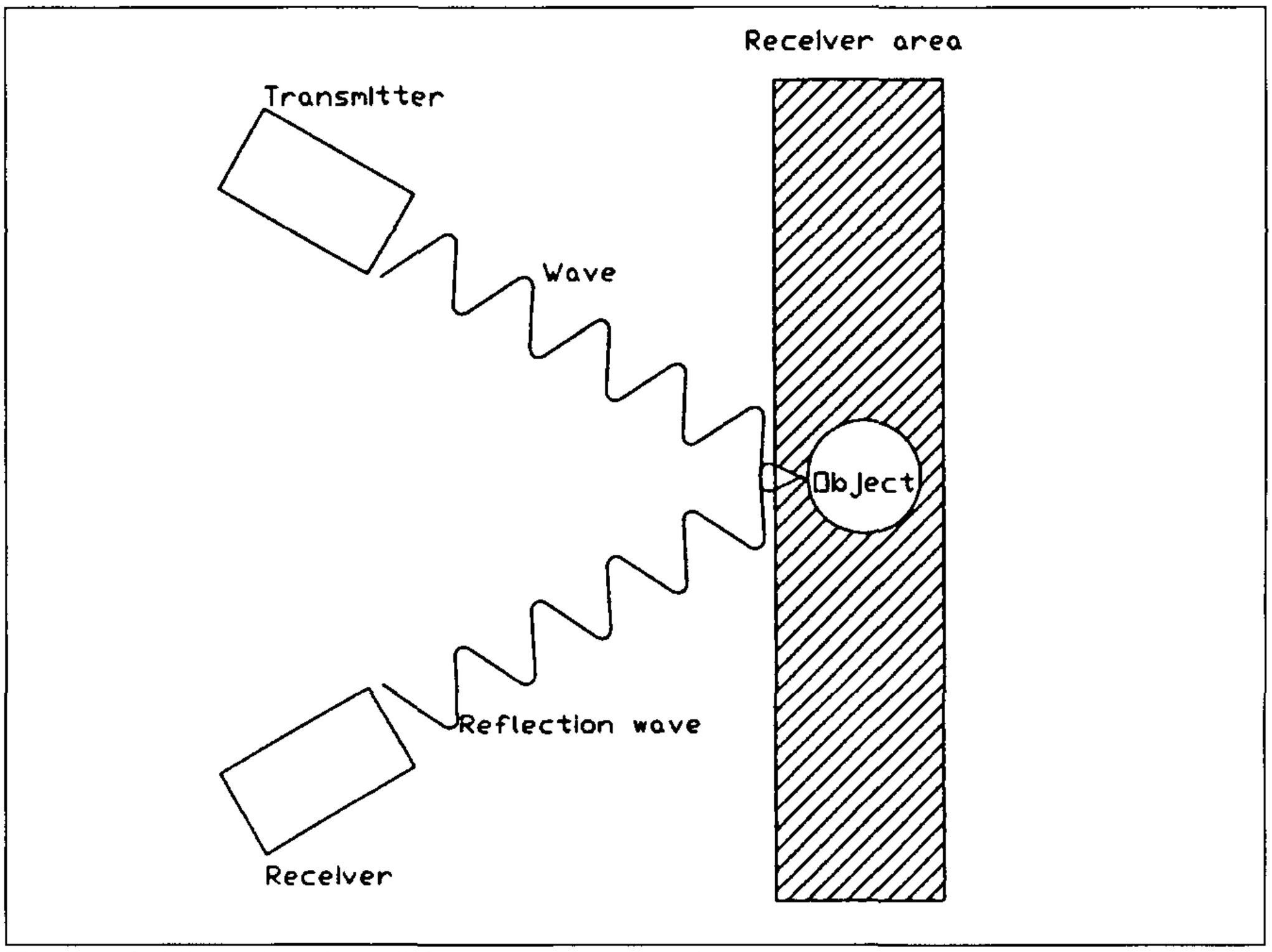

Figure 3. The reflection of the waves on an object.

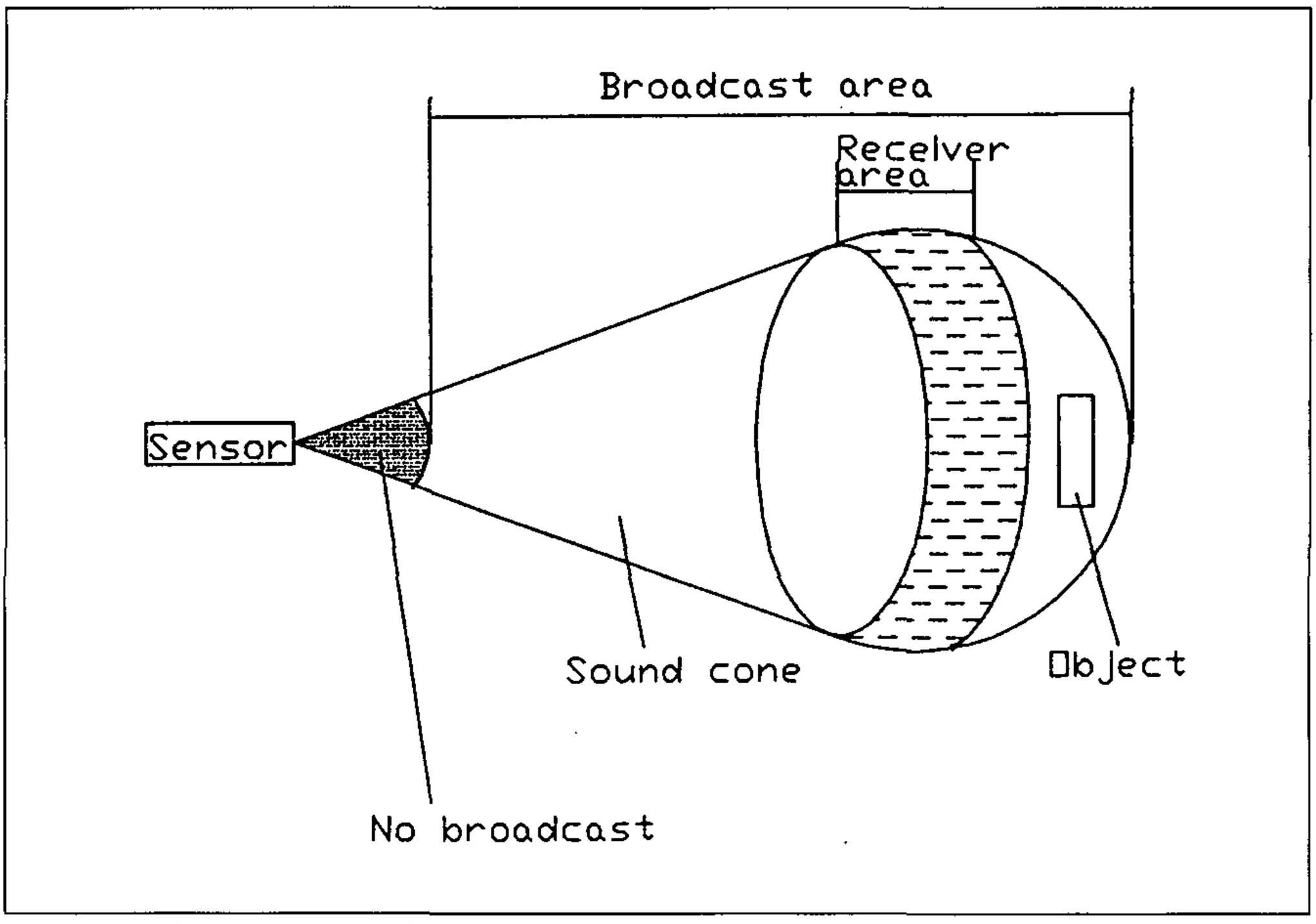

Figure 4. Receiver area of an ultrasound sensor (transmitter and receiver).

The receiver coverage can be adjusted from 5 cm to 3 m and the angle of spread ranges from 6 to 90 degrees. A maximum of three objects can be recognised per second. The sensor can be adjusted to recognise objects three times in order to avoid mistakes. Ultrasound sensors have the advantages that both foreground and background cut off are possible and that the receiver area can be adjusted accurately. But dust, fog, smoke, and hot air can cause errors, which is why there have been problems with thermal weed control using ultrasound sensors. An ultrasound sensor costs between 50 and 100 Euros ($56 and $133 U.S.A).

Infrared Light. The transmission principles are the same as for ultrasound, and infrared sensors can be used for object identification. The degree of reflection by objects depends on the surface colour. The maximum range for object identification is 8 m (Fig. 5).

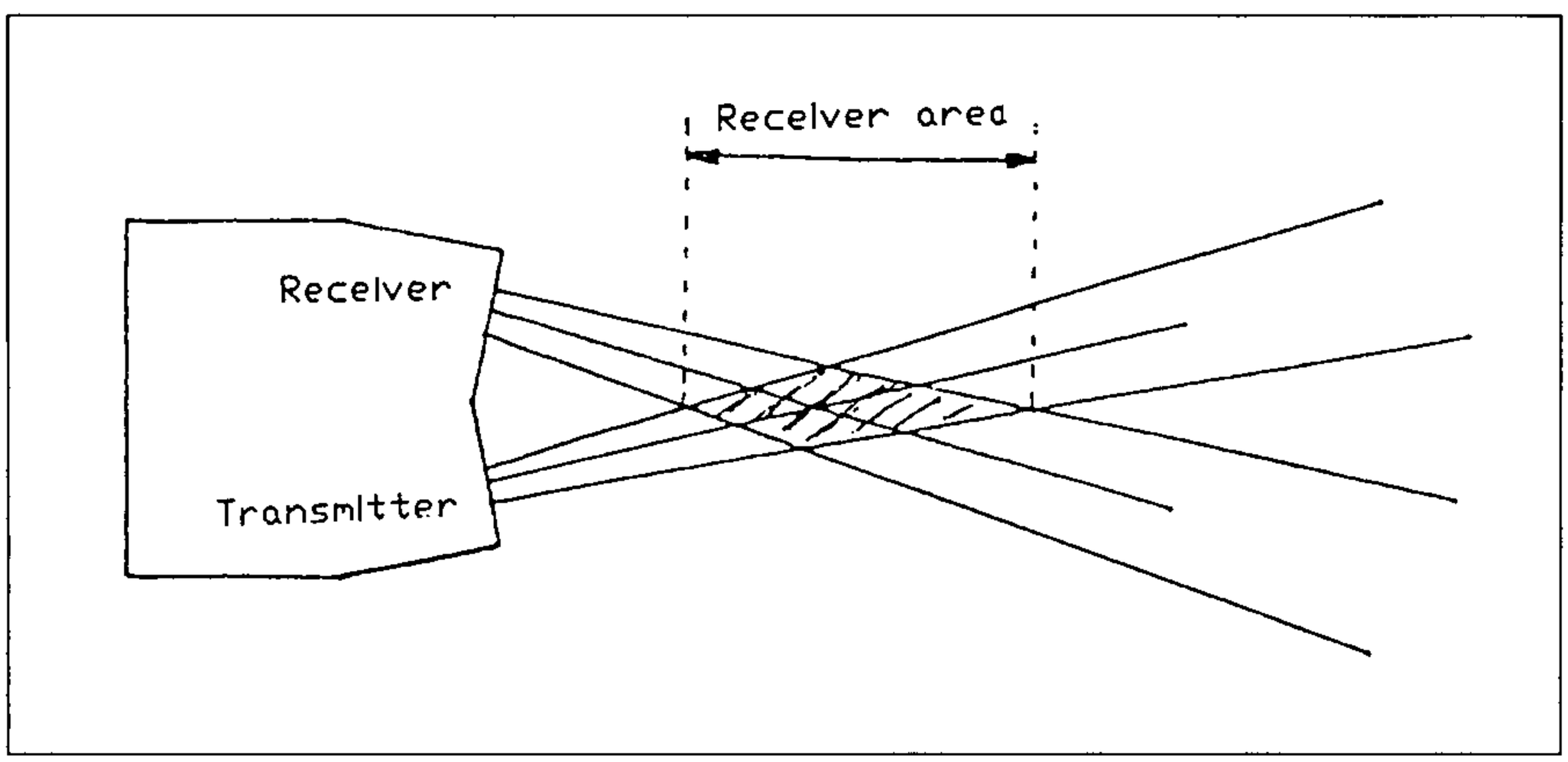

Figure 5. Principle of the background cut off.

In another kind of infrared sensor the direction of waves is parallel between transmitter and receiver (Fig. 6).

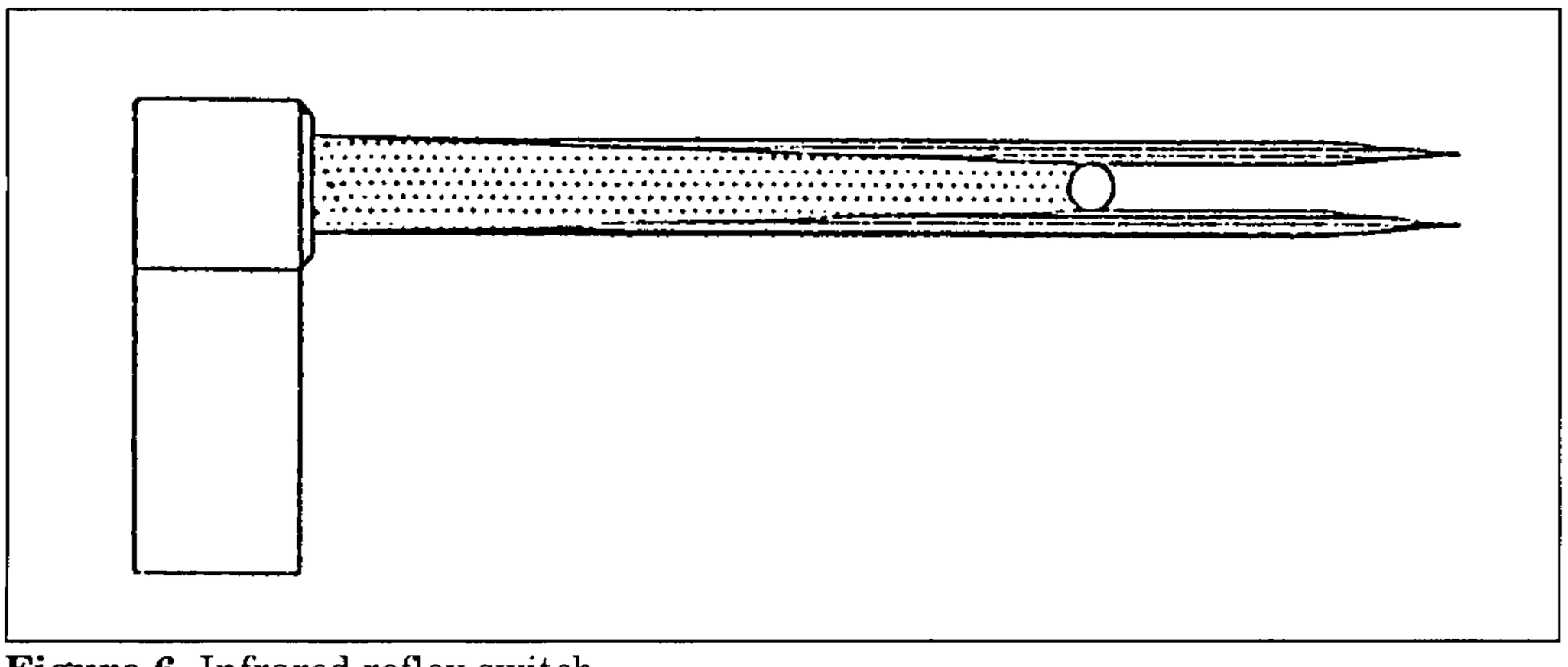

Figure 6. Infrared reflex switch.

The receiver area is adjustable within fixed limits with some infrared systems but foreground cut off is not. Infrared systems can be very good at higher speeds (over 1 km h^{-1}) and for small objects (not less than 2 mm thick). Dust, fog, and smoke do not have any effects on the identification process. The cost of infrared sensors is between 50 to 100 Euros ($56 and $113 U.S.A).

Laser Light. Laser light has been used both to carry signals for systems based on reflection (as in ultrasound and infrared light) and to operate steering over a long distance with separated transmitter and receiver. Reflected laser light systems will detect objects of less than 2 mm and the plant rows are used for the steering signal. The price is about 500 Euros ($560 U.S.A).

As laser light has a virtually parallel beam, rather than a spreading beam of the other systems, it can be used to guide cultivators over long distances with separated transmitter and receiver. For example, planting machines can use laser guidance for high quality, straight-row planting. This system works over a distance of 500 m between transmitter and receiver. In such a system the laser is set up to transmit 5 or 7 beams arranged close together horizontally. When the tractor mounted receiver detects the middle beam the position is correct. If a beam to the left or right is detected a corresponding adjustment is made to the steering. As laser light travels in a straight line there must be a clear unobstructed view between transmitter and receiver. Compensation can be made for small height differences across the field (Fig. 7).

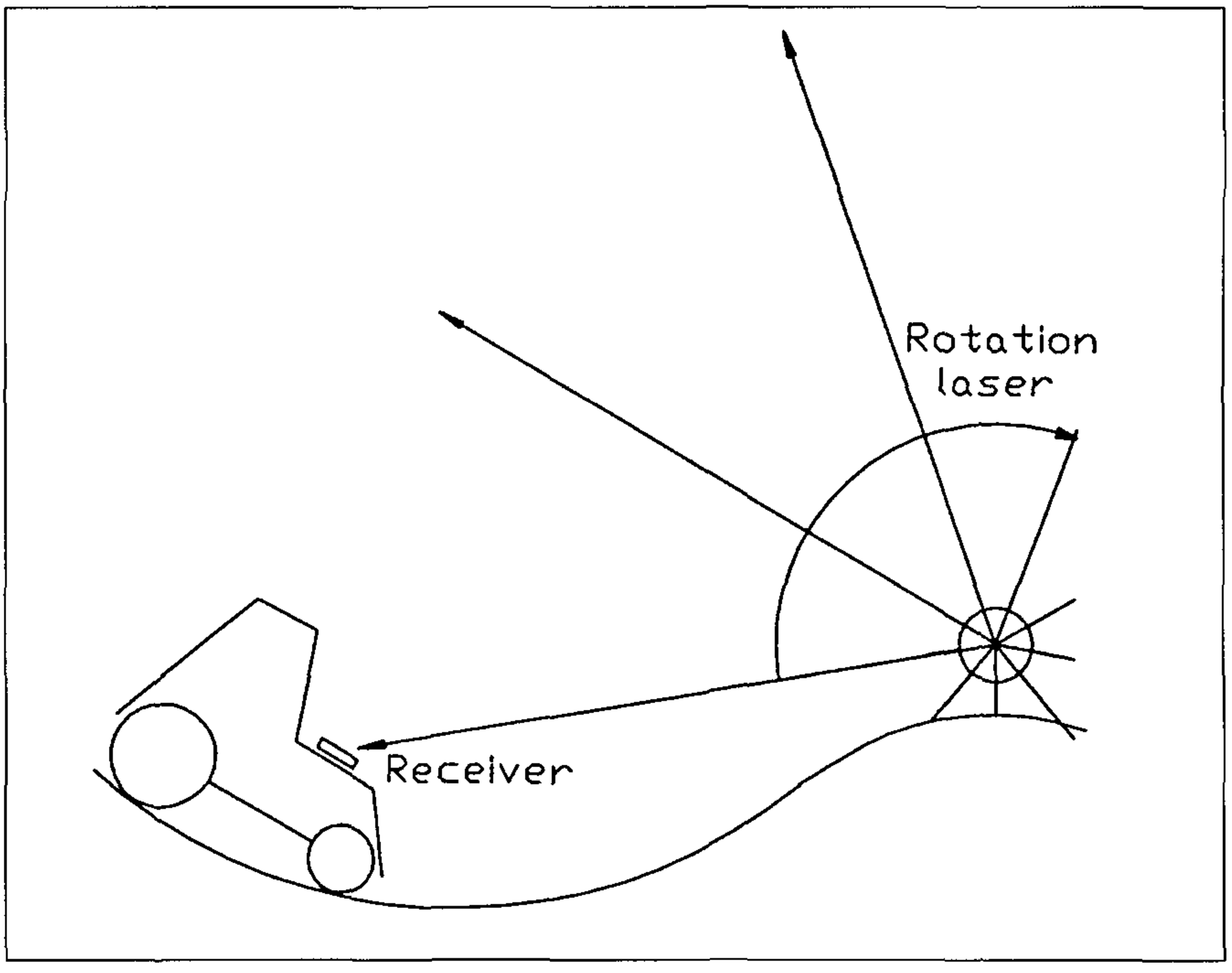

Figure 7. Laser steering in the field.

In theory, laser-guided systems can be used at distances of over 500 m but in practice systems cannot make fine enough adjustments at more than this distance. The cost for steering systems of this kind is approximately 5000 Euros ($5600 U.S.A).

Steering Systems. The technology needed to receive the steering signal is not very complex. An electrical connection gives a command to a pneumatic or a hydraulic steering mechanism like those used in car power-steering systems.

PRACTICAL APPLICATIONS

Thermal in-row Weed Control. At the Institute for Engineering in Horticulture, of the Fachhochschule Weihenstephan, we have run trials with a thermal weed control machine for in-row weed killing. The device has two burners which send a flame and hot air between the plants in the rows. Two sensors have been installed. The first detects the cultivated plant and switches off the burner. The second is placed 3 to 7 cm back from first and recognizes the weeds and switches on the burners. The signals from the sensors close and open a magnetic valve from the gas supply.

Soil Cultivation for in-row Weed Control. The Clemens company developed a soil cultivator which used an ultrasound sensor to guide the shear and steer the machine. When the ultrasound sensor detected a crop plant, a signal was transmitted to the hydraulics. The signal had to steer the hydraulics and move the share out of the rows. Combining two functions on one sensor caused problems with the equipment so, in cooperation with the Clemens Company, the Institute for Engineering in Horticulture, of the Fachhochschule Weihenstephan, has added an infrared sensor to a new steering system and this has improved the effectiveness of the machine. The machine is effective with plant distances in the rows greater than 40 cm and with a workspeed slower than 4 km h^{-1}.

Laser Guided Steering for Planting Accurate Rows. There are many situations in horticultural production where exact straight rows are necessary (e.g., 6-row planter and 12-row spraying systems for strawberry production) and for accurate cultivation work exact rows are a great advantage. Planters with laser light steering, such as those currently being produced by the Wagner Company, can be used.

There are two kinds of laser-guided steering system. In one, the receiver emits an acoustic or a light signal. The tractor driver uses this signal to keep on a straight line. In the other, the signals from the receiver are used to control an electrical or hydraulic steering mechanism and the driver has only a supervisory function.

TECHNICAL ASPECTS OF STEERING CONTROL

Very costly systems have been developed to transform the signals received from sensor but new technical developments are helping to greatly reduce costs. For example, on-board computers have been developed for use on agricultural machinery. It is possible for the computer to accept signals from, for example, sensors so that the steering can be guided by the computer. It is also now possible to develop programmable industrial steering originally developed for factory handling systems.

SUMMARY

Plant rows can been used as guide lines for steering machines on the nursery. Sensors which emit ultrasound or light detect the position of the plants. In many cases infrared and ultrasound sensors work very well in soil cultivators. For planters, laser beams are used for accurate rows.

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Within-Shoot Variation in Propagating Stem Cuttings of Two *Eucalyptus globulus* Interspecific Hybrids

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INTRODUCTION

Interspecific hybrids of *Eucalyptus grandis* Hill ex Maid, propagated by stem cuttings, are planted widely in the tropics and subtropics, especially on sites which are marginal for the pure species. In Mediterranean regions, interspecific hybrids of *E. globulus* Labill. could become equally prominent on analogous sites where, for example, the pure species suffers from excessive winter cold or summer drought.

Clones of the hybrids *E. viminalis* × *E. globulus* (VG) and *E. cypellocarpa* × *E. globulus* (YG) were each multiplied from a seedling by stem cuttings. Within-shoot variation in the initial survival and rooting ability of the hybrid cuttings was investigated, and compared to that in *E. globulus*.

MATERIALS AND METHODS

Hybrid seed was created by controlled pollination in the Stora CELBI breeding programme. The pollen parent was *E. globulus* Labill. from the Portuguese landrace, while the seed parents were of unknown provenance.

The juvenile shoot morphology of the hybrids was intermediate between that of the parent species. Leaves were narrowly lanceolate (VG) or ovate (YG), and in both hybrids the leaves were opposite, sessile to slightly petiolate, and nonglaucous. In both, the stem was also square in cross-section and nonwinged close to the apex, otherwise rounded. The VG stem bearing mature leaves tended to be relatively thin and stiff while the YG stem was more like that of *E. globulus*.

Mother plants were grown in 10-litre pots in a double-skin plastic greenhouse. Minimum night temperatures were 10 to 15C and day temperatures were 25 to 35C. The plants were harvested for cuttings every 2 to 4 weeks when principal shoot length was up to 20 to 30 cm. Shoots less than 15 cm long were left on the mother plants to facilitate renewed growth, maintaining a globular crown on a low woody framework. Cuttings were prepared from harvested shoots (including first order laterals) at least 10 to 12 cm long.

The cuttings were set in a glasshouse in a peat and perlite mixture (2 : 1, v/v) (containing 3 kg m^{-3} of slow-release fertiliser 15N : 10P : 12K), and kept well wetted with intermittent mist. Temperatures were 15 to 20C at night and 20 to 30C during the day, minimum relative humidity was 85% to 90%, while shade of 85% was provided on clear days. Cuttings harvested in January and February received supplementary light in the glasshouse, extending day length to 16 to 18 h.

Trials Conducted.

1) ***Contiguous One-node Cuttings.*** The shoot apex and immature leaves (less than 75% full-size) were removed from harvested shoots and four contiguous one-node cuttings were then prepared

from each, starting from the distal node (node 1). The stem of the distal node was relatively thin but internode length and trimmed leaf area (approximately 33% of entire area) were similar at all node positions. The cuttings were set in February (VG) and May (YG).

2) ***Decapitation.*** Entire apical cuttings consisted of two leafy nodes (lower leaves fullsize, upper leaves at least 75% full size) which were trimmed to approximately 33% of their entire area, the internode below and the apical region of the shoot above (apex and immature leaves). Cuttings of both clones were set in January, either entire, or decapitated by removing the apex and immature leaves less than 75% full size.
3) ***The Length of the Cutting Stem.*** Entire cuttings (as in 2 above) were set in February in both clones, retaining either one or two internodes below the lowermost leaf pair. Cutting lengths were 8 to 10 cm and 12 to 15 cm respectively, and the longer cuttings were thicker and woodier at the base.

Each trial consisted of one harvest of cuttings from each clone (80 to 120 cuttings per treatment per clone in randomised blocks). Cuttings were lifted after 35 to 40 days and the following variables were recorded: survival (%), rooting (%) of survivors (if there was any mortality), and roots per rooted cutting. Cuttings were "dead" if they had no surviving stem below the level of the substrate or no remaining foliar area. Original percentages are cited but were angular-transformed before analysis of variance.

RESULTS

1) **Contiguous One-node Cuttings.** Table 1 shows that, in both hybrids, node position had no effect on survival. Rooting (%) of survivors was highest in subdistal (node 2) cuttings, while the more basal cuttings had much lower rooting ability.

Table 1. Survival (%), rooted (%) of survivors [root (%) survivor] and roots per rooted cutting (roots/rooted cutting) of one-node cuttings of two *Eucalyptus globulus* hybrids. Node 1 is the distal node, node 2 subdistal, etc.

	Node				
Hybrid	1	2	3	4	F
E. viminalis × *E. globulus*					
Survival (%)	92	95	95	86	NS
Root (%) survivor	39	51	24	17	5.5^{++}
Roots/rooted cutting	1.7	1.9	1.2	1.2	2.7 NS
E. cypellocarpa × *E. globulus*					
Survival (%)	100	100	100	100	NS
Root (%) survival	42	50	24	14	7.2^{**}
Roots/rooted cutting	1.8	1.9	1.8	2.3	1.2 NS

$^{++}P < 0.025$
$^{**}P < 0.01$
NS = not significant

2) Decapitation. Decapitation slightly increased survival in the YG hybrid but not in the VG hybrid, and had no effect on rooting ability in either hybrid (Table 2).

Table 2. Survival (%), rooted (%) of survivors, and roots per rooted cutting, of cuttings of two *Eucalyptus globulus* hybrids, either left entire or decapitated.

Hybrid	Entire	Decapitated	F
E. viminalis × *E. globulus*			
Survival (%)	100	100	NS
Root (%) survival	72	75	NS
Roots/rooted cutting	2.5	2.0	2.0 NS
E. cypellocarpa × *E. globulus*			
Survival (%)	92	97	2.9^{++}
Root (%) survival	91	90	NS
Roots/rooted cutting	2.6	3.0	2.4 NS

$^{++}$P <0.1. NS = not significant

3) The Length of the Cutting Stem. The results were similar in the two hybrids (Table 3). Survival was uniformly high, but cuttings with a longer stem had slightly lower rooting ability than cuttings of standard form.

Table 3. Survival (%), rooted (%) of survivors and roots per rooted cutting of two *Eucalyptus globulus* hybrids, in which either 1 or 2 internodes were retained below the lowermost leaves.

Hybrid	1	2	F
E. viminalis × *E. globulus*			
Survival (%)	99	99	NS
Root (%) survival	87	74	6.1^{**}
Roots/rooted cutting	2.3	2.1	0.9 NS
E. cypellocarpa × *E. globulus*			
Survival (%)	97	99	NS
Root (%) survival	93	87	2.1 NS
Roots/rooted cutting	3.0	2.4	7.2^{++}

**P < 0.1 and
$^{++}$p < 0.025.
NS = not significant

DISCUSSION

Within-shoot variation in the initial survival and rooting of stem cuttings was similar in two *E. globulus* interspecific hybrids. In both, the rooting ability of one-node cuttings was concentrated close to the apex of the shoot (Table 1). Decapitation of entire apical cuttings (leaving the cutting with only newly mature leaves) had no effect on rooting (Table 2). And in apical cuttings with the same leaf complement, a relatively long stem slightly reduced rooting (Table 3). In both hybrids, the moderate to low rooting of one-node cuttings (Table 1) indicates that only one (larger) cutting should be prepared per shoot.

The survival of cuttings was consistently high in both hybrids. Their leaves were nonglaucous, hence easy to wet, and physically tougher than those of *E. globulus*. However, in the YG hybrid, mortality was slightly higher in entire than in decapitated cuttings (Table 2), as was found in *E. globulus* (Wilson, 1993).

The characteristics of the hybrid cuttings, considered together, were slightly different from those of *E. globulus*. In contiguous one-node cuttings, rooting was highest in subdistal cuttings in the hybrids (Table 1) but in the distal cutting in *E. globulus* (Wilson, 1993), suggesting that the newly matured leaf and the maturing leaf, in the hybrids and *E. globulus* respectively, had a particularly positive effect on rooting. Thus, decapitation of entire apical cuttings (removal of the shoot apex and immature leaves) tended to reduce rooting in *E. globulus* (Wilson, 1993) but was not prejudicial in the hybrids (Table 2). However, in both the hybrids and in *E. globulus*, the decline in rooting towards the base of the shoot was rapid (Table 1; Wilson, 1993).

In conclusion, similar propagation techniques for the hybrid and *E. globulus* cuttings should be appropriate, although there may be some differences in (for example) the appropriate form of cuttings or their resilience in the propagation environment.

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Personnel Management in Propagation: Report on the Mary Helliar Travel Scholarship 1997

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INTRODUCTION

In all sectors of the European horticulture industry, including propagation, it is becoming more and more difficult to recruit good technical staff. Therefore, it is of paramount importance to ensure that, once an organisation has recruited good people, it is able to keep them. While much research has been undertaken on the technical aspects of plant propagation, little has been recorded about the equally important aspect of personnel management. This study attempts to redress this imbalance, by reporting the findings of a study trip to the West Coast of North America to look specifically at personnel management in propagation.

The report is based on a total of 15 nurseries visited, from Washington in the north, through Oregon, and finishing in California. The West Coast of North America was chosen because the nurseries there have an international reputation for technical innovation and are also very successful at implementing techniques in personnel management.

MANAGEMENT STYLE AND STRUCTURE

Most of the 15 nurseries had a traditional tiered management structure, while a few had changed to a flatter structure.

Tiered Management. This structure has clearly defined roles and written rules. Often managerial action is governed by conformity to procedures and "custom practice". Management monitors and controls the work force based on the assumption that managers and workers have very different interests, with managers being concerned about company profits and staff being concerned about their individual wages. My observations on this tour revealed this attitude is changing. As workers or staff become more assertive and show that they are willing to take on more responsibility, they are being recognised, supported, and encouraged by managers to do so.

Flatter Management. Some organisations are developing management structures which seem to have fewer top level managers and more middle level managers and supervisors. Where it has been introduced it has been a success and the benefits include better communication and less bureaucracy with staff enjoying being on a more equal footing. Generally speaking, management policies in these organisations reflect an individual approach with rewards and opportunities being linked to individual effort assessed by the performance appraisal method.

Some of the nurseries visited appeared to successfully combine these two approaches. As the industry changes, it is likely there will be a swing over to the more humanistic flatter management structure. However, if in an individual business the change is too sudden, benefits could be short lived. The most obvious problem could be the loss of morale and commitment that can affect those who remain in an organisation which may be having to increase productivity with fewer people.

RECRUITMENT

Generally speaking, propagation technical staff are recruited by the propagation manager. Most of the propagators and managers in the survey said it was becoming increasingly difficult to find good staff. Some nurseries have had to resort to employment agencies to recruit staff.

On most of the nurseries in this study, Hispanic people make up the main complement of the work force, although these workers tend to be more settled in California than further north in Oregon and Washington. One of the reasons for this is California's proximity to Mexico and the fact that the diversity of horticulture there can provide many of them with year-round work.

Nurseries in the states of Oregon and Washington have not been employing or relying on the Hispanic work force for as long as those in California, but this situation is changing rapidly.

Staff are recruited by various different means, including: advertisements placed in local newspapers, existing staff recommending relatives or friends looking for work, and recruitment agencies.

Recommendation, however, appears to be by far the most popular method and seems to work well because the responsibility of recommending someone good rests with the existing employee.

In some nurseries new recruits are expected to fill in questionnaires to help discover hidden talents. This simple yet effective questionnaire is a useful tool for propagators and managers to find the right staff and fit them into the work for which they are best suited. For example:

- What kinds of work have you done in the past?
- Have you ever worked with plants?
- Have you ever watered or irrigated?
- Have you ever planted?
- Do you like to:
  - Do construction work?
  - Do cement or brick work?
  - Do plumbing?

At Hines Nurseries of Vacaville they say, "unused talents never grow". Finding people's hidden talents and getting them to use them to their full potential is the aim.

The majority of nurseries visited, especially the larger companies such as Briggs Nurseries, Hines, Monrovia, and Skagit, provide job descriptions so that new recruits know what is expected of them.

In the U.S.A., health and safety are a very important part of working life. It is not unusual for new recruits to spend their first day entirely being briefed on health and safety guidelines. The onus is put very much on the staff to behave and work responsibly or suffer the consequences.

There is a shortage of good skilled propagators, especially those with a proven track record, in the U.S.A. For this reason skilled horticulturists and propagators are well paid and highly regarded in the industry.

INDUCTION AND TRAINING

Staff training is vital to the success of any business and without competent staff who have been trained to do the job, productivity suffers and quality becomes indifferent. Such is the structure of the larger nurseries visited, that there would not be enough

skilled staff to oversee an unskilled workforce. The emphasis is therefore on teaching, even the general workers, the basic skills to do the job and be accountable for their work.

Induction is more or less the first real training that new recruits gain. It is mainly about rules, guidelines, and orientation and it is the time when they are made familiar with the employee handbook. On most nurseries visited, these handbooks are very comprehensive and informative. There seems to be little funding or support from government agencies for the training of staff in these nurseries.

In one particular nursery, staff are trained to set standards for safety, quality, productivity, housekeeping, and team development. From day one they are trained using the "buddy" system, which involves pairing up an established worker with a new recruit. New recruits are not required to work on their own for the first 2 months, the time they are given to reach the required standards.

On the majority of nurseries, for staff who show initiative, training is available at all levels from management training, to in-house training for basic communication skills.

Hispanic workers are encouraged to learn English to improve their working life, their communication skills, and their promotion prospects. Equally, U.S.A. workers are encouraged to become bilingual in English and Spanish.

In the U.K. "Total Quality Management" (TQM) and "Investors in People" (IiP) are commonplace throughout the nursery industry. In the United States TQM is widespread, but nurseries seem to have changed and adapted it to suit their own individual situations and make it more relevant to their staff. The nurseries who have invested in this area really stand out. It shows in consistency of quality of the product and most importantly in the attitudes of the staff themselves.

HEALTH AND SAFETY

After staff retention, health and safety is the single most important issue for nursery management in the U.S.A. Health and safety committees are run by staff and departments meet monthly to discuss improving the safety, safety awareness, and general health of fellow workers. At Hines Nurseries a health and safety awareness day is scheduled every week and all key people wear yellow T-shirts to emphasise the day.

On most of the nurseries surveyed, propagators and managers take health and safety issues very seriously and, being good people-managers, they make the welfare of their staff their top priority.

COMMUNICATION

All the American managers and staff I met on this tour were great communicators. I met many propagators and growers who, for the most part, were open, honest, and uninhibited, when it came to communicating with me or members of their team. I was constantly told that "people are the greatest resource" in the nursery, not the "greatest expense", as so many people in Europe often seem to see it. Most nursery managers I met also seemed to feel that it was important to communicate positively; there is no point preaching doom and gloom. If you have something negative to say, turn it into something positive, by coming up not only with a problem but with a solution.

Good communication was ensured by involvement of staff at all levels, a high degree of mutual respect between staff and managers, encouragement of participation, and by getting the message across that good communication is to the benefit of everyone.

MOTIVATION

To be highly motivated one needs to like what one is doing and be happy in one's work environment. On the tour I met very dedicated propagation staff who put in long hours and take ownership of their crops because they enjoy it and, sometimes, because if they don't no one else will. Some say propagation is like a vocation, in the extreme it takes you over and you are swept along. It's like an obsession.

Money, of course, is also a motivating factor, but by no means the main one. Those working in propagation know horticulture is not the best paid industry in which to have a career — but that's not why they became propagators. Profit share is common on most of the nurseries visited, both large and smaller businesses. This not only provides a bonus on top of salary, it gives staff a stronger sense of belonging and instills greater commitment. They can own a part of the business in a way, and it places the success of the business in their hands.

HOW PROPAGATION MANAGERS MOTIVATE STAFF

Managers and propagators of the nurseries visited said this was sometimes difficult. Because well motivated staff are so hard to come by, every nursery employs some staff who are only there "because it is a steady job". Although there are struggles with staff who are set in their ways, efforts are made to encourage and motivate them, especially when it comes to upgrading and promotion. If they show willingness, they have the potential to earn more money. From the beginning it is important to establish and maintain the trust and support of your staff and your managers, by creating and maintaining effective working relationships.

COMMITMENT AND EMPLOYEE INVOLVEMENT

Because commitment is important to the success of the business, managers of the nurseries studied feel that employee involvement at all levels is the way forward. Those in charge of propagation say that providing opportunities for staff to meet with management, through membership on committees and arranged social gatherings, encourages involvement and sends signals to individuals that they are valued. Managers of some nurseries believe that commitment from staff comes from having strong clear messages. These include business mission statements and policies but it is important that management actions follow these statements and policies. Low staff commitment can show itself in high labour turnover, high absenteeism, and poor performance.

Team briefing, or downward communication as it is also known, is a system operated by U.S.A. management. Its objective is to make sure that all employees know and understand what they and others in the company are doing and why. It is about leaders and their teams getting together in groups for about a half an hour on a weekly basis to talk about things that are relevant to their work. These meetings reinforce management by differentiating team leaders from their people and reminding them and their team that they are accountable for the group's performance. This increases commitment by setting clear objectives and giving feedback on performance. These meetings also improve upward communication by relating problems to people's jobs, thereby making them more likely to voice suggestions for solving them.

At Monrovia Nursery, a suggestion box inviting employees to submit new ideas to improve company performance has a successful history. The company rewards staff who come up with good suggestions and ideas for improvements. This idea helps to identify employees who may have creative or lateral thinking skills so that their talents can be put to better use, making them in turn feel more committed.

STAFF WELFARE

Welfare is driven by organisational needs, providing benefits that employees value and which simultaneously link with the needs of the nursery.

Stress. The managers of the nurseries studied aim to identify signs of stress in individual employees as early as possible. Steps can be taken to help individuals, and where necessary and possible, note is taken of an employee's limits. Stress is identified as a common reason for absenteeism.

Stress is also thought to influence levels of staff turnover. Most of the larger nurseries I visited had a human resource manager who deals with staff welfare and is available to staff at all times. The majority of the nurseries visited provide health insurance to full-time members of staff (and in certain cases, to specified family members of the employee).

CONCLUSIONS

The nurseries visited varied in size from 6-ha companies employing up to 15 people to the other extreme of 200-ha companies employing 450 people. Some propagators seem to like the smaller family-type nursery where everyone knows each other. On the other hand, propagators from the larger companies find the larger-scale operations more of a challenge. The support of a good team makes it all possible.

Skilled propagators are held in very high regard throughout the nursery industry of the West Coast of the U.S.A. I am told there is a shortage of skilled people and in some cases poaching of propagators goes on. The lure of better pay and conditions can be a temptation. However, the majority of propagators I met were very devoted to their jobs and value the good working relationships they have with fellow managers and staff.

Overall the study tour has revealed some very valuable things about how to manage staff, what motivates them, and how to get commitment. American and Hispanic propagators have a great sense of humour and are good communicators. They are as tuned into their people as they are to their plants. One propagator said to me: "We don't just grow plants here, we help people grow too." This may be a useful lesson for all nurseries.

A full report of the Study Tour, together with a list of nurseries studied, is available to sponsors of the Mary Helliar Travel Scholarship. Details may be obtained from the GB&I Region Secretary. The author wishes to acknowledge all current sponsors for their part in making the study possible.

Plant Health Inspections During Active Growth

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INTRODUCTION

In 1980 the well established Danish plant health control system became compulsory. This was a result of cooperation between growers, growers organisations, and the plant protection service, now known as the Danish Plant Directorate. Since 1980 all firms producing plants for sale — even small producers — must be officially registered by the Danish Plant Directorate, and must have their plants inspected and approved for sale.

STATISTICS

Today about 1600 plant producing firms distributed as follows are under control:

- 944 firms producing glasshouse crops on an area of about 4 million m^2.
- 636 firms producing outdoor nursery stock on an area of about 2200 ha.

In addition, the control system comprises 42 firms producing flower bulbs, seed onions, and strawberry plants.

Plant health control covers all living plants intended for sale. The sale can be directly to other nurseries, to wholesalers, or to private persons. In practice the control system, therefore, covers plants to the final consumer as well as propagation material for the professional grower.

THE CONTROL CONCEPT

One of the basic philosophies in the Danish plant control concept is that sick plants cannot be made healthy by control. Although control is a good thing, control alone is not sufficient to ensure healthy plants.

Requiring intensive plant health controls in all nurseries — and having done this for many years — provides us with detailed information about the plant health situation, not only in the nursery in question, but also in the supplying nurseries. This information is used to solve present problems but perhaps more important to try to prevent future problems.

The earlier in a production chain you can solve a problem the better. More focus is, therefore, put on breeders and propagators. Why multiply 10 million cuttings and discover that all have a plant health problem, when this could have been solved when you only had five plants? The growers have realised this. Today it is more common that breeders have a strong interest in certification systems. The reason is obvious. It is a logical and systematic way of propagating healthy plants.

PLANT HEALTH REQUIREMENTS TO BE FULFILLED

Minimum Requirements (Compulsory). These requirements include those from EEC directives in combination with Danish requirements. The minimum requirements include both quarantined harmful organisms and some which the plants have to be "practically free from".

Special Export Requirements (Voluntary). Freedom for some pests or diseases for a certain period or special requirements in relation to the growing medium.
Certification Requirements (Voluntary). To make the requirements in the Danish certification system known to both producers and buyers of certified material, requirements, to nuclear stockplants and certified plants as well as the companies performing this production, are written in the official order about plants.

EXECUTION OF THE PLANT HEALTH INSPECTIONS

The practical plant health inspections are done by inspectors located at district offices throughout Denmark. Each plant producing firm is inspected from 1 to 20 times a year. The number of inspections depends on many factors:

- Genera and species produced (different risks).
- Type of plant material (propagation material/plants for the final consumer).
- Production period of the year.
- The specific requirements to be fulfilled (destination of the plants).
- Results of previous inspections.

Glasshouse nurseries producing propagating material generally are inspected every 3 weeks. Within the European Union, Denmark is recognised as a protected zone for *Bemisia tabaci*. This means that the organism must not be established or spread. *Bemisia tabaci* must, therefore, not be found in either production nor trade. If it is found action will be taken.

We try to be flexible and always take the current results into consideration when planning the following inspections. About 4600 inspections are made each year. Furthermore, about 3000 samples of plants or sticky traps are examined for the possible presence of harmful organisms. These samples include also random sampling in the certification system.

Plant lots having pests or diseases where the tolerances are exceeded are put into quarantine or rejected. The plants being put into quarantine must stay in quarantine until the next inspection where they can be either approved or rejected. Plant lots which cannot be approved or put into quarantine must be destroyed.

On a yearly basis a few hundred thousand plants are destroyed after decision by the Danish Plant Directorate. The costs have to be born by the individual grower. Generally it is rare to find harmful organisms during the inspections. Pests like thrips, white flies, spider mites, and aphids are the most common.

After each inspection, the plant producer receives an inspection report. The inspection report lists which plants are to be destroyed or put into quarantine; all the other plants at the producer are approved and can be sold. If the plants fulfill special export requirements this will also be written on the inspection report. If the nursery produces plants in the certification system information about these plants will be given in a special certification report issued to the nursery.

All information about findings of pests and diseases in all Danish nurseries are collected in a computer system and are available for all inspectors at all district offices. This information can be used in case of future inspections in the nursery, in case of export, or in other control situations.

All plants must, before they leave the nursery, be labelled with either a plant passport, if this is required, or another label identifying the nursery (each nursery has its own registration number). This labelling system gives very good trace-back possibilities.

PAYMENT

All expenses in relation to the inspection system are paid by the individual grower. The payment is based on two elements:

- An annual basic fee for each company: 1438 dkr.
- A fee for each inspection of a certain area (1000 m^2 glasshouse or 1.5 ha outdoor land): 220 to 260 dkr.

For example, a very small firm with a 500 m^2 glasshouse, producing flowering plants in the spring (two inspections) pays in total about 2000 dkr per year. A larger firm with e.g., 20,000 m^2 glasshouses would have six inspections per year and must pay about 30,000 dkr. All costs for laboratory tests are included in the above mentioned fees. If products are going to be exported the company must pay 140 dkr for issuing of a phytosanitary certificate.

CONCLUSION

Many years of experience in the area of plant health has shown that:

- Registration of nurseries and inspection of all plants provides a good basis for fulfilling international obligations as well as the wishes of the horticultural industry.
- That it is better to solve a problem as early as possible in the production chain.
- Preventing problems is even better. Use of certified material is one way of obtaining this.
- Cooperation and agreement between growers, advisers, researchers, and the Danish Plant Directorate has made it easier to reach the goal of production and marketing of healthy plants.

Testing for Plant Diseases in Plant Material

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EXCLUSION OF PESTS

Controlled propagation of quality plants and plant products requires more than horticultural excellence. It also requires tests or indexing procedures to ensure freedom from specific pests and pathogens.

Plant diseases can be controlled by chemicals, altering cultural conditions, breeding or engineering resistant cultivars, and by various administrative methods. One aspect of the administrative approach aims to exclude specific pests and pathogens. This exclusion of pests and pathogens can be of interest from:

1) An international point of view and be done for example by prohibiting the movement of plants from an infested country into one which is free of the particular pest or disease.
2) A national point of view and be done by preventing the spreading of a disease from one nursery to another.
3) From the point of view of the single grower and be done for example by preventing the spreading of the disease from the production area to the propagation area. One should look at specific diseases and find out if there are only one or several host plants.

In most situations absence of the pathogen or pest must be demonstrated in order to get a certificate that guarantees freedom for specific diseases, but in some cases a tolerance may be allowed. A low percentage of infection in a seed crop may be allowed because at that level it is not considered damaging. Above a given level the risks of damage are considered too high and the crop is rejected.

INDEXING

When dealing with exclusion, indexing is essential for this purpose and implies that some assessment for the presence of a specific pathogen or pest on a given crop or consignment has been made. Where a pathogen is established the ultimate objective of indexing is usually eradication. But it must of course be cost effective to achieve this goal.

There are different factors which influence the success of indexing:

- The plant material.
- The sample size.
- The specificity and sensitivity of the diagnostic methods.
- The biology of the plant and pathogen.
- The possibility of re-introduction of the pathogen.

Reducing the incidence of a pest or pathogen is likely to reduce the intensity of disease but because all indexing methods have a threshold of detection below which they give a negative reaction, they are unlikely to guarantee the absence of a specific pathogen in a single indexing exercise.

Ten years ago Danish potato growers had a major problem with potato ring rot caused by *Clavibacter michiganensis* subsp. *sepedonicus*. Through the use of meristem culture for production of the prebasic potatoes and indexing the seed

potatoes no cases of potato ring rot in Danish seed production are present and only a few incidences per year are found in the final production (Table 1).

The situation is similar for the production of *Pelargonium*. A number of countries have severe problems with respect to *Xanthomonas campestris* pv. *pelargonii*, however, in Denmark an effective system of indexing has been introduced and the inspectors never see the disease.

METHODS OF DIAGNOSIS

The different methods used in indexing for diagnosis should be cheap, rapid, specific, and/or sensitive.

Cheap and Rapid. Cheap and rapid are the two issues covering the costs of actual staff input and the length of time it takes to obtain the results of indexing procedures. Some virus testing methods include grafting and take many months before results are obtained. Many diagnostic methods are labour intensive because bacterial isolation, purification, and identification by traditional bacteriological methods are required.

Specificity. Specificity means that the actual pathogen has been found by a certain method and the taxonomic parameters are acceptable.

Sensitivity. All the diagnostic methods have a threshold of detection. Two major factors affect this threshold — the efficiency of sampling and the test methods which are used to detect the presence of the pathogen in a selected sample. A negative result in an indexing test means only that the target organism was not found in that sample.

Sampling, Extraction, and Diagnostic Methods.

Bacteria. As the density of pathogenic bacteria is generally higher in older than in younger plant parts, the samples to be tested should be taken from the base of the stem. The optimal time of year for sampling depends on the actual pathogen to be detected. Bacteria are extracted by shaking the plant material in water. After shaking one of the following diagnostic methods is used: immunofluorescens, ELISA, DNA-based methods, bioassays, isolation, or protein profiles.

Viruses. Factors that influence the success of indexing tests for viruses include the type of plant tissue collected, distribution of virus in the plant, time of the year, stage of plant maturity, time and temperature at which plant samples are stored, and presence of different virus strains. Samples to be tested usually are prepared by squeezing the leaves in an extraction buffer with a press or a power driven crusher (Pollähne roller press). After squeezing the sample is tested by one of the following diagnostic methods: ELISA, indicator plants, electron microscopy, DNA-based methods, or protein profiles.

Fungi. Testing for fungi is generally limited to specific instances where symptomatic plant parts are sampled and tested for the presence of fungi. The diagnosis of fungi is done by isolation, bioassay, and light microscopy.

Table 1. Testing for potato ring rot in seed potatoes.

Year	Samples (no.)	Area of control (ha)	Infected samples (no.)
1992	2813	10,357	30
1993	3643	7647	9
1994	1388	5505	8
1995	1476	5660	0

Eradication of Fireblight in Norway 1986 to 1998

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Fireblight is a destructive disease of apple, pear, and some commonly grown ornamentals. Many countries have expended a great deal of resources attempting to eradicate the disease, but few have experienced success. Fireblight eradication in Norway during 1986-1998 is reviewed. Among important factors to avoid fireblight introduction and establishment are early detection of the disease and the establishment of a programme with the necessary statutory powers and resources to do surveys and remove diseased plants. Testing for latent infections in plant propagation could be of importance. Planting of highly susceptible host plants should be banned.

INTRODUCTION

Fireblight, caused by the bacterium *Erwinia amylovora*, is regarded as one of the most destructive diseases of pome fruits in the world. It rapidly kills flowers and shoots, and may spread further into branches and the trunk, whereby the tree usually dies. Trees may be killed in one season. The incidence and severity of fireblight is highly dependent on rainfall and temperature conditions. The most commonly affected hosts are pear (*Pyrus*), apple (*Malus*), hawthorn (*Crataegus* spp.), *Cotoneaster* spp. (particularly the larger species), *Sorbus aria*, and *Pyracantha* spp. Fireblight has been known in North America since 1780, it appeared in New Zealand in 1919, and in England in 1957. In 1966 the disease was detected in the Netherlands, and during the next 30 years it became established in most of the other European countries. Up to 1998 fireblight was known in more than 40 countries (EPPO, 1997). In the European Community Finland and Portugal are now the only countries where the disease has not been detected.

EXPERIENCES WITH THE CONTROL OF FIREBLIGHT

Fireblight may cause serious losses in apple and pear orchards, both in the current years crop, and in the subsequent years production by killing fruit spurs, branches, and whole trees. In the U.S.A., pear cultivation has been largely abandoned in some states because of the disease. In parts of Europe with warm conditions at first flowering (18 to 24C), frequent periods of rain or high humidity, and highly susceptible pear cultivars, severe losses have been reported. Fireblight is usually not of major economic importance to apple and pear production in northern Europe but occasionally damage could be severe. Commercial growers of ornamentals may also experience heavy losses because of the disease (Garrett, 1990). Indirect losses to growers because of export difficulties as a result of quarantine measures are also of considerable importance.

Although fireblight has been known for about 200 years, there is still no completely satisfactory and reliable control measure. The present knowledge of the disease cycle and the many factors that affect disease development demonstrate that there

is no single, easy answer to fireblight control. Successful preventive measures are import restrictions of susceptible hosts from countries where the disease occurs, eradication and containment campaigns to stop or limit spread soon after the introduction of fireblight, and orchard management of susceptible hosts to minimise the effects of infection, including encouragement of the use of cultivars that are resistant or have low susceptibility.

Fireblight is difficult to control with known chemicals. None of them are curative and must, therefore, be used to prevent entry and establishment of the pathogen. Copper compounds and antibiotics have been used with some success, but they both have severe disadvantages. Some new chemicals have been introduced recently, showing promising results in controlling fireblight, but they need further investigation under a range of conditions. Among other approaches are the use of biological control agents, which again need much testing before they can be released commercially. With our present knowledge the best control of fireblight can be attained through an integrated programme of legislation, good orchard management, and the use of preventive sprays.

The EPPO (1990) recommends all countries to list *E. amylovora* as a quarantine pest. According to the specific quarantine requirements put up by EPPO, countries which do not yet have the disease in whole or major areas of the country should prohibit the import of plants for planting and cut branches from host plants from countries where *E. amylovora* occurs. Most countries follow these recommendations, and planting of the most susceptible hosts are banned. In spite of this, fireblight continues to spread. Dissimination of *E. amylovora* by air, insects, and birds is important, but introduction of the disease into some countries, like Norway, most likely has been by infected nursery stock. In most countries, following the initial discovery of the disease, eradication campaigns have been initiated. These intensive and costly measures have served to delay the eventual spread of fireblight and have thus enabled other measures to be prepared and brought into operation. If an eradication campaign fails, it is usually succeded by containment policies to protect the interests of fruit growers and nurserymen, to restrict spread of the disease, and to preserve the landscape.

Few, if any country have yet managed to completely eradicate fireblight. Several countries have had success in containing the disease, at least for some years. Others have given up at an early stage, usually because of lack of money for eradication campaigns, and very rapid spread of the disease.

CONTROL OF FIREBLIGHT IN NORWAY

In Norway fireblight was detected for the first time in 1986 (Sletten, 1990). The focus of infection was in the county of Rogaland, in and around the city of Stavanger on the south west coast of the country. Diseased plants were found in private gardens, around public buildings, on recreation grounds, along roads, and in rural areas. In this district there is no commercial fruit-growing, however, many large nurseries are situated there. Spring is often dry and cold, but in the summer temperatures can be well above 20C. Rainfall in July, August, and September is usually high. *Cotoneaster bullatus* and *C. salicifolius* were the two most important hosts, but the disease also occurred on other *Cotoneaster* spp., as well as on *Sorbus aria* and *Pyracantha coccinea.*

A Government funded eradication campaign was set up in 1986. The Norwegian Crop Research Institute, the Plant Quarantine Inspection Service, and the local County Agricultural Advisory Service were in charge of the eradication campaign. The aim was to protect large nurseries in Rogaland, as well as important fruit-growing areas about 40 km north of the infection site. Weather data from these areas analyzed with Billing's revised system for fireblight risk assessment (Billing, 1992) indicated that weather could be favorable for fireblight development. The campaign has been carried out every year, with a total expenditure of about NOK 5 million. So far no compensation for the removal of diseased plants has been paid.

The necessary statutory powers for the campaign were given in the Fireblight Disease Order. The disease is notifiable, and the cultivation, production, and sale of *C. bullatus* and *C. salicifolius* are prohibited throughout the country. A quarantine area of about 700 km^2 was established around the focus of infection. Within this area the production and sale of all common fireblight hosts were prohibited, and such plants were not allowed to be removed from the area. From the quarantine area *C. bullatus* and *C. salicifolius* were allowed to be removed from private and public grounds, regardless of whether they were attacked by fireblight or not. Around fruit orchards and nurseries protective zones of 500 m, free from the most susceptible hosts were established. Beehives in the quarantine area were only allowed to be moved to areas free from fireblight hosts.

In the growing season of the first years of the campaign, between 20 to 40 persons were engaged in the tracing, cutting, and removal of diseased plants. Roots were killed with glyphosate or imazapyr. In 1989 the strategy was changed. To reduce the possible build-up of inoculum on *C. bullatus* and *C. salicifolius,* these two species were completely removed from about 300 km^2 of the quarantine area. The work started from the south, where fireblight so far had not been detected, and moved north, into parts where the disease was common. More than 60,000 private gardens were checked, in addition to public areas, recreation grounds, and rural districts. The efficiency of removing and destruction of plants was greatly increased when we instead of burning plants used a transportable wood chipper, grinding shoots, branches, and stems quickly into fine chips, which were decomposed in heaps for a year. By voluntary agreement all nurseries in the quarantine area stopped their production of the most common hosts of fireblight, and they destroyed their stocks of *C. bullatus* and *C. salicifolius.*

These drastic measures could not have been accomplished if the public awareness of the disease and its destructive potential had not been raised at an early stage of the campaign. Information about fireblight and which measures that were to be taken were given in leaflets distributed to the public by post, and in "grower bulletins". Newspapers and local radio stations gave regular reports about the progress of the campaign.

Fireblight was detected at around 2000 locations in the quarantine area during the years 1986 to 1993. Disease incidence increased during the first years, but from 1990 there was a decrease in number of new outbreaks. Fireblight also became limited to the two main hosts. Since 1993 fireblight has not been detected, either in the quarantine area nor in other parts of the country. The systematic surveillance of the quarantine area has continued every year, and in 1998 it was extended to many other counties in Norway, particularly in the

eastern part of the country. Trained personel have been looking for the disease in nurseries, garden centres, fruit orchards, private gardens, and recreation grounds in build-up areas. So far, fireblight has not been detected.

CONCLUSIONS

It has been of advantage that there was no commercial fruit-growing in the district with the first outbreak of fireblight, and that the disease did not enter nurseries. The removal of the main hosts greatly reduced the build-up of inoculum, and made the surveillance work easier. Among other important factors for the success can be mentioned the establishment of a well organized eradication campaign shortly after fireblight was detected for the first time. Many countries have experienced that the failure of eradication is not caused by insufficient legislation and organization of the campaign, but by the common distribution of very susceptible host plants, in particular if some of these are wild growing. Infections in ornamentals in build-up areas and cities are usually extremely difficult to control, and they may be an important reservoir of inoculum for further spread of the disease. A low level of infection is not easy to detect, even with extensive surveys and trained personel. It may go on unnoticed for a long time, especially if weather conditions are unfavorable for rapid disease development.

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The Path to Better Plants

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The Danish Elite Plant Station produces healthy and true-to-type plant material, also called certified plant material, for commercial production of trees, shrubs, perennials, pot plants, and tree and soft fruits. The Danish Elite Plant Station was founded in 1980 by the Danish Association of Horticultural Producers and the Association of Danish Fruit Growers to meet a growing need for healthy and true-to-type plant material. The majority of products from the Danish Elite Plant Stations are labelled with the trademark Dafo, short for Dansk Forskning (Danish Science). This label serves as a guarantee for specific quality properties, variety trueness, and healthy plant material. More than 150 different taxa of Dafo landscape plants have been developed along with about 100 tree and soft fruit cultivars and 60 cultivars of pot plants.

THE LONG WAY

The Danish Elite Plant Station works with new plants, which must be tested in Denmark before they are launched into the market, and with taxa which are too unhomogeneous or too infected with pathogens to create a basis for efficient production. Plant producers, the Danish Institute of Agricultural Sciences, and the Danish Elite Plant Station cooperate on selecting the most suitable plants. These plants are propagated and tested at The Danish Institute of Agricultural Sciences. The plants are tested for pathogenic properties, growth properties, climate tolerance, and propagation properties. The plants also are described with regard to morphology and usage. The best clones continue in the system and are called candidate stockplants. They are further tested and viruses are removed using heat treatment and meristem propagation. In addition, candidate stockplants are tested for fungi and bacteria and propagated to candidate stockplants 2, which are kept isolated under conditions approved by the Danish Plant Directorate. If candidate stockplants 2 are approved after testing they are nuclear stockplants and are stored in an approved nuclear stockplant area (Fig. 1).

The nuclear stockplant is the first plant with defined genetic properties and/or free from specific pathogens. Propagation material from nuclear stockplants is grown under hygienic surroundings to protect against reinfection by pathogens and called elite stockplants. Plants derived from elite stockplants, certified class AAE plants, which are approved by The Danish Plant Directorate, are delivered to the growers by The Danish Elite Plant Station. Plants derived from class AAE plants can be certified as class AA plants, if they are grown according to strict control procedures stipulated by The Danish Plant Directorate. Finally, plants meeting the minimum requirements stipulated by the Danish Plant Directorate for plants to be sold commercially in Denmark may be certified as class A plants. Whether a plant is a nuclear stockplant or a class A plant it is tagged with a Dafo label as a quality guarantee.

A WORLD OF POSSIBILITIES

The Danish Elite Plant Station offers a wide assortment of tree fruits as graftwood and budwood; soft fruit; and trees and shrubs for parks, hedges, and gardens as plants and cuttings; strawberry plants; and pot plants as cuttings and plantlets. The assortment is described in three seperate catalogues: tree fruit and soft fruit; pot plants; and trees, bushes, and perennials.

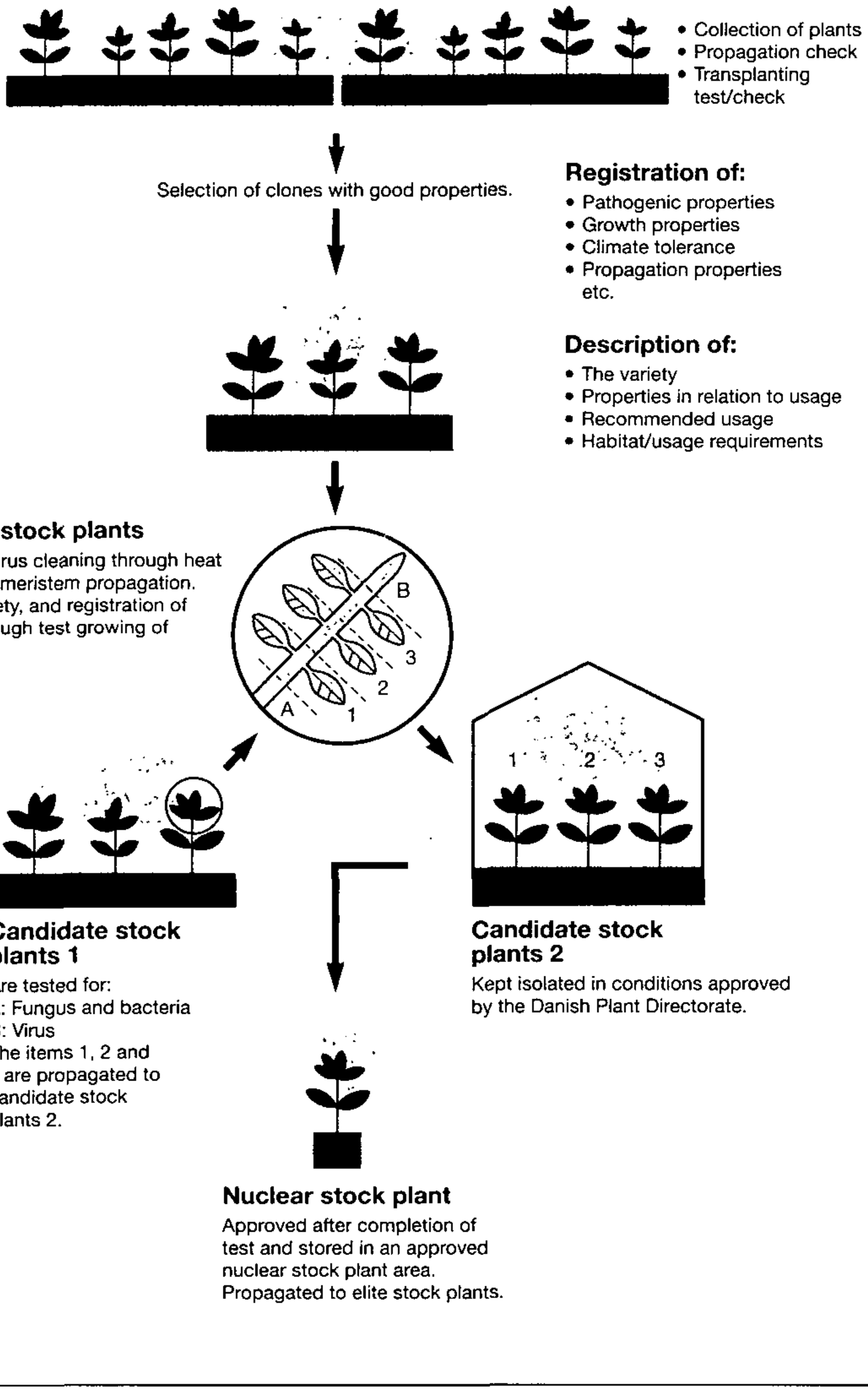

Figure 1. Selection from existing cultures, identification of taxa, and registration of properties during testing of plants.

Disease Free Plants as Basis for Production of *Kalanchoe*

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BACKGROUND

Knud Jepsen A/S produces 15 million *Kalanchoe* pot plants per year. Production started in 1963 with an area of 1200 m^2; current *Kalanchoe* production covers 80,000 m^2 of glasshouses.

The nursery has a special section for development of new products where the tasks are: product development, new cultivar breeding, propagation of new clones, and improvement of existing cultivars. Last, but not least, stockplant material free of specific diseases is being produced in this section.

DISEASES

Kalanchoe plants are attacked by a number of diseases.

Bacteria. The most important bacteria is *Erwinia* which causes soft rot. Hygienic measures are used to prevent *Erwinia*.

Fungi. *Pythium*, *Phytophthora*, and *Fusarium* cause root rot. These fungi as well as mildew on leaves are also prevented by the use of hygienic measures.

Viruses. Five to six different viruses cause problems with *Kalanchoe*. Prevention is done by means of hygienic measures and virus infected stock is cleaned by thermotherapy and meristem culture.

MEASURES AGAINST REINFECTION

Because of all these potential diseases it is very important to our nursery to use stockplant material free from specific diseases. Therefore, we use propagation material from the Danish Elite Plant Station at Lunderskov or from our own research section with elite plants.

As a producer of only one plant species health is of supreme importance. Our production system with moveable tables is completely mechanized and makes it impossible to enter the production area. This increases the demand for keeping a high hygienic standard during production. We, therefore, pay close attention and use a lot of energy to maintain the nursery free from diseases. The irrigation water is biofiltered and tested before and after use. Growth substrates are never reused and the climate during production is kept optimal for the plants.

Our most stringent measures are taken in the propagation area. New cultivars are tested intensively before they enter the production area. Plants are kept in quarantine under observation and every second month sent to a laboratory and tested for specific diseases.

Our elite stockplants which are the basis for our whole production are grown in a special area of the nursery which has no physical contact with the production plant area. This restricted area is equipped with drip irrigation for each plant and the incoming air is filtered. Additionally, a positive pressure is maintained to keep spores and other pests from entering the propagation area. The propagation area is divided into six separate rooms.

Cuttings are excised from the stockplants with knives that are disinfected before the next plant is handled. The conditions in this area are more like a laboratory than a nursery.

In the breeding of *Kalanchoe* we aim at healthy cultivars and are always starting the production with plant material as clean as possible. It is far too expensive to cure problems and there is no doubt in my mind that healthy plant material is a requirement for future horticultural production.

Use of Healthy Plant Material in Nurseries

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INTRODUCTION

Use of healthy plant material in nurseries seems to be the most obvious and logic thing of all. Somehow, however, healthy plant material does not always move forward as fast as expected in the nursery business. The reasons for that are many and one should know these to help improve the situation.

There are advantages and disadvantages of using healthy plant material from a nursery operators point of view. The most important disadvantages are the direct investment of time and money and the problems with estimating future advantages. In addition, blocks may develop.

LOOKING AT HEALTHY PLANT MATERIAL

Advantages. Economic benefits result from a reduction in plant losses and better growth resulting in more uniform plants. In addition, healthy plants need less chemical treatment and are in high demand by consumers.

Disadvantages. Healthy plant material is more expensive to use in the beginning. This is true whether budwood is bought from The Danish Elite Plant Stations or healthy mother plants are established. Additionally, a new healthy clone may require its own protocol for growth and handling and in the end may require extra nursery effort in selling the product. Finally, a new product can create replanting problems at the user.

Blocks. The nurseries may have experienced problems in the past with new healthy crops. For example, healthiness did not last or the demand for the new healthy crop was not present either because the consumer was not sufficiently informed about the new product or because there was no interest in the product.

A breeders new products are always said to be better than products seen before! However, nurserymen and landscape architects want to continue to produce and use products which have already proved to be good enough.

Important Factors. In order to have more healthy plant material used in nurseries it is important to strive towards large and visible benefits for the industry. Blocks should be avoided as far as possible by making the costs and risks clear and small. Bad experiences make people say "let others try first ", and then the market and production will never meet. Important to growers and consumers are true and lasting improvements of the new product. Timing of production and marketing of the new product is one of the most important factors.

Virus Aspect in *Malus* and *Prunus*: Spreading of Viruses in the Field

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INTRODUCTION

When apple (*Malus*), plum(*Prunus*), and sour cherry (*Prunus*) are propagated there is a risk of disease transfer which could in time affect new clones. This is especially a problem with virus diseases. In the past the only way to avoid this problem was to select stockplants that were not infected.

Since the beginning of the 1950s research using heat treatment (thermotherapy) and meristem culture have shown that it is possible to remove viruses from plants. The combination of thermotherapy and meristem culture has proved to be more effective than either method alone. However, treated plants can not be declared virus free until a careful test has been carried out (Thomsen, 1987).

Virus diseases affecting fruit trees have many ways of spreading in nature. The most effective transmitter of these pathogens is the propagator by using virus infected material. In an orchard dissemination occurs by pollen, insect vectors, and natural root grafting.

TRANSMISSION THROUGH SEED AND POLLEN

The embryo cells in a seed can be infected in different ways:

1) When egg cells in virus infected plants are fertilized by pollen from non-infected plants.
2) When egg cells from non-infected plants are fertilized with pollen from infected plants.
3) When egg cells and pollen both originate from infected plants.

All three ways are involved in spreading Prunus necrotic ringspot virus to mazzard rootstocks. In some cases it has been observed that pollen from infected trees has been able to infect non-infected cherry trees. This way is of practical importance in spreading Prunus necrotic ringspot virus from tree to tree in cherry orchards.

TRANSMISSION OF VIRUSES THROUGH VECTORS

Virus vectors (e.g., mites, aphids, leafhoppers, and nematodes) have a prominent role in transmission of viruses in *Prunus*. Vectors for transmission of viruses to *Malus* seem to be more rare in Denmark.

TRANSMISSION THROUGH ROOT GRAFTING

Viruses spread by natural root grafts are found most commenly in rootstock beds and in intensive fruit orchards. Through root-transmission experiments with apple mosaic virus in Denmark it has been confirmed that transmission through root grafting takes place.

CONCLUSIONS

Detection of viruses in fruit trees has been carried out in Denmark using the indexing techniques compiled by the International Committee for Cooperation in Fruit Tree Virus Research (1986). Virus vectors occur more often in *Prunus* than in *Malus*. After a period of 20 years original virus-free plants of *Prunus* and *Malus* are being retested. To date results of the retesting indicate that many *Prunus* clones are reinfected whereas most *Malus* clones are virus free. Seed transmission of Prunus necrotic ringspot virus is often a problem in *P. avium* seedlings used as rootstocks. Therefore, it is strongly recommended to use only seed from virus free *P. avium* populations for the production of rootstocks.

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Prevention of Phytophthora Root Rot in Pot Plants, a Review

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INTRODUCTION

In 1992 and 1994 experiments showed that the infection of *Phytophthora cryptogea* Pethybr. & Lafferty in *Gerbera jamesonii* L. plants grown in an ebb-and-flow system with recirculation of the nutrient solution could be reduced by increasing the soluble salt concentration measured as electrical conductivity (EC) in the nutrient solution (Thinggaard and Andersen, 1995). The results demonstrated that it was possible to reduce attacks of *P. cryptogea* considerably by elevation of the EC. A reduction in plant death from 74% at EC 1.5 mS cm^{-1} compared with 13% at EC 2.2 mS cm^{-1} was observed. The experiments also showed that *P. cryptogea* zoospores in the nutrient solution could cause an epidemic root attack.

What could be the reason for the decrease in root attacks? What elements in the fertilizer composition could harm the zoospores? It is generally known that copper ions have a fungitoxic effect on *Phytophthora* (Halsall, 1977; Kennedy and Erwin, 1961; Slade and Pegg, 1993). Could it be the elevation of copper from 0.07 to 0.12 ppm in the nutrient solution?

MATERIALS AND METHODS

In two experiments in 1996, the concentration of copper ions was increased from 0.07 to 0.28 ppm in the nutrient solutions with EC 1.5 or 2.2 mS cm^{-1}. *Gerbera jamesonii* plants were inoculated with zoospores of *P. cryptogea* and *Hedera helix* L. with zoospores of *P. cinnamomi* (Toppe and Thinggaard, 1998; Toppe and Thinggaard, 1999). Both cultures were grown in ebb-and-flow systems with recirculation of nutrient solutions. The iron source was iron sulphate and in *Gerbera* both iron sulphate and iron chelate were used.

RESULTS

In *Gerbera* as well as in ivy the results clearly demonstrate the positive impact of elevated copper ion concentration in the nutrient solution for prevention of Phytophthora root rot. By increasing the level of copper ions from 0.07 to 0.28 ppm the disease severity was reduced in *Gerbera* at all inoculum levels tested, when iron sulphate was used as iron source (Fig. 1). No significant differences between the two EC levels were observed. No reduction in disease was observed in *Gerbera* when iron chelate was used.

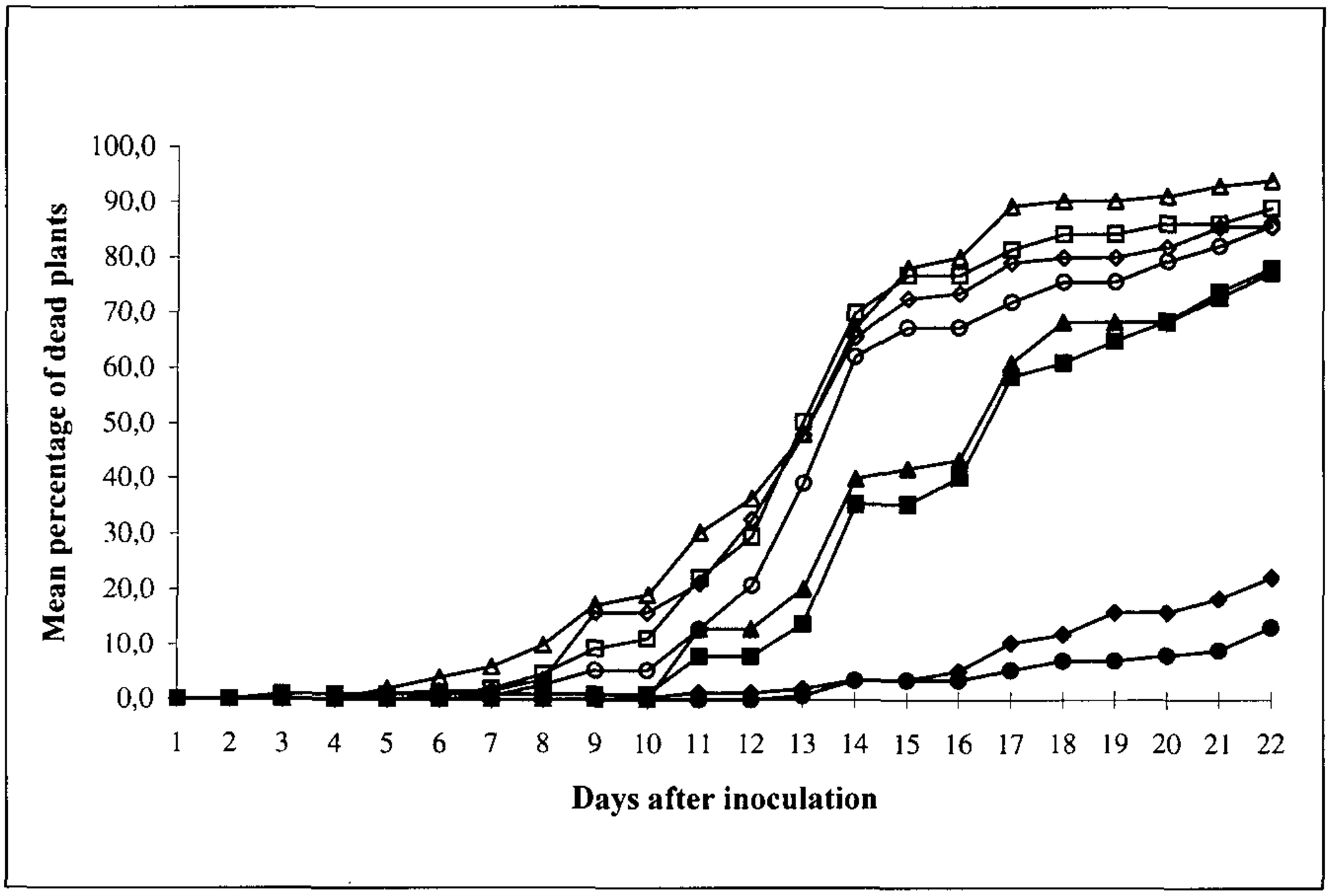

Figure 1. Mean percentage of dead *Gerbera jamesonii* plants infected with Phytophthora root rot. Plants were grown in nutrient solutions of different EC (1.5: ■, ●, □, ○ or 2.2: ▲, ◆, △, ◇) with copper sulphate of different concentrations (0.07 ppm: ■, □, ▲, △ or 0.28 ppm: ●, ○, ◆, ◇). Nutrient solutions with iron sulphate (closed symbols) or iron chelate (open symbols). The results were recorded every other day after inoculation with *P. cryptogea*. Mean values of three experiments.

DISCUSSION

Elevation of the copper-ion concentration caused an even bigger reduction in the attack of *P. cinnamomi* in ivy than in *G. jamesonii* inoculated with *P. cryptogea*. The observed effect of increased copper ion concentration is most likely due to copper sensitivity of the cell wall free zoospores. The reduced availability of cupric ions is most likely due to the complex binding to humic substances in the solution (De Kreij and Basar, 1995). In spite of this reduction in cupric ion concentration, a copper level of 0.28 ppm as used in these experiments was sufficient for a significant inhibition of disease attack. Low cupric-ion concentrations between 0.06 and 1 ppm Cu^{++} have previously been reported to inhibit sporangial production in *P. cinnamomi* (Halsall, 1977). Mycelia of *P. cinnamomi* are reported to be killed when immersed for 24 h in suspensions containing 13 to 45 ppm copper (Smith, 1979). This indicates that higher copper concentrations are necessary to inhibit mycelial growth compared to those concentrations needed to inhibit sporangia formation and zoospores. The copper level used in our experiments would, thus, inhibit the zoospores in the nutrient solution, but not mycelial growth, oospores, or germination of encysted zoospores.

The present results suggest that the preventive effect of increased EC observed by Thinggaard and Andersen (1995) could be explained by an increased level of specific ions in the solution rather than as a general effect of increased EC. *Phytophthora* is known to cause high infection rates due to short latent periods and rapid

production of high numbers of zoospores, whereby the introduction of a small amount of inoculum in the growing system could be of considerable risk. Thus, there might be a great potential for effective control of *Phytophthora* by elevating the copper concentration in the early stage of an epidemic disease.

In practice the amount of copper added to the nutrient solution must be adjusted regularly to provide a concentration lethal to the pathogen. Earlier investigations have also demonstrated metal chelates to reverse the suppressive effect of increased copper concentration (Halsall, 1977; Kennedy and Erwin, 1961). Therefore, alternatives to metal chelates as iron source, e.g. chelates with stronger binding of iron ions or $FeSO_4$ at the right concentrations, must be found before the enrichment of copper would be recommended for disease control in commercial production.

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Mass Propagation of *Primula sieboldii* Through Leaf Segment Culture

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The population of *Primula sieboldii* E. Morr., which is native to Japan, has been decreasing because of development in rural regions. The objective of this research was to develop a micropropagation method for the propagation of *P. sieboldii* to protect the plant from extinction. Young expanding leaves excised from donor plants grown in vivo were sterilized with 1% sodium hypochlorite solution, then divided into two halves, a distal half and a proximal one. The leaf segments were cultured on a modified MS medium (Murashige and Skoog, 1962) supplemented with benzyladenine (BA) and naphthaleneacetic acid (NAA) in various concentrations and combinations. After 2 or 3 weeks of culture on medium supplemented with BA and NAA, small globular tissues, so-called nodules were formed at the cut surface of the leaf segments. Most of the shoots developed from the nodules. The formation of shoots on leaf segments from in vivo plants was most promoted on medium with 1 mg liter^{-1} BA and 0.1 mg liter^{-1} NAA. The formation of shoots was not observed on media without NAA. The condition of total darkness for the 2 weeks of initial culture promoted shoot formation from the cut section of leaf segments. Leaf segments from in vitro plants had a higher potential for shoot formation than those from in vivo plants. At all conditions, the formation of shoots from cut sections of the distal half of the leaves was greater than that from the proximal half. The shoots formed rooted easily in medium without hormones. With this method, a lot of plantlets available for acclimatization could be obtained within 3 months after the initiation of culture. The plants that regenerated grew well and flowered in early spring. No phenotypic variation in the regenerants was observed.

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Low Irradiance Levels and the Rooting of Selected Easy- and Difficult-to-Root Tree Taxa

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INTRODUCTION

The formation of adventitious roots by stem cuttings depends upon a complex interaction between endogenous and environmental factors. Environmental factors, such as irradiance, can have dramatic effects on adventitious root formation. For example, etiolation and opaque banding treatments when applied to plants prior to cutting collection, can increase rooting success of difficult-to-root species (Maynard and Bassuk, 1986; Bollmark and Eliasson, 1990; Leakey and Storeton-West, 1992). However, etiolation can be difficult and costly to apply, especially on mature trees (Hecht-Poinar et al., 1989). Zaczek et al. (1997) in a recent study with typically difficult-to-root mature tree species demonstrated that rooting was significantly improved in some species by subjecting shoot cuttings to shade levels up to 97% of ambient irradiance in the rooting environment. Potentially, high levels of shade applied in the rooting environment could, therefore, prove to be useful in the rooting of cuttings from other recalcitrant taxa. This study reviews our propagation studies with high shade levels in the rooting environment, with and without hormone application, on the rooting of cuttings of selected tree taxa.

MATERIALS AND METHODS

Propagation Environment. The rooting chamber was located in a greenhouse at Penn State University, University Park, Pennsylvania, and consisted of a frame (1-meter-tall [3.3-ft]) constructed of polyvinyl chloride (PVC) pipe on three 1.7 m × 3.0 m (5.5 ft × 10 ft) roller benches. The frame was covered by a single sheet of 6-mil (1 mil = 1 thousandth of an inch) polyethylene; this configuration formed a single rooting chamber which minimized potential humidity and temperature differences among treatments. Intermittent cool fog was provided by four ultrasonic humidifiers (Sunbeam model 667, Northern Electric Co., Chicago, Illinois) set outside opposing ends (two per end) of the rooting chamber. Whitewash (Kool-Ray white shading compound, Continental Products Co., Euclid, Ohio) was applied to the exterior of the greenhouse to reduce irradiances and limit solar heating inside the polytent. It is essential to provide relatively heavy shading to minimize solar heating during summer use of polytent systems in climates with high irradiance. Previous experience (Zaczek, 1994) has shown that moderate temperatures can be maintained in a polytent rooting environment with ca. 80% to 85% shade. Therefore, we selected a shade level in this range for our control treatment. Shade treatments in the rooting chamber were made by subdividing the chamber into

three compartments and the application of shade cloth. Two compartments had black polypropylene shade fabrics (Yonah Manufacturing Co., Cornelia, Georgia) suspended 10 cm (4 inches) above the roof and along the vertical walls of two sections of the rooting chamber. The third compartment (control) received no shade fabric except was bordered by a 47% shade fabric wall from the adjacent shading treatment. Shade fabric on the inside of the chamber between shade levels was suspended from the top of the chamber down below the top of the cuttings but leaving the lower 25 cm open. This coupled with the porous nature of the shade fabric allowed for humidity and air exchange between the three compartments.

Percentage shading e[B the three treatments was determined by measuring photosynthetic photon flux density (PPFD, µmoles m^{-2} s^{-1}) on different days and times during daylight hours at 15 locations in each treatment and outside the greenhouse using the quantum sensor of a portable infrared gas analyzer (model LCA-2, Analytical Development Co., Ltd., Hertz, England). The percentage reduction of ambient irradiance for each compartment was determined relative to the outside ambient PPFD [(1-(PPFD tray/PPFD outside))x100]. Shade levels were 97%, 91%, and 83% (control). For reference, the average ambient PPFD was 1584 µmoles m^{-2} s^{-1}.

Cuttings were then inserted in a mix of peat moss, perlite, and sand (1 : 1 : 1, by volume) in Ray Leach Single Cell Cone-tainers™ (Stuewe and Sons Inc., Corvallis, Oregon).

Relative humidities were maintained at 100% except for short time periods when the chamber was opened to check for roots, apply fungicides, or change chart paper. Air temperatures varied less than 1C (1.8F) on average among shade treatments.

Fungicide solutions, either Cleary's 3336-F at a rate of 0.7 ml $liter^{-1}$ water (0.5 tsp gal^{-1}) or Chipco Aliette (Rhone-Poulenc Company, Research Triangle Park, North Carolina) at a rate of 1.2 g $liter^{-1}$ (0.2 oz gal^{-1}) were sprayed on the leaves ca. every 2 weeks during the rooting period. Approximately weekly, the chamber was opened and the Leach cells were checked for emerging roots.

Plant Material.

Experiment 1. Softwood shoot cuttings of *Quercus rubra* were collected from 1-year-old seedlings and mature trees at Penn State University, University Park, Pennsylvania. In this experiment, shade levels of 88% and 97% were used. All *Quercus* cuttings were treated with 10,000 ppm of indole-3-butyric acid (IBA).

Experiment 2. Softwood shoot cuttings of *Acer rubrum* 'Bowhall', *A. rubrum* 'Franksred' Red Sunset™ red maple, and *Cornus kousa* were collected from several sources and kept cool and moist until treatment application. *Cornus kousa* cuttings were collected from mature trees located on the campus of The Pennsylvania State University and processed the same day. *Acer rubrum* cultivar cuttings were collected at The Buddies Nursery, Birdsboro, Pennsylvania and processed for rooting over the next 2 days. Field-grown trees of *A. rubrum* cultivars were between 4 to 5 m (13 to 16 ft) tall and approximately 5 cm (2 inches) in caliper. For each species, 180 cuttings were processed except for *C. kousa* where 216 cuttings were used. One-half of the number of cuttings of each species were treated with IBA. All the bases of freshly trimmed cuttings were dipped for 5 sec 2 cm (0.8 inches) deep in either 95% ethanol (control) or in an IBA and

ethanol solution. The concentration of the hormone solution was 10,000 ppm for *C. kousa* and 5000 ppm for *A. rubrum* cultivars.

Experiment 3. In this experiment, the effect of length of shade (93%) treatment was studied. *Acer rubrum* cultivars and *Q. imbricaria* cuttings were collected at The Buddies Nursery, Birdsboro, Pennsylvania and processed as in Experiment 2. The length of the study was 117 days for *A. rubrum* and 119 days for *Q. imbricaria* and cuttings were subject to 0, 10, 20, 40, or 117/119 days of 93% shade. The remainder of the days was at 82% shade. Hormone treatments were as above.

All cuttings were trimmed to size, soaked in a solution of Olympic Triathlon, (Olympic Horticultural Prod., Mainland, Pennsylvania, U.S.A.) at a rate of 1.3 ml liter^{-1} of water (1 tsp gal^{-1}) for 5 min, rinsed in water, soaked in a solution of Clearys 3336-F (W. A. Cleary Chemical Corp., Somerset, New Jersey, U.S.A.) at a rate of 1.6 ml liter^{-1} water (0.2 oz gal^{-1}) for 5 min, removed, and air dried.

RESULTS

The effect of light reduction from 88% of ambient to 97% of ambient is shown in Table 1. The resulting increase from 30.5% to 54.6% in rooting with *Q. rubra* provided our first results suggesting that a reduction in irradiance to a very low level may prove promotive to rooting.

Table 1. Percent rooting of juvenile and mature *Quercus rubra* cuttings.

Age	88% shade (control)	97% shade
1-yr-old seedlings	73.5% (n=49)	92.3% (n=52)
mature trees	30.5% (n=154)	54.6% (n=119)

In Experiment 2 we studied the effect of low irradiance on the of rooting easy- and difficult-to-root cultivars of *A. rubrum* and also the easy-to-root dogwood, *C. kousa*. Again, the difficult-to-root taxon, *A. rubrum* 'Bowhall', show a dramatic increase in rooting; the easy-to-root cultivar, Red Sunset^{Tm} red maple and the easily rooted *C. kousa* exhibited little effect (Table 2). As found with *Q. rubra*, rooting was influenced by shade and hormone treatments.

In Experiment 3 the effect of length of shade treatment on rooting was studied. The purpose of this study was to examine if the shade reduction was needed for the entire rooting period. As shown in Table 3, the difficult-to-root *A. rubrum* 'Bowhall' showed a continued increase in number of cuttings with roots during the entire 80-day rooting period. *Quercus imbricaria*, on the other hand, peaked at 20 days and then decreased.

Table 2. Percentage rooting and the average number of roots per rooted cutting by species, shade, and hormone treatment.

Species	Shade (%)	Rooting (%)		Roots per cutting	
		IBA	no IBA	IBA	no IBA
Acer rubrum 'Bowhall'	83	26.7	6.7	4.6	2.5
	91	66.7	20.0	7.1	2.5
	97	66.7	23.3	13.5	12.7
Acer rubrum 'Franksred'	83	80.0	56.7	16.7	5.7
Red Sunset[Tm] red maple	91	86.7	46.7	18.0	3.4
	97	76.7	40.0	16.3	3.0
Cornus kousa	83	77.8	44.4	10.4	6.8
	91	83.3	47.2	11.0	5.7
	97	83.3	50.0	11.4	6.0

Table 3. Effect of length of shade treatment on rooting of *Acer rubrum* 'Bowhall' and *Quercus imbricaria* (n=30 per treatment).

Treatment[1]	*Acer rubrum* 'Bowhall' rooted (no.)	*Quercus imbricaria* rooted (no.)
0	16	8
10	17	9
20	17	15
40	21	4
117/119	24	3

[1]Treatment numbers refers to number of days out of 117/119 in 93% shade; i.e., 0 = 0 days of 93% shade and 117 (*Acer*)/119 (*Quercus*) days of 82% shade.

DISCUSSION

Beneficial effects of stockplant etiolation, shading, and banding pretreatments have long been recognized and well studied (Maynard and Bassuk, 1988); this extensive literature has shown the promotive effects of such treatments on adventitious root initiation, however such treatments are difficult and costly to apply.

It is commonly assumed by propagators that leafy cuttings should be subjected to a rooting environment with an irradiance that is conducive to photosynthesis (Davis,

1988; Hartmann and Kester, 1983). Hess and Snyder (1955) suggested that an important advantage of mist was the higher irradiances which could be tolerated, thus increasing photosynthesis in cuttings. However, little scientific evidence supports this assumption (Davis, 1988) and cuttings do not require high irradiances until rooting occurs (Dirr and Heuser, Jr., 1987; Loach and Gay, 1979). There is evidence that photosynthesis may be limited by the restricted sink-capacity for carbohydrates in unrooted cuttings (Loach and Gay, 1979) and by stomatal closure, so a low irradiance is needed to saturate photosynthesis (Davis and Potter, 1987).

Only limited research is available which addresses the interaction between root initiation and irradiances during the rooting process in leafy cuttings. Shading experiments have suggested that reduced irradiance can be beneficial for rooting of some species under mist (Grange and Loach, 1983). Veierskov (1993), working with *Hibiscus* cuttings, reported that the best light conditions for rooting occurs at an irradiance just above the light compensation point. In the present report, the reduction of irradiance to very low levels, in our case down to 3% of ambient irradiance during summer propagation in central Pennsylvania, has shown a promotive effect with several difficult-to-root tree taxa — *Quercus* and *A. rubrum*. In the case of *A. rubrum*, a comparison of easy-to-root and difficult-to-root cultivars has shown that the promotive effect was confined to the difficult-to-root cultivar with no significant effect on the easy-to-root cultivar. In a study with aseptically cultured shoot apices of juvenile and adult forms (adult forms are difficult to root) of *Hedera helix*, Hackett (1970) found that a reduction in irradiance brings about a qualitative change in the rooting response of adult shoot tips to indole-3-acetic acid (IAA) and catechol. There was essentially no response to IAA and catechol when adult tips were grown in high irradiance but when grown in low irradiance adult tips responded markedly to these factors and in much the same manner which juvenile shoot tips responded to those factors in high irradiance. Hackett was not able to extract the light controlled factor from mature apices that promoted rooting.

The physiological changes leading to increased rooting in difficult-to-root taxa reported here is not known, however, additional research is necessary if they are broadly applicable to other plants.

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New Propagation Material to Substitute for the European (Wych) Elm

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INTRODUCTION

Ulmus glabra, European (wych) elm, has a range of qualities which make it a very valuable tree species in Denmark. First and foremost it is one of the most wind resistant tree species that we have. Furthermore it is easy to establish, robust, and responds well to pruning (Madsen, 1997). When Duch elm disease (DED) in the late 1970s became a reality in Denmark and damage began to show up as numerous dead trees in parks and urban areas a need for alternative trees arose either in the form of new tolerant *Ulmus* species, their hybrids, or in the form of trees from other genera.

BREEDING EFFORTS WITH ELM

True hybridisation and selection work has been carried out in the Netherlands and U.S.A. The species involved were primarily from Asia where DED is thought to have been present for ages and where selections for DED tolerance have been made in domestic *Ulmus* species. As the relation between the host and the pathogen is a dynamic one researchers are reluctant to talk about resistant or immune trees because one never knows how long this situation will last.

At the former Institute for Landscape Plants in Hornum, North Jutland a number of selected Dutch clones were imported for testing their climatic adaptation and aboricultural value. From these trials the cultivars 'Lobel' and 'Plantjin' were recommended. The problem is to find DED tolerant *Ulmus* clones with the same aboricultural value as *U. glabra*. 'Lobel' came out of the tests with high scores due to its hardiness and healthiness. The growth habit is slender with a central leader. *Ulmus* 'Plantjin' has a growth habit similar to 'Lobel', but is slightly less winter hardy. The twigs of this cultivar have a slight red/purple blush and the leaves are less rough giving it an attractive appearance (Brander and Bøvre, 1987). Both of these cultivars are included in the Danish elite plant system, Dafo, and are distributed through the Danish Elite Plant Station in Lunderskov.

In addition numerous of American *Ulmus* selections have been imported to the Department of Ornamentals in Arslev where they are being tested together with *U. japonica* seedlings that were imported by Poul Erik Brander on several occasions. In spite of the harsh winter climate in the eastern U.S.A. where the clones were selected, several of them lack winter hardiness in the mild maritime winters of Denmark. This fact probably highlights the importance of summer heat unit accumulation for the development of sufficient winter hardiness. Several of the American clones have shown signs of lack of phenological timing with the Danish climate. A few clones have started bud burst and blooming in October shortly after leaf senescence. In comparison with this several of the *U. japonica* seedlings have done well and have been propagated by cuttings. Several of these have a growth habit that resembles that of *U. glabra* but are slightly smaller trees (Brander and Johansen, 1997). While efforts around the world have concentrated on hybridisation followed by clonal selection, the

Department of Ornamentals at the moment is surveying the possibilities for development of a defined seed source of *U. japonica* with relatively uniform offspring and a sufficient degree of resistance againsts DED. Such a program would meet the wish for genetic diversity in the reforestation material in combination with low costs of establishment. A potential side effect from this program could be that the Japanese elms through hybridisation could introduce resistance genes in the domestic population of *U. glabra* and thus enhance the natural process in which a species genetically adapts itself to the pressure from a serious disease. Such a process may otherwise take hundreds and maybe even thousands of years.

USE OF OTHER GENERA

Brander (1980) screened a number of broad-leaved tree species and clones for their suitability as substitutes for elms. The conclusion was that several of our broad-leaved tree species, after some selection work, could act as substitutes for elm although none of them on an overall basis compared well with *U. glabra* in the windy areas of Western Jutland. As part of this program numerous Danish linden clones have been tested for their suitability as alley trees and/or as substitutes for elm. From his work three new cultivars have been released that should be available in the nurseries shortly (Brander, 1995). Two of the cultivars are thought to be potential substitutes for elm and are briefly described here.

***Tilia platyphyllos* 'Fenris'.** A clone of the European large leafed linden that was originally found at the Arboretum at Hørsholm in North Zealand. The cultivar is characterised by its strong and stiff growth habit. It has compared well in trials and is less susceptible to aphids than the species itself.

***Tilia* 'Odin'.** This clone was found in a 40-year-old urban planting in Zealand thought to consist only of *T. platyphyllos*. However, a single look is enough to distinguish 'Odin' from this species. The leaves are larger and the growth more vigorous just as a number of less visible features are different. In that respect the clone has more resemblance with the American linden, *T. americana*, that has been planted to a certain extent south of our borders. A qualified guess is that 'Odin' is a hybrid between *T. platyphyllos* and *T. americana*, the so called *T.* ×*flaccida* (Woldemar, 1998). This could also explain the extreme vigour that is also known from interspecific hybrids in other genera, e.g., *Populus* and *Salix*. Overall, 'Odin' is a tree that gets attention wherever it is displayed as it differs significantly from any other tree normally seen in the country. However, only time will show whether this tree also has a future in the windy parts of Western Jutland.

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The Plant Evaluation Program at Bernheim — New Direction

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INTRODUCTION

The Bernheim Arboretum and Research Forest is located in north central Kentucky, approximately 35 km (Approx. 22miles) south of Louisville. The arboretum itself consists of 200 ha (Approx. 500acres), which is adjoined by an additional 5500 ha (Approx. 13,600acres) natural forest. As a result of its close proximity to the Louisville metropolitan area, Bernheim provides a wide array of recreational and educational opportunities to approximately 185,000 visitors per year.

Historically, Bernheim was founded in 1929 by a German immigrant named, Issac W. Bernheim, who wanted to provide a unique natural area and arboretum to the citizens of Kentucky. Design of the arboretum grounds was laid out by the Frederic Law Olmstead landscape design firm, and the arboretum was opened to the public in 1949. Since those early years, the arboretum's collections have increased to over 5200 accessions.

EVALUATION PROGRAM

Bernheim is located in plant hardiness Zone 6a (37 55' N 85 40' W), and is in the unique geographic position of providing a site for the evaluation of landscape plants capable of growing in Zones 5, 6, and 7, that is also west of the Appalachian Mountains. Plans are being developed to establish a new, regional plant evaluation center at Bernheim by the year 2004. These plans include the construction of new greenhouses, laboratory, library, and propagation facilites, in addition to the development of new field and container nursery areas.

The following genera and/or species will be included in the plant evaluation program: *Acer, Aesculus, Carpinus, Cornus kousa, Fothergilla, Hamamelis, Hydrangea, Ilex,* and *Viburnum.* While we do not have adequate space available to evaluate all cultivars, or even species of some genera, we intend to assemble collections of source-documented and verified representatives of some of the larger genera such as *Magnolia, Quercus,* and *Syringa.*

At this point, our plan is to focus on genera that have traditionally been underutilized in Midwestern U.S. landscapes, i.e. *Fothergilla* and *Hamamelis*. The evaluation program will focus on the field performance of cultivated taxa for such characteristics as: flowering cold hardiness, frost susceptibility, heat tolerance, insect/disease resistance, fall coloration, and growth rates.

In addition to cultivated taxa, there will also be ample opportunities to propagate seedling populations of a number of species for which no selections have been made to date, such as within certain species of *Acer* and *Viburnum*.

OPPORTUNITES FOR COLLABORATION

Since our plans to develop the plant evaluation center are still being formulated, it is premature to announce any formal, collaborative agreements with other botanic gardens and arboreta in the U.S.A. It is our intent to contact other institutions located in hardiness Zones 5, 6, and 7. We would especially like to focus on those institutions nearer the Atlantic coast that would provide us with a definitive contrast of results in comparison with the climatic effects of our more continental location. In addition, we would invite representatives of European institutes, who may have an interest in our plant evaluation program, to contact us to possibly exchange plant materials for these listed genera.

Nitrogen Leaching from Container-Grown Plants

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INTRODUCTION

Production of high quality container-grown ornamentals requires adequate levels of nutrients and water in the container medium. Water use efficiency and nutrient leaching from agricultural and horticultural crops are attracting much attention because of exhaustion of drinking water resources and pollution. In order to reduce leaching of nutrients during production of ornamentals it is important to have a balance between the concentration of applied nutrients and nutrients in the root zone, which, at the same time restricts the leaching of nutrients to a minimum and supports optimal plant growth. In outdoor production systems in Denmark, container-grown ornamentals are often supplied with a high level of fertilizer. Part of the fertilizer is often mixed into the potting medium before transplanting, and part of it is supplied with the irrigation water in a non-recirculating system.

The objective of this study was to investigate how irrigation frequency and nutrient concentration (electric conductivity, EC) in the root zone influence nitrogen leaching and plant quality of *Campanula carpatica* 'Dark Blue'.

MATERIALS AND METHODS

Campanula carpatica Jacq. 'Dark Blue' was propagated in 4 × 4-cm plugs (Vefi, Larvik, Norway) and grown in a full-fertilized peat medium in 10-cm containers from June to Oct. 1997 on outdoor benches. Fertilizer was added to the irrigation water using an AMI-5000 irrigation and fertilizer computer (DGT, Denmark) to maintain either high (EC: 2.5) or low (EC: 1.5) nutrient concentration in the root zone. The nutrient solution was supplied with a non-recirculating drip-irrigation system. Two irrigation frequencies were included. Plants were irrigated after 4 or 6 mm of evaporation. All treatments received the same total amount of irrigation water. However, plants from the 4-mm treatment were irrigated more frequently and with a smaller amount of nutrient solution per irrigation compared with the 6-mm treatment.

Leachate from each bench was collected in 25-litre tanks and analysed for NO_3 and NH_4. Plants were harvested every 2 weeks throughout the experiment and biomass accumulation of the aboveground part of the plant, plant height, and number of flowers and buds were recorded.

Nitrogen (N) balances were estimated by indexing the values of total amount of N added, N leaching, N found in growth substrate at the end of the experiment, and N uptake with total amount of N added as 100.

Plants overwintered outdoors, were transferred to a greenhouse in February 1998, and grown until flowering. During forcing, plants from all treatments received identical nutrient concentration and irrigation frequency.

RESULTS

Plant quality from June to October was quite similar regardless of nutrient concentration and irrigation frequency. There were no significant differences in plant height, biomass accumulation, production time, or number of flowers (data not shown).

Nitrogen leaching was significantly affected by both nutrient concentration and irrigation frequency. The highest nitrogen leaching was seen from plants grown with the high EC level in the root zone and irrigated with the relatively large volume of nutrient solution per irrigation (Fig. 1). Plants supplied with the low nutrient concentration and irrigated more frequently with a low irrigation volume per irrigation had the lowest accumulated nitrogen leaching (Fig. 1). The percentage of nitrogen leached was more affected by irrigation frequency than by nutrient concentration. When plants were irrigated after 6-mm evaporation (low irrigation frequency) more than 80% of the applied N was leached, compared with 60% to 70% when irrigated after 4-mm evaporation (high irrigation frequency) (Figs. 1 and 2).

Both nutrient concentration and irrigation frequency affected the number of shoots and flowers after forcing in the greenhouse (Fig. 3). Plants grown with the low EC and irrigated frequently with a low volume had a significantly higher number of shoots and flowers than plants from other treatments. The lowest number of flowers was observed in plants grown with the high nutrient concentration and a high irrigation volume per irrigation (Fig. 3).

DISCUSSION AND CONCLUSION

Although nitrogen leaching was reduced when growing plants with the low nutrient availability, nitrogen leaching was also to a large extend affected by irrigation frequency/irrigation volume. Irrigating plants with small volumes per irrigation reduced the nitrogen leached from plants grown with the high EC in the root zone by almost 70 kg ha^{-1}, indicating that nitrogen leaching and thereby the environmental pollution can be significantly reduced just by choosing the right irrigation strategy.

Plant growth and quality were apparently not affected by nutrient concentration and irrigation frequencies during the outdoor production period. However, after an outdoor overwintering and forcing to flower in the greenhouse, differences in number of shoots and flowers were found. Plants grown with the low nutrient availability and high irrigation frequency during the previous outdoor production period had a significantly higher number of shoots and flowers than plants grown at the other combinations. The increase in number of shoots and flowers in plants grown with the low nutrient availability during the outdoor production period 5 to 10 months before forcing may indicate that these plants had a more active root system since the shoots emerging during forcing are secondary shoots from the roots. A high number of secondary shoots from roots are important to growers since such shoots are used as propagation material.

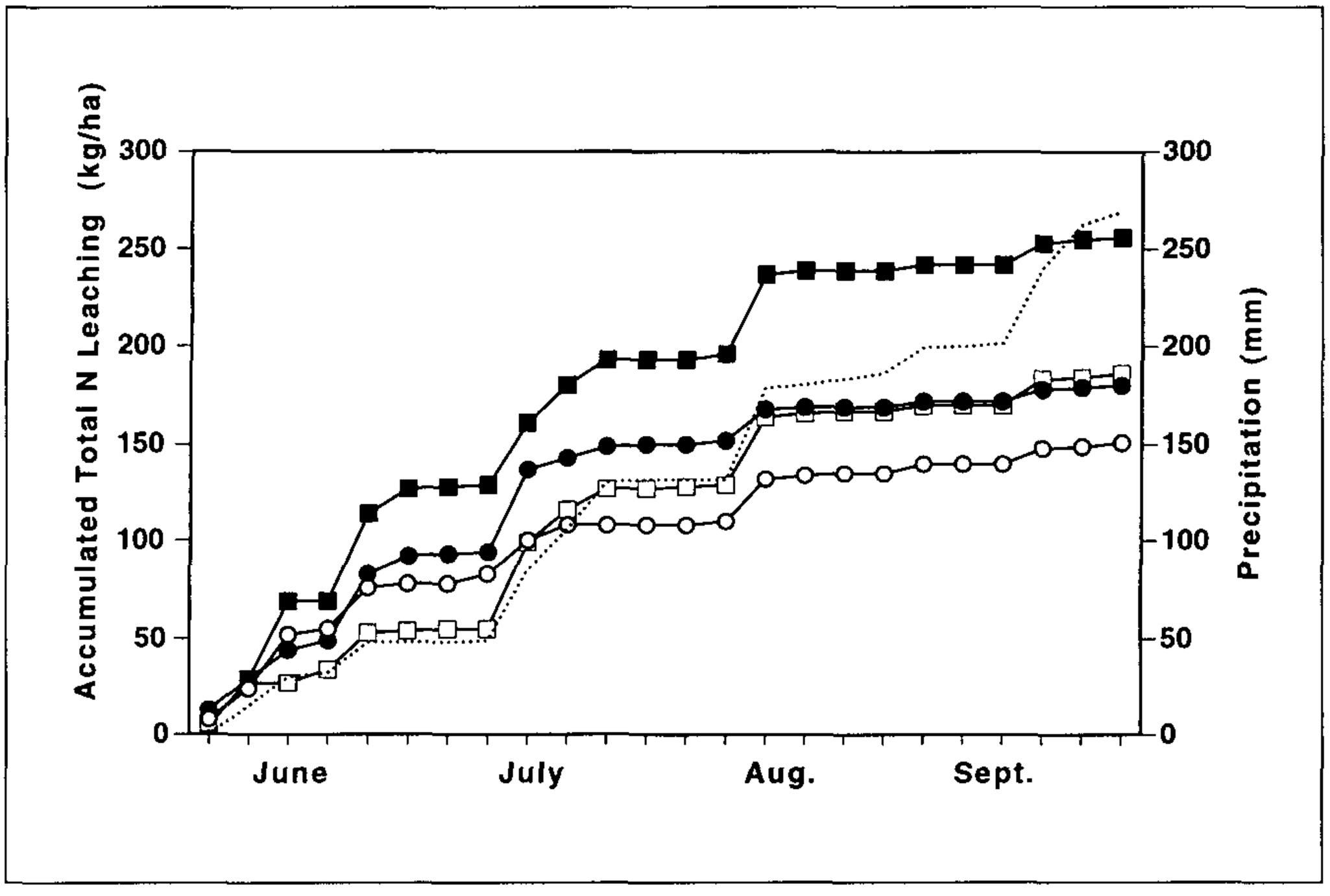

Figure 1. Accumulated total nitrogen leaching from *Campanula* fertilized with different nutrient concentrations, EC 1.5 (●,○) or 2.5 (■,□) after 4 (open symbols) or 6 mm of evaporation (closed symbols). Dotted line represents precipitation.

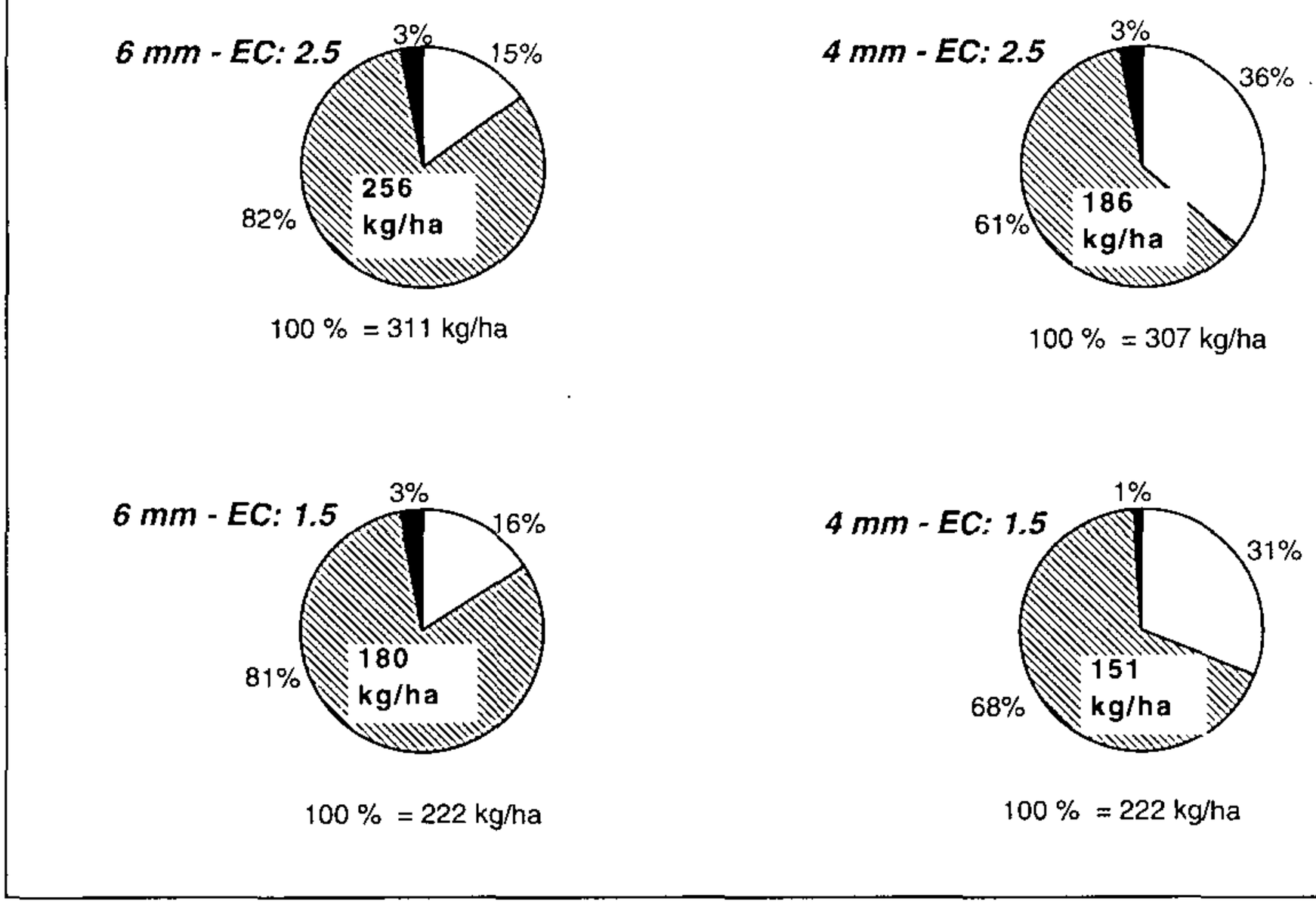

Figure 2. Nitrogen balances for *Campanula*. The figure shows the percentages of total nitrogen (N) added throughout the experiment used for N uptake (□), N leaching and not recovered (▥), and N content in the growth medium (■) at the end of the experiment. The figure below each pie chart is the total N in kg ha^{-1} added throughout the growing period.

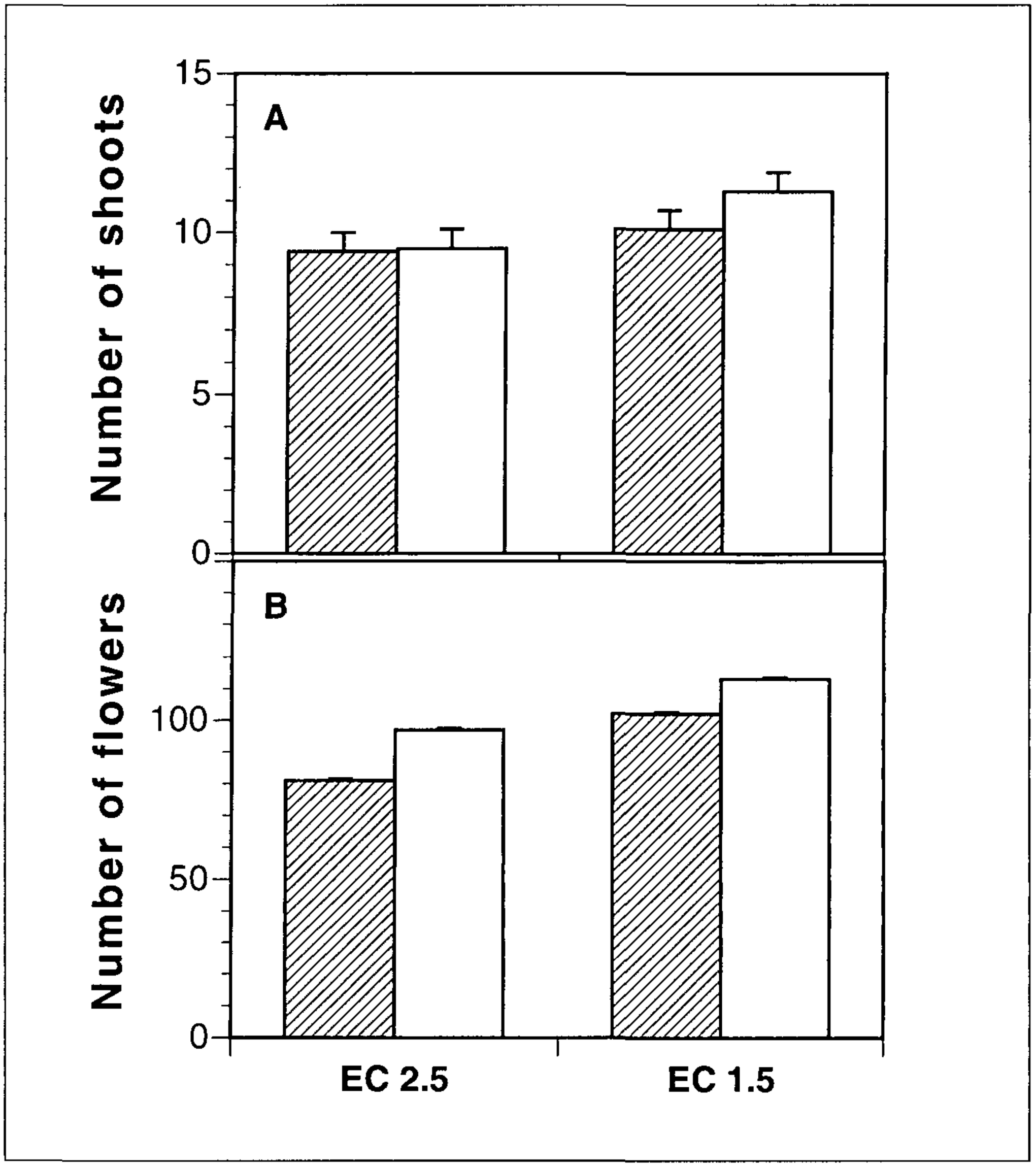

Figure 3. Number of secondary shoots (A) and number of flowers (B) in *Campanula* after greenhouse forcing. Plants were previously grown at different nutrient concentrations (1.5 or 2.5 EC) and irrigated after 4 (□) or 6 (▥) mm of evaporation. Vertical bars denote mean standard error.

Fiber Pots for the Ornamental Plant Industry

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INTRODUCTION

Prior to World War II most nursery stock was marketed either balled in burlap (B&B) or bareroot. Now, more than half of all nursery plants sold in the U.S.A. are marketed in containers, and the percentage is slowly increasing. Plants are grown in containers for a variety of reasons; ease of shipping, attractive sales units, and some plants, like *Pyracantha*, *Cotoneaster*, and *Viburnum* that do not transplant well as field-grown plants, are ideally suited to container culture.

Container growing began after World War II when a California nurseryman tried to grow plants in used 1-gal juice cans. Plant growth was acceptable, but the insides of the cans corroded and, because the sides were not tapered, it was very difficult to remove the plant from the container. To correct this, the juice cans were placed in a press that tapered and crimped the sides (Fig.1).

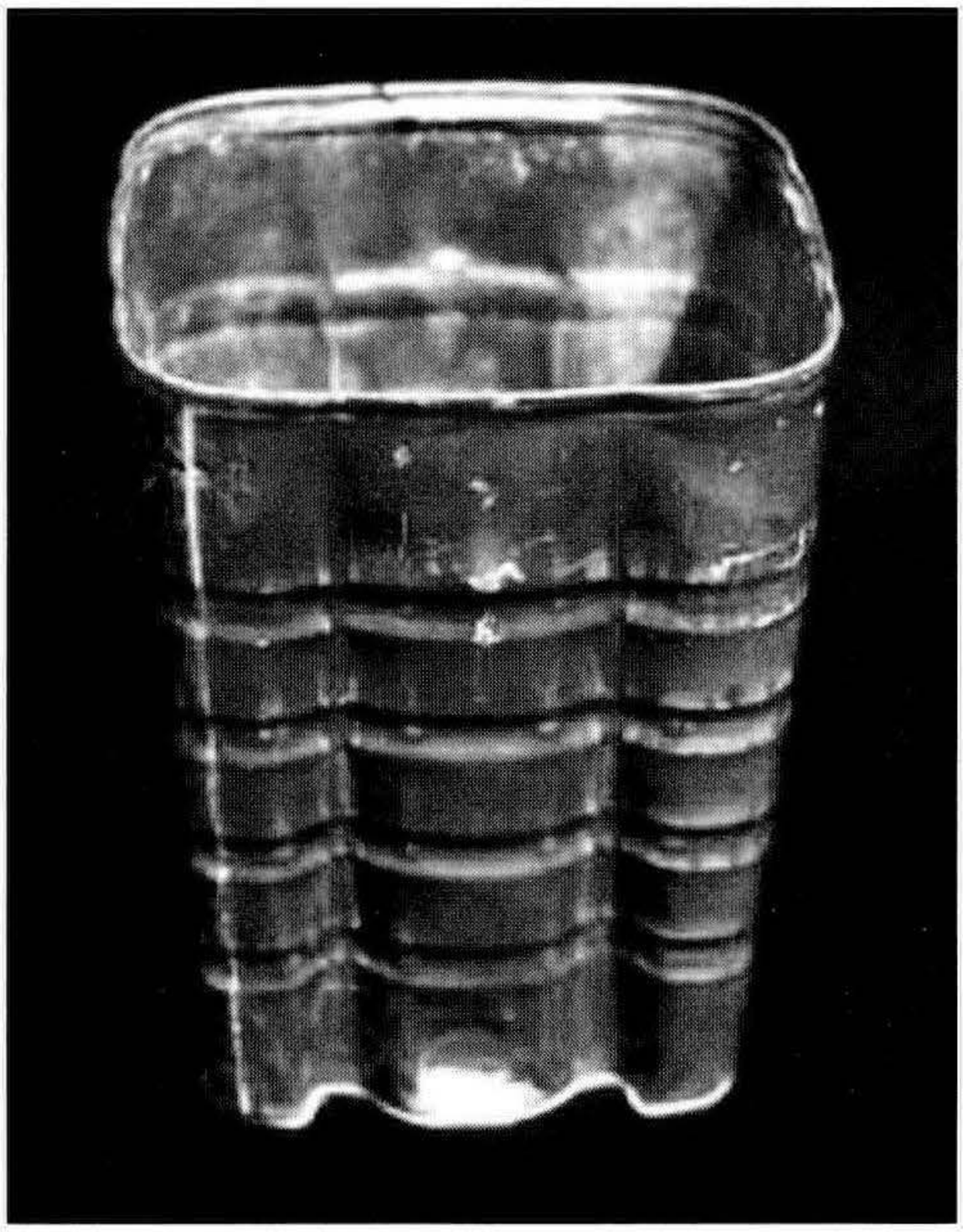

Figure 1. Used 1-gal juice cans were crimped to taper pot sides to allow easy extraction of the root system.

The result of this innovation was the birth of nursery container growing in the U.S.A. The negative part of this story was that, while the original container held 1 gal, the volume of the new crimped and tapered container was now reduced to about 3 quarts (0.75 liters). Thus began a long and confusing history of nursery-pot size based on an incorrect volume rather than on either actual volume or on dimension. The use of pressed juice cans continued well into the 1950s when they were replaced by plastic pots.

In addition to steel and plastic, plants have been grown in a variety of other containers including: plastic bags, tarpaper pots, pressed peat pots, pressed paper, and clay. The pot with the longest history has been the clay pot used primarily in glasshouse culture for centuries. Heavy, easily broken, and prone to surface algae buildup, but stable on the bench top, and above all, well aerated, the clay pot became the standard for container culture. Even today, older growers wax nostalgically about the advantages of clay, especially its superior aeration qualities which resulted in fewer root diseases.

Paper, or fiber, pots have been used for many years, especially for seasonal, bareroot crops like roses, field-potted shrubs, small trees, but pot longevity has been unpredictable. If fiber containers were overwintered and froze to the ground, moving pots before spring thaw could rip the bottoms open. Fiber pots, depending on how wet or warm they were kept, often lasted only for a few months. Recently, copper-based fungicidal additives have consistently extended the life of these pots to more than 1 year (Fig. 2). Longer pot life should breathe new life into a product that has distinctive cultural and environmental advantages.

Figure 2. Fiber containers can be treated (right) to last more than one season.

Combined with other advantages, fiber pots appear to be a more attractive choice to some growers. Environmentalists would consider fiber pots to be "green" because they are manufactured of recycled paper. The obvious advantage is that used fiber pots can be composted rather than placed in a landfill where plastic pots usually go (Fig. 3).

Figure 3. Many nursery businesses have pot dumps that cannot be effectively recycled.

Fiber pots "breathe". Like the old-fashioned clay pots, fiber pots are highly aerated, probably resulting in fewer root related diseases. Because water vapor moves through pot sides and evaporates to the surrounding atmosphere, evaporative cooling results in reduced root zone temperatures (Fig. 4). Roots on the south side of black poly nursery containers, especially in the southern U.S.A., can easily reach root-killing temperatures. Some plants like *Thuja occidentalis* or *Euonymus alatus* and *Hosta* are sensitive to high root temperatures, thus southern nurseries may have difficulty growing these taxa. Finally, copper-containing fungicides added to the fiber not only lengthen pot life, but also reduce root penetration of pot bottoms in much the same way that happens in copper coated polyethylene containers (Fig. 5). Besides being easier to remove from copper-treated fiber pots, copper truncated roots freely branch to more thoroughly explore the growing medium. Implications related to water use efficiency and nutrient uptake remain to be investigated as does the possible reduction of root-born diseases in copper-treated fiber pots. Further, while root systems are more highly aerated in fiber containers, water also moves through container walls more freely, so more attention has to be paid to irrigation practices (Fig 6.) Rather than using lightweight media, growers may have to consider heavier media to alleviate this problem.

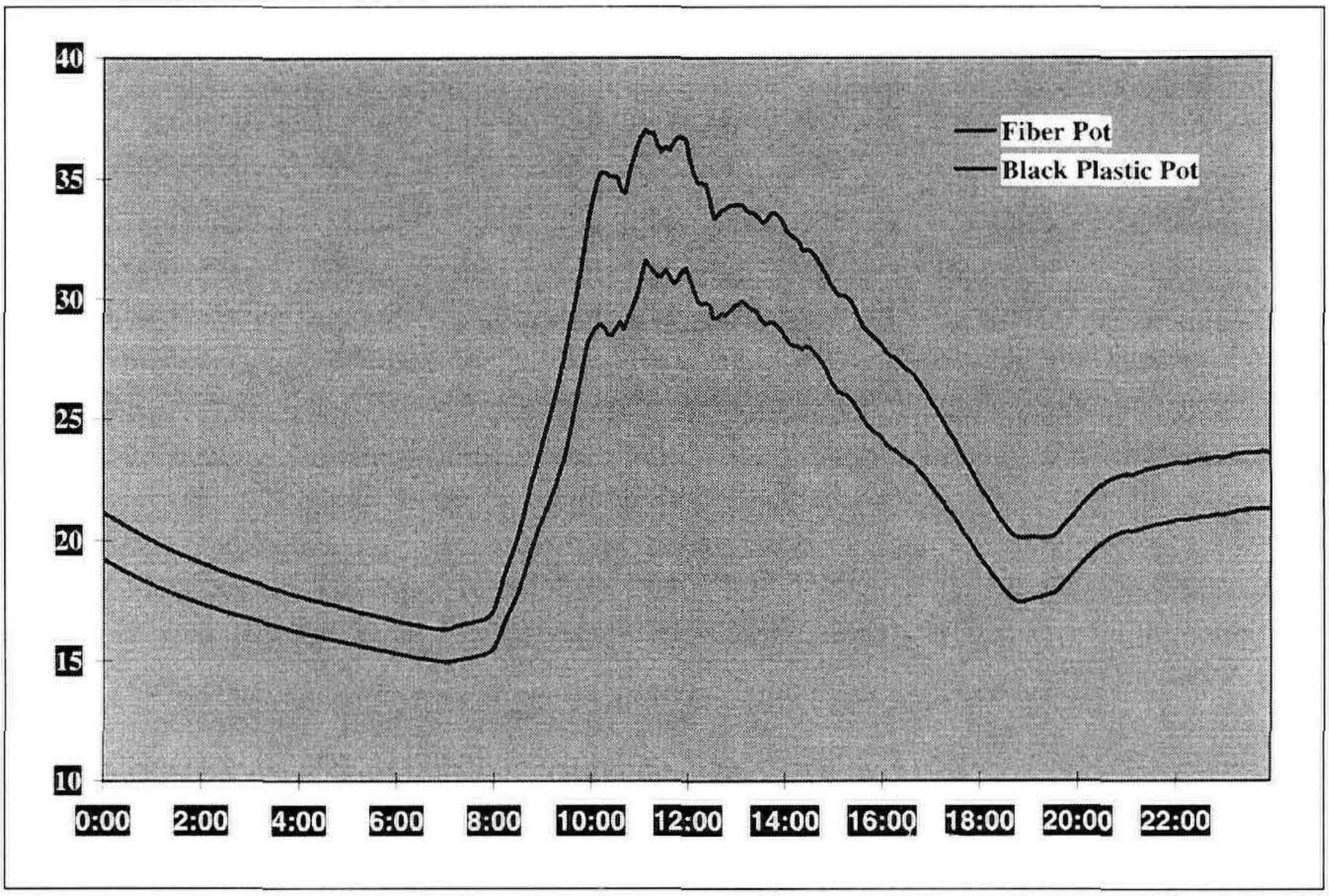

Figure 4. Evaporative cooling through the pot wall can significantly reduce medium temperature on the south sides of pots.

Figure 5. Copper treated fiber pots reduce root penetration of pot walls by *Forsythia* roots.

Figure 6. A large east coast grower raises 1-gal liners in fiber pots.

Although there are many advantages to using treated fiber containers there are some significant research challenges. It appears that the lower sides and bottoms of sizes larger than 2 gal need to be strengthened. Adding inside bottom gussets may solve this issue but that remains to be tested. Smaller pot sizes are competitively priced and larger sizes are actually less expensive than comparable sized poly containers.

Determining Optimal Lifting Time of Nursery Stock for Cold Storage

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As one of several physiological parameters for determining the optimal lifting time of barerooted nursery stock for cold storage, shoot and root frost hardiness were studied as possible indicators of storability. During autumn (September to December) 1997, seedlings of pedunculate oak (*Quercus robur*) and Scots pine (*Pinus sylvestris*) were lifted at 7 and 6 occasions, respectively. At each lifting date seedlings for field performance trials were stored at -1C, while samples of shoot tips and fine lateral roots were frozen to - 5, -10, -15, and -20C. A control sample was kept at +2C. Frost damage was assessed using the electrolyte leakage method. In April 1998 the cold stored seedlings were planted for field performance. The results indicate that shoot frost hardiness at -20C can be used as an indicator of storability, and that the relatively simple, fast, and inexpensive method described here has potential for operational use in the future.

INTRODUCTION

For several decades, autumn lifting and subsequent cold storage of nursery stock have been common practice in Scandinavia in order to overcome peaks of demand for spring time planting and to prolong planting time until early summer (in this text the term "cold storage" refers to storage in the range of a few degrees above or below 0C). It has for some time been common knowledge that lifting and subsequent cold storage of seedlings before a certain state of physiological maturity is reached has detrimental effects on survival and growth after planting the following year (Omi et al., 1994; Sønderhousen and Bøvre, 1980). For many deciduous species leaf abscission is a fairly good indicator of physiological maturity and is often used in practice. However, juvenile forms of some species, e.g., *Quercus robur* and *Fagus sylvatica*, do not drop all their leaves in autumn and the state of physiological maturity can therefore be difficult to determine. The same difficulty is obvious for conifer species.

Storage of barerooted seedlings is a drastic environmental change. An important prerequisite for storability, therefore, must be that seedlings have reached a high level of stress resistance towards cold and dehydration. Maximum stress resistance has been found to coincide with maximum bud dormancy (Hermann, 1967; Lavender and Wareing, 1972), and measurement of dormancy status is, therefore, a possible parameter for determining optimal lifting time. Measuring bud dormancy, however, may take weeks (Ritchie, 1984) and is not suitable for operational nursery purposes where results often are required within a few days.

Shoot frost hardiness correlates quite well with development of stress resistance (Lavender, 1991), and could be an alternative parameter to dormancy. Several methods for assessing frost hardiness are available:

Visual Evaluation. A rather simple and widely used technique is visual evaluation of frozen tissue (tissue browning). Major disadvantages with this method are the long incubation period of 1 or 2 weeks (Anisko and Lindstrom, 1996; Stergios and Howell, 1973) and the element of subjectivity in the evaluation.

Shoot Tip Dry Matter Content. Rosvall-Åhnebrink (1985) found that the dry matter content of shoot tips (SDM) was correlated with shoot frost hardiness and it has for some years been used rather commonly in Swedish nurseries as a parameter for storability. It is relatively simple and inexpensive to measure, but practical experience, as well as later experimental results, have revealed some uncertainty about the reliability of this parameter (Mattsson,1998 pers. comm.; Lindstrøm and Håkansson, 1996).

Chlorophyll Fluorescence. This parameter is a measure of the functionality of the photosynthetic apparatus and provides information about both dormancy status and frost hardiness in conifers (Strand and Öquist, 1988). The method is fast and has also proven to be useful in determining seedling storability (Vidaver et al., 1989), but the equipment is expensive and the use is restricted to conifers and other evergreen species.

Electrolyte Leakage. Physiological injuries of cell membrane integrity caused by freezing or desiccation can be detected with the electrolyte leakage (EL) method (Dlugokecka and Kacperska-Palacz, 1978; McKay and White, 1997; Wilner, 1960). Cells within plant tissue (e.g., shoot or root sections) exposed to frost, will be more or less injured depending on the severity of the freezing process or the degree of frost tolerance of the tissue. Freezing of extracellular water causes an efflux of water from the cytoplasm through the cell membrane out into the extracellular lumen. This process often leads to alterations in the cell membrane, apparently affecting the ion transport properties, which results in increased leakage of electrolytes (Palta and Li, 1980). The frost damage can be quantified by placing the frozen tissue in deionized water for a specific period of time (e.g., 24 h) which allows electrolytes to leak out of the injured cells. The resulting increase in electrical conductivity of the water is a measure of the freezing damage. The EL method is relatively fast, simple, and inexpensive to perform in comparison with other physiological tests, and could be done by larger nurseries or offered as a service by commercial laboratories.

The objective of this investigation was to study shoot and root frost hardiness as possible parameters for detecting the optimal lifting time of barerooted seedlings for cold storage. For frost hardiness assessment, the EL method was chosen because it is relatively fast, simple, and inexpensive and because of its potential use as a more universal method for detecting plant tissue injuries under operational nursery conditions. Two model species, pedunculate oak (*Q. robur* L.), and Scots pine (*P. sylvestris* L.), were selected because of their wide distribution and economic importance in Scandinavian and European forestry.

MATERIALS AND METHODS

Sampling. From September until December 1997, seedlings of *Q. robur* (1+0) and *P. sylvestris* (2+0) were lifted at 7 and 6 occasions, respectively, in a commercial nursery and immediately transported to the Department of Ornamentals in Årslev. Lifting dates for *Q. robur* seedlings were 15 Sept., 6 Oct., 27 Oct., 10 Nov., 24 Nov.,

and 8 Dec. and for *P. sylvestris*. 15 Sept., 6 Oct., 27 Oct. 17 Nov., and 8 Dec. At each lifting date samples were prepared for freezing tests, pre-planting measurement of root growth potential (data not presented here), and field performance. The freezing test included a frost treatment and subsequent evaluation of frost injury with the EL method. Seedlings for the root growth potential test and field performance were stored at -1C until April 1998.

Freezing Test. At each occasion shoot tip and fine root samples of 75 seedlings of both species were prepared for freezing tests. From each seedling a 3-cm-long stem segment was cut out right below the apical bud, and root samples were prepared from fine lateral roots (400 to 900 mg per sample, diameter 2 mm, and approximately 3 cm long). Shoot tips and roots were washed in tap water and afterwards carefully rinsed in deionized water to avoid contamination with surface ions. Each sample was put into a 25-ml plastic bottle and capped. The 75 samples were divided into four sets of 15 replicate samples per target freezing temperature and a set of 15 samples was kept at +2C as control. The 60 samples were frozen in a programmable freezer at a rate of 2C h^{-1} to the target temperatures -5, -10, -15, and -20C. Each set of samples was kept at the respective target temperature for 60 min, before they were removed from the freezer and placed at -1C to thaw overnight.

Evaluation of Frost Injury. Twenty ml of deionized water, with a known low electrical conductivity (C0, mS cm^{-1}), were added to each bottle and the samples were left to leak in darkness at room temperature for 24 h ±15 min. After shaking the samples briefly, the resulting conductivity of the water (C1, mS cm^{-1}) was measured with a conductivity meter. The samples were then autoclaved at 110C for 60 min to obtain maximum possible electrolyte leakage. After cooling samples to room temperature, a second reading of the conductivity (C2, mS cm^{-1}) was made. The root electrolyte leakage (REL) and shoot electrolyte leakage (SEL) were calculated as relative conductivity (RC):

$$RC = \frac{C1 - C0}{C2 - C0} \times 100\ \%$$

Relative conductivity (RC) expresses the injury caused by freezing as a percentage of maximum injury and thus eliminates the effect of sample size. To eliminate the effect of membrane damage caused by environmental factors in the nursery and during the lifting process, shoot and fine root frost hardiness of both species were expressed in terms of $SEL_{diff\text{-}20}$ and $REL_{diff\text{-}5}$, respectively. The $SEL_{diff\text{-}20}$ and $REL_{diff\text{-}5}$ are defined as the difference in SEL or REL of samples frozen to -20 or -5C and the respective control samples, kept at +2C, according to Lindström and Håkansson (1996). Low values indicate that the tissue is frost hardy in the range of the specified temperatures.

Field Performance. *In April 1998, cold stored seedlings of both species were* planted in an experimental field at the Research Center in Årslev for assessment of field performance. Trials were laid out in a randomized block design with five replicate blocks of 19 seedlings per lifting date. Strips of lawn grass were sown between seedling rows to simulate weed competition in a controlled reproducible way. Measurements of first-year field performance (survival and growth) have not

been completed yet. At this point only survival in August 1998 has been recorded, while growth parameters (height and stem diameter increment) will be measured during the winter 1998-99.

RESULTS AND DISCUSSION

Field survival in August 1998 of *P. sylvestris* was clearly affected by lifting time (Table 1). Lifting in September and early October and subsequent cold storage had a detrimental effect on field survival, while lifting by the end of October or later resulted in satisfactory field performance. Survival of *Q. robur* seedlings was high (100%), irrespective of lifting date. Growth data (height and stem diameter increment) has not been recorded yet, but there are clear visual differences between lifting dates, showing poor performance of early lifted seedlings.

The freezing test results showed a considerable increase in shoot frost hardiness in terms of $SEL_{diff-20}$, and for both species the values stabilized around 0% to 8% from 27 Oct. (Table 1). The increase in root frost hardiness of *Q. robur* during the period

Table 1. Shoot tip and fine root frost hardiness and first-year field survival (August 1998) of *Quercus robur* and *Pinus sylvestris* seedlings lifted on different dates during autumn 1997. Shoot and root frost hardiness is expressed as $SEL_{diff-20}$ and REL_{diff-5} respectively, i.e., the difference in SEL or REL of samples frozen to -20 or -5C and the respective control samples.

Quercus robur

	Lifting date					
	15 Sept.	6 Oct.	27 Oct.	10 Nov.	24. Nov	8 Dec.
$SEL_{diff-20}$ (%)	58.0	35.5	3.2	7.7	5.5	3.1
REL_{diff-5} (%)	28.9	18.2	19.1	20.3	21.5	17.8
Field survival (%)	100	100	100	100	100	100

Pinus sylvestris

	Lifting date				
	15 Sept.	6 Oct.	27 Oct.	17 Nov.	8 Dec.
$SEL_{diff-20}$ (%)	35.2	22.6	4.9	5.4	0.5
REL_{diff-5} (%)	43.5	26.8	31.8	9.2	17.7
Field survival (%)	0	27	97	100	100

was small in comparison with the development in shoots. For *P. sylvestris* there was a general but rather unstable increase in root frost hardiness. A rather good correlation ($r^2 = 0.97$) between shoot frost hardiness and storability, in terms of post-storage field survival, was obtained for *P. sylvestris*. The stabilization of $SEL_{diff-20}$ coincided with 97% to 100% field survival of *P. sylvestris* seedlings lifted 27 Oct. and later, which indicates satisfactory storability from that date. The described method of combined freezing test and electrolyte leakage measurement was able to detect the onset of maximum seedling storability for at least *P. sylvestris*, with threshold

values of $SEL_{diff-20}$ for storability in the range of 0% to 5%. Similar results have been obtained by Lindström and Håkansson (1996) for *P. sylvestris* and Norway spruce, *Picea abies* (L.) Karst. With these promising results in mind, we hope to develop the method further and to introduce it on a more operational scale as a future service for nurseries.

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Welcome Address for the International Plant Propagators Meeting

Tony DiGiovani
Executive Director, Landscape Ontario, Canada

Good Morning and welcome to Toronto, Ontario, Canada, for the I.P.P.S. Eastern Region conference. My name is Tony DiGiovani, Executive Director of Landscape Ontario Horticultural Trades Association.

Landscape Ontario represents the horticultural industry. Our membership is comprised of over 1500 horticultural firms who derive their livelihood from working with plants. Many of our members are also members of your Society.

It gives me great pleasure as a representative of the horticultural industry to welcome you.

Your work confers immense and immeasurable benefit to the entire horticultural industry and even more to the generations of society whose quality of life is improved by the plant material that surrounds them. The work you do forms the root and is largely responsible for the growth and nurturing of an entire industry.

Plant propagation is one of those special pursuits which has been practiced since time began. It is only fitting that a special activity would attract special people who have formed a special organization. Recently our publisher, Rita Weerdenburg, wrote an article in Landscape Trades magazine which pays tribute to your august group.

I.P.P.S. is truly a remarkable Society. The principles and attributes of unselfish information exchange, commitment, enthusiasm, focus, scholarship, research, networking, sharing, and camaraderie set your group up as a role model not just for associations but for living in general.

Yours is important work. Your activities contribute economic, societal, aesthetic, spiritual, and therapeutic benefits; yet so often your role is not properly acknowledged.

There is a popular Canadian artist who in one of his songs has a line "If you stare at too much concrete you forget the earth is alive". Your activities remind us that the earth breathes.

It is with great pride as a representative of Ontario's horticultural industry that we thank you publicly for the important role your activities play in the continued health of our industry and environment. We are proud to be associated with your visit.

In the next few days we hope you will learn and see a great deal and trust that along with plants you will also propagate many fruitful relationships.

Thank you for coming to Ontario.

Open-Roof Greenhouse

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INTRODUCTION

J. C. Bakker & Sons is a family-run nursery business which has been involved in the growing of woody ornamentals for 50 years. As the business grew throughout the years, our propagation facilities also grew. Most of our facilities consisted of Quonset-style polyhouses which were about 18 ft × 100 ft. As we required more space we would construct more of these type of houses.

Although the results we were getting in these structures were satisfactory, there were a number of problems or difficulties we encountered. The work environment was not always pleasant. The people in the houses were often cramped between wet poly and plants. Caring for the plants and the maintenance of the houses started to become a large task. Each house had its own heating and cooling system and its own controls and alarm systems.

Another difficulty we had was all the plant material growing in the house eventually had to be moved outdoors for growing on. The plants, having been grown under poly, had little exposure to ultraviolet light and when brought out to the fields, would burn up under the bright sunlight. This we would overcome by some type of shading, either in the field or in the greenhouse, after removing the plastic. Needless to say this was very labor intense.

We began to look for a solution. Our desire was to pull all of our propagation under one roof and, if possible, overcome our weaning-off problems. We looked at the greenhouse industry around the world and found many different designs. None fit our exact needs. After talking with the people at Westbrook Systems, a local greenhouse manufacturer, we together came up with the system we now have—a double-poly, gutter-connected house which vents at the peak. In this presentation I will speak about this structure and its controls and then talk briefly about the various crops produced in this range.

THE DOUBLE-POLY, GUTTER-CONNECTED HOUSE

The range is 53,000 ft^2 in which we do all of our hardwood cuttings, softwood cuttings, conifer grafts, and top grafts. Depending on ventilation or sun exposure required, roof panels hinge at the gutter and can be opened anywhere from 0% to 100%. Every two peaks are operated by one motor. The house is 14 ft high to the gutter, and spans 42 ft on trusses between posts. All of the heating pipes, water pipes, shade curtains, and H.A.F. fans are held up in the trusses so there are no obstructions in the house.

Throughout the propagation season the peaks open and close to provide necessary ventilation. The ventilation is very uniform and there is no need for exhaust fans or side louvers. The H.A.F. fans are used to help keep temperatures even and reduce disease. As the crop matures, prior to planting out, the roof is allowed to open to 100% and shade is used to help the plants become acustomed to full sun.

The greenhouse is divided into two sections one in which we grow on the ground the other section is on benches. The benches we are using for our winter hardwoods

are a precast concrete. We have found them to be easy to clean, give uniform bottom heat, and they can withstand the weight of our winter medium—sharp sand. Every bench is zoned with its own heat.

The majority of the watering is done overhead through combination mist/water nozzles. Water lines are fed from the center outward to avoid water hammer and each line is controlled by electronic valves. Fertilizer can be injected into the water system using a simple dosatron injection system.

Heat is provided by two, 80 HP, Boiler Smith hot-water boilers. These boilers are dual fired and can be run on either gas or oil. The boilers are rated at 150% capacity and run in tandem. If one can't keep up the other helps out. The lead boiler is alternated every day. The boilers keep a constant supply of hot water in the boiler loop. As different areas of the greenhouse require heat, the water is mixed into the various zone loops. The computer decides the optimum water temperature for heating the different areas of the greenhouse.

In the case of power failure, we use a P.T.O.-driven generator as backup.

Controls. Control of the entire greenhouse is done using an Argus Computer system. A local computer is used to communicate with the system. The greenhouse can also be contacted and controlled from home, using a modem. We have found the Argus system to work very well in our greenhouse. The system looks at many different factors such as outdoor light, outdoor temperature, wind speeds, and your greenhouses' abilities. It uses all of these in combination to achieve the desired climate.

Sensors are located throughout the greenhouse to gather information for control. There are over 120 sensors throughout the greenhouse including the following: aspirated, humidity, position, bench, and weather.

Because the greenhouse is mainly used for propagation, the climate we are trying to create is often not typical of most growing environments. The Argus system, however, we found to be very flexible allowing us the control we need. Argus uses many different equations to which you can tie in any variable or sensor to control mechanical devices within the greenhouse, such as, sample of a vent-tuning program, mist program, climate settings, and alarm equation.

From these different programs, we create user screens. User screens show only the parameter needed to control the different functions in the greenhouse. They simplify changes and can be made up in any fashion to suit the operators needs. Examples of user screens include, vents, mist valve, and boiler.

The Argus system also keeps total records of climates inside and out of the greenhouse and keeps track of the operation of the equipment. This information can be displayed in many different graphical forms. An alarm system monitors up to 160 different alarm parameters, and is set up in different levels starting with a local siren. If problems are not addressed, the system will phone for help until it gets a response.

PROPAGATION

Summer Softwoods. In our old systems of propagation, we used various types of clocks and timers to control our misting in the greenhouse. This worked okay, but we had to constantly adjust for changes in the weather conditions.

In the new greenhouse we now use accumulated light to control mist bursts. We set a threshold, for example 200 watts m^{-2}, and every time this threshold is reached,

a burst of mist is triggered. The more light, the more frequent the bursts. This threshold can be tuned to suit every different type of plant being rooted.

With softwood summer cuttings, the roof is kept closed as much as possible to maintain high humidity. The temperatures are allowed to reach 98F at crop level. As we approach these temperatures the shade is used for the initial cooling, only when the temperature can no longer be controlled by just shade and mist, is roof venting used.

Once cuttings are rooted, mist is reduced and the roof is allowed to open to 100%. The shade is now used to help wean the plants off and get them accustomed to the ultraviolet sun rays. At this point the shade is controlled by light levels rather than by temperature.

Most of our softwood cuttings are direct stuck into the G.T. 38 trays from Growing Systems and are set in the benches or on the ground. Once the hardening-off process is complete, plants can be planted out into containers with no UV protection. These plants show no stress and quickly re-establish in the pots.

Winter Hardwood Production. For our winter cuttings, The benches are filled with sharp sand. The sand is moved in using a self-dumping bin. The bin is filled in the center isle and rolls over the benches on an angle iron track which lies in the paths. Once medium is leveled in benches, dormant cuttings are direct stuck in the benches. Bottom heat is maintained at 68F and air temperatures are allowed to go down to 50F. Venting is kept to a minimum and once again first-stage cooling is achieved with the shade in order to maintain humidity.

Once cuttings are well rooted, a hardening-off process, similar to what was done with the softwood cuttings is carried out. After this the cuttings are planted out, either into containers or field beds with no protection from the sun.

After all of the cuttings are removed from the greenhouse, the sand is removed from the benches. For this job, we have a simple belting system made up using greenhouse gutters. This belting system sits on top of the benches using the same angle iron tracking system which was used for filling the benches. The belt can be rolled from side to side over the tops of the benches and the sand is shoveled in. The sand moves down the belt and dumps into a trailer in the center isle. Whenever a crop is finished and moved out, the entire greenhouse is power washed and disinfected.

Top Grafting. In February we begin our top-grafting program. Dormant plant material is grafted and potted up in a barn and moved into the greenhouse where they are set down on the ground. Minimum night temperatures are allowed to drop to 45F and day temperatures are allowed to reach 85F once again maintaining high air temperatures first with shade and later with ventilation. When the grafts are well established, the roof is again opened, and the hardening-off process is repeated. Tender foliage is allowed to get used to the strong spring sun, and soon can be planted out into our fields.

This new greenhouse structure and controls have performed very well for us. We are now entering our 4th year of production and invite anyone interested to come and visit (especially if you are missing the tour).

Tissue Culture for Beginners: What It Takes to Setup a Lab

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INTRODUCTION

Tissue culture is a valuable tool for plant propagators. In tissue culture bud or other plant tissue is used to produce a large number of genetically identical uniform plants. This procedure is often used when other methods of propagation are unsuccessful. Setting up a plant tissue culture lab requires a basic knowledge of plant culture procedures. There are a number of reference books useful for plant culture procedure and lab design. *Plants From Test Tubes* by Lydiane Kyte and John Kleyn is very helpful and gives a great deal of information for setting up a successful lab.

A laboratory generally consists of three components; media preparation, culture transfer, and culture growth. Lab design is as unique as the individual setting up the lab. A lab can be a number of rooms or one large room. It is important that the lab is isolated from other operations and traffic to keep contamination at a minimum. The lab needs adequate heating and cooling so windows and doors can be kept closed. At Evergreen Nursery a mobile home was purchased and placed at the nursery. The kitchen is used for media preparation, the living room for culture growth, a bedroom for culture transfer and the remaining areas are for storage.

MEDIA PREPARATION

A media preparation area can be a simple kitchen. Culture media are prepared by mixing together stock solutions or adding water to powdered pre-measured media formulas. Water must be purified using a still, deionizer, or reverse osmosis. For small labs bottled distilled water is inexpensive and readily available. A refrigerator to store stock solutions, a sink to wash glassware, a stove to heat media, pressure cookers, and cupboards to store supplies are necessary. Specialized equipment needed for media preparation includes lab glassware and a hotplate stirrer or other automatic stirring device for mixing media. A balance is necessary for weighing stock solution and media components. A pH meter is used for adjusting medium pH to its proper level and dissolving growth regulators. Individual culture vessels can be test tubes, baby food jars, or other commercially available culture vessels. Media sterilization can be accomplished using an autoclave or stove top pressure cooker. The media preparation area is for producing sterile media, it is important that it is kept clean.

TRANSFER ROOM

The transfer room is where cultures are transferred from old to new media. Cultures must be sterile so transfer work is done in a sterile environment. A transfer hood consists of an enclosed HEPA filter with a blower forcing air through the filter into the transfer area. Transfer hoods can be purchased complete or in kit form. Prices vary widely depending on the type of construction. Transfer hoods are often left on continuously to purify the transfer room air.

Cultures cannot be manipulated by hand. Sterile instruments such as tweezers and scissors are used to cut and pull plants apart. Instruments must be continually sterilized during transfers and may be sterilized several different ways. Alcohol lamps are inexpensive but dangerous. Devices such as a Bacti-Cinerator can be purchased, they rapidly heat the instruments without a flame. Other supplies utilized in the transfer of cultures are tube or jar covers, marking pens to label cultures, and alcohol and paper towels to wipe down the transfer hood before and after transfers. Often prepared media are stored ready for use in the transfer room.

GROWTH ROOM

Plant cultures require light and moderate temperatures for proper growth. A culture growth room can be a room with wood or metal shelves. Fluorescent fixtures are suspended approximately 18 to 24 inches above the cultures on each shelf. The growth room should be kept closed from outside air if possible. If the room has windows they should be sealed. Employee traffic should be kept to a minimum. It is important to have adequate heating and cooling.

SHOOT HARVEST

Shoots may be cut in the lab and sent to the rooting area or the culture itself is opened and shoots harvested in the greenhouse. Shoots produced in the lab are often treated as softwood cuttings and stuck in greenhouse media. Shoots are tender and root rapidly. Pots or trays filled with media are stuck and placed in a high humidity environment. Flats covered with clear domes can be placed under lights or a mist tent system can be constructed.

CONCLUSION

An efficient small tissue culture lab can be set up for under $10,000. Once the lab is set up it must be staffed. Personnel must be trained in media preparation and sterile techniques. Labor is an ongoing cost and must be considered in the lab cost. A lab can be very valuable for propagating specific plants needed in your operation. Before setting up a lab estimate lab set up and labor costs to determine if it is more economical to produce the shoots yourself or contract a commercial lab to propagate the shoots for you.

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Production of *Magnolia kobus* and *Magnolia virginiana*

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SITE SELECTION

Our primary soil types are Chillum silt loam and Matapeake silt loam. Both of these soils are slightly sloping and well drained. These have a topsoil of 8 to 10 inches thick of moderate fertility. The available water holding capacity is high at 2 to 4 inches. The subsoil is a 20-inch-thick brown silt loam. These are underlain with a yellow-red gravelly sandy clay loam 60 inches thick. We chose this site because in the early spring and late winter we can harvest our crops on a timely basis. This site also provides adequate air drainage for early and late frosts as we are on high ground.

SITE PREPARATION

This task is of the utmost importance as it reduces annual and perennial weed populations, chances of soilborne diseases, and elimination of nematodes.

An application of Roundup (4% solution) is used for elimination of perennial weeds. This is done in two or three applications over the summer months.

In a new field never planted, we apply 50 tons of composted sewage sludge per acre and work this in to a depth of 6 to 8 inches. This is a vital part of our program as it increases organic matter, cation exchange capacity, water holding capacity, and acts as a slow-release fertilizer.

Fumigation with Vapom at a rate of 55 gal $acre^{-1}$ is used to eliminate weed seeds, soilborne diseases, and nematodes.

The soil is then prepared into raised beds 1 ft high and 4 ft wide with 2 ft of aisleway.

SEED SELECTION

We collect all of our own magnolia seed. Collection is from trees exhibiting superior phenotypic expression such as leaf color, habit, flowering, fruiting, and disease.

SEED COLLECTION

Magnolia virginiana. In southern New Jersey, *M. virginiana* is normally ready from the last week of August to the first week in September. We wait until the follicles have started to expose the red fleshy seeds. A cut test is performed; if this is above 60%, we will collect the seeds. The whole follicle is collected and then spread out on screens one-follicle deep until about 80% of the seeds are exposed.

Seeds are shaken or picked from the follicle and are immediately cleaned to remove the fleshy endocarp. Once the endocarp is removed, the seed is put into 5-gal buckets, stirred in water, and any floating seed removed.

Magnolia kobus. The same process is used with the collection date during mid to late September. Once the seed are cleaned, they are then dried just enough to prevent mold during storage until planting time. Seeds are stored in plastic bags in the refrigerator at 41F.

SEED SOWING — OCTOBER

With *M. virginiana* and *M. kobus* we find that five seedlings per ft^2 is an excellent density. These plants are very large-leaved and need room to grow. For our market, nurseries want a ¼ to ⅜ inch-caliper seedling from 12 to 18 inches to 16 to 24 inches tall.

Since *M. kobus* is used primarily as a rootstock, it is essential that these make a good ¼ caliper for budding or grafting. In our soil type with the addition of the compost we find an added benefit of straight fleshy roots with many fiberous roots.

The seed is then rolled into the bed and covered with an additional ½ inch of fine compost with particles no more than ½ inch.

Magnolia species have an embryo dormancy which is best overcome by fall sowing. We feel fall sowing is best since this is what "Mother Nature" does. Generally speaking, *M. virginiana* and *M. kobus* need a 90- to 120-day cold stratification period for germination.

Germination usually does not occur until mid May in our area. Once germination is complete, after 10 to 14 days, we then hand weed the beds to reduce competition for nutrients and water. The covering of beds with compost provides immediate fertilization which we feel is essential for healthy, sturdy plants.

Once the seedlings have their second set of true leaves we supplement fertilize with a 6-8 month formulation of 17N-6P-12K slow-release fertilizer. This fertilizer is released by water and not by soil temperature; rate is 300 lb $acre^{-1}$.

In mid June we apply ⅛ pound of active ingredient factor to the beds. By having the sludge wood-chip compost this herbicide is tied up on the bed surface and does not move into the root zone. The herbicide application is activiated with ¼ to ½ inch of water — depending upon soil moisture. This is followed up at 21- to 28-day intervals until fall. We do not shade the beds because this allows more photosynthesis and better growth for caliper and height. Herbicide application is followed up with hand weeding.

Along with our other crops, the magnolias are sprayed with Talstar and Dursban alternately at 14- to 21-day intervals. So far the magnolias have not had any fungal problems; therefore, we have not had to implement a fungicide program.

HARVEST AND STORAGE

We harvest most of our magnolia seedlings in the late winter to early spring. Careful attention is given when pulling the seedlings. We harvest with an Egedal digger. They are not completely lifted out of the ground during this operation. The seedlings are then pulled and shaken with some soil left on the roots and covered in bundles to prevent root drying.

When pulling the seedlings from the beds a spray of water is used and plastic tarps are pulled over the harvested seedlings to prevent root desiccation. A 1-0 seedling is of no use after 20 min of drying.

Our magnolia seedlings are stored with moist roots and dry tops. Grading and packing for shipment occur at the same time. This is accomplished by using fibrous sphagnum moss on the roots and jelly rolling them in 6-mil polyethylene plastic. Our experience has been that magnolias do not like storage any longer than 21 days. The cooler is maintained at 36F. We dig and ship so they are usually gone within 7 to 10 days.

IRRIGATION

In our soil type during the summer months we must irrigate for adequate growth. As a rule of thumb we apply 1 inch of water per week. Irrigation is supplied overhead with a traveling sprinkler. This can be accomplished with two workers instead of a whole crew of five or six.

THERE ARE SEVERAL KEY FACTORS IN SEED PROPAGATION OF MAGNOLIA.

Use a well drained soil for prevention of soilborne pathogens. Adequate air drainage is important to avoid early frosts in the fall when the seedlings are still somewhat soft.

In site preparation, elimination of weeds and pathogens is critical for superior growth.

The addition of compost to the soil is beneficial as this increases microbial activity for prevention of diseases. Compost promotes mycorrhizal fungi which allows for greater uptake of water and nutrients.

Application of systemic insecticides is important as a preventative against insects.

Fertilization with soil-building compost and slow-release fertilizer allows for a constant feed as the seedlings need it.

Adequate water of 1 inch per week keeps the seedlings growing for height and caliper. This is followed up by proper hardening off in late summer to early fall.

Weed prevention through hand weeding and herbicide so the seedlings obtain adequate water and nutrient level is important.

Proper handling from harvest, grading, and packing is critical to prevent roots from drying out. This prevents plant stress and increases plant survival.

CONCLUSION

With our program great care is given to the seedlings. As a result our plants survive and grow with little loss.

Magnolia Propagation at Arcola Creek Nursery

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INTRODUCTION

I begin my presentation with a quote from the last I.P.P.S. newsletter written by this year's program chairman, Mr. Tim Brotzman, who also happens to be a good friend and neighbor. In his comments regarding this year's program, he wrote, and I quote, "Fundamentally, propagators (and nursery operators) have been inventive, practical, and blessed with keen powers of observation, skills that become well honed by time and experience." After considerable thought, I concluded that "yes", I can relate to that.

Tim's quote brought a remembrance of one of my first experiences in the nursery industry which involved the calibrating and mixing of water soluble fertilizer. Upon completion of my task, my employer, a highly respected nurseryman and plantsman of that day, and I believe a charter member of this organization, carefully inspected my work by a rather unusual method of scrutiny. For his final approval, he reached down, cupped his hands in the tank of fertilizer and slowly raised his hands toward his face! As he proceeded, I said to myself, "Oh no! He's going to drink it!" Fortunately, he was just sniffing it, but much was learned through that episode. I soon learned that time, experience, observation, and a natural feel for plants are truly key factors to success in this business. I have always approached propagation and growing from a common sense point of view rather than a scientific viewpoint, and have carried that philosophy since 1982 when we began to build our nursery.

So, with those thoughts in mind, I introduce you to Arcola Creek Nursery. We are a small wholesale operation of 25 acres located in Lake County, Ohio, more specifically, Madison Township, about 50 miles east of Cleveland along the shores of Lake Erie. The heavy concentration of nurseries in this area is largely attributed to the moderate climate conditions, natural water supply, moisture, drainage, and other protective factors due to the proximity of Lake Erie. Our main focus is field production of high-demand, somewhat unusual flowering trees and shrubs, for the landscape and retail use. Although balled and burlapped material is 75% of our annual income we also sell bareroot hostas and daylilies, and do custom propagation in the form of rooted cuttings, bareroot liners, and seedlings. We propagate over 90% of the plant material that eventually goes to the field to be finished off. Liners are purchased only when we want to try something new, or when there is a crop failure. Our annual production constitutes approximately 40,000 softwood and semihardwood cuttings, 1000 grafted pieces, and 20,000 seedlings along with bareroot perennial divisions. One may conclude from these figures that we are definitely a "mom and pop" operation!

People inside and outside the trade often ask how I decide what to grow in the nursery. Personal preference is always a considerations but more importantly is the quality and diversity of the sandy loam soils that help make the decision.

One item that performs very well in our soil is some taxa of magnolia (Table 1). It just so happens that magnolias are also a favorite of mine!

Table 1. Magnolias propagated at Arcola Creek Nursery.

Magnolia (*M. liliiflora* 'Nigra' × *M. stellata* 'Rosea') 'Betty', 'Ricki', and 'Susan'
Magnolia (*M. acuminata* × *M. denudata*) 'Butterflies' PP #7456 (grafted)
Magnolia ×*loebneri* (*M. kobus* × *M. stellata*) 'Ballerina', 'Leonard Messel', and 'Merrill'
Magnolia ×*soulangiana*) 'Alexandrina'
Magnolia stellata 'Centennial', 'Royal Star', and 'Waterlily'
Magnolia virginiana glaucous form (seedling grown)

METHOD AND MATERIALS

The majority of our magnolia plants are rooted from softwood cuttings which are processed and stuck beginning around June 15th. I cannot emphasize enough the importance of timing in the rooting of softwood cuttings. Many cultural aspects and techniques such as hormone treatment aid in the process, but it is my personal opinion that none is more important than the condition and quality of the cutting itself. As a television commercial once stated, "timing is everything!" Considering all of the summer activities that are done throughout the nursery, none of them is of higher priority than propagation! For us, magnolias are normally the first plants we propagate due to their overall difficulty and short window of success time.

When we first started propagating magnolias, we took "heel" cuttings. However, having a field production operation, the demands of planting and harvesting made it difficult to get heel cuttings in a timely manner. In other words, we had high incidences of crop failure! Through observation and experimenting, we have found that cuttings made from lateral shoots taken from juvenile plants 3 to 4 years in age, have consistently higher rooting percentages than heel cuttings taken too late, or those cuttings taken from vigorous strong terminal shoots. Cuttings are quickly brought in from the field and washed in a large tub of water to cleanse from any pesticide residues, sand, and pests as well as to maintain turgidity. During the process of preparing the cutting, I have found a basal wound to be very beneficial in the overall success and production of root primordia. This is due to an accumulation of hormones and carbohydrates in the wounded area and also an increase in respiration. Wounded cuttings are also able to absorb growth regulators and more water from the rooting medium, thus promoting callus production and eventually root initiation. We also clip the leaves to reduce transpiration, as well as to provide increased air circulation, thus cutting down on potential fungal problems.

After wounding, the cuttings are first dipped into Hormo Root, a talcum-powder-based indolebutyric acid product of 2% strength. Due to the overall difficulty of magnolias, we have found 2% to be the most effective with very little burning.

The cuttings are then stuck in Christie Nursery polyflats which are 18 inches long × 15 inches wide, and 3½ inches deep. Each flat will contain approximately 100 cuttings. Our growing medium consists of Canadian peat moss, coarse perlite, and coarse concrete silica sand (5 : 5 : 2, by volume). This recipe has proven to provide

excellent drainage and porosity. We use this same ratio for most everything we propagate including *Rhododendron* and *Daphne*.

The filled flats are placed in our propagation polyhouse which measures 22 ft × 48 ft. The climate in the greenhouse is easily maintained due to its compact size. Intermittent mist nurtures the cuttings until root initials form which takes from 3 to 6 weeks. Rooting time varies among taxa. The National Arboretum's "girls" selections being first, followed by the *M. stellata* or star-type magnolias, and finally the *L.* × *loebneri* cultivars. Periodic checks of the bottoms of the flats helps determine the progress of root activity.

When sufficient roots are seen, the flats are moved from the mist house to a hardening off house that is covered with 47% shade cloth. Occasional misting is done by hand until the plants have acclimatized to the new environment.

Magnolias, along with all other tender crops, are overwintered in our minimum heat polyhouses which are maintained at a temperature of 38 to 40F. The following spring, plants are removed from the flats, root pruned, and planted in liner beds and grown for 2 years. The reason for the liner beds is threefold: (1) Growing in a confined area rich with organic matter, including composted ryegrass and composted leaves, provides nutrients to help the rooted cuttings push growth quickly; (2) plants in beds are easy to maintain with regard to weeding, fertilizing, and watering; (3) beds act as a quality control measure from which we can select the most vigorous plants to be grown on to finished B&B stock.

Magnolia virginiana or sweetbay magnolia has been propagated somewhat successfully by cuttings in the trade. However, at our nursery we prefer to grow them from seed because we usually have an abundant supply of seeds and have experienced a high percentage of germination. We are also able to sow the seeds outdoors rather than taking valuable greenhouse space.

Seed is collected during the month of September primarily from our own field stock. The seed is then picked from the follicles and the pulp removed from the seed using screens. Cleaned seed is then placed in plastic bags along with moist sand to prevent desiccation, and placed in the refrigerator until it is time to sow.

Proper seedbed preparation is critical to the overall success of the seedlings. Composted leaves and Michigan peat are spread and incorporated into the natural soil to create a rich sandy loam soil. The site is next fumigated with methyl-bromide canisters placed under a sealed clear poly tarp, and then punctured, thus sterilizing the top few inches of soil. Normally the site is fumigated for 48 h followed by a minimum of 14 days of airing before the seeds are sown. Planting of seeds usually takes place in October or November. The actual procedure we use to plant the seeds is quite antiquated, but very effective in saving valuable space. Furrows are made by gently hammering 1 inch × 4-inch boards in the soft tilled soil. After the furrows are made, the seeds are dropped by hand into the furrows and covered with soil. Salt hay is thickly spread over the seed bed area; it aids in keeping the soil moist and weed free.

Germination takes place the following spring, generally around the end of April or early May. With the emergence of the hypocotyl and the first "true" leaves, the salt hay is largely removed to provide only a thin covering and shade is provided by means of a snow fence up on raised blocks and pipes. Although the germination percentage is normally high, the growth of the seedlings during the 1st year is minimal. During spring of the 2nd year, the sweetbays are undercut, pulled, root

pruned, and transplanted in a regular 6-row, liner-bed configuration. At their new location, they are pruned, fertilized, and nurtured for 2 years to establish heavier branching and fibrous roots. Much development takes place during this stage. Plants can attain a height of 30 inches which is desirable for field planting. The 3-year-old plants are once again undercut, root and top pruned before being hand planted in 4-ft nursery rows, and grown to finished sizes for harvest.

At Arcola Creek Nursery, we are very excited to have the growing rights for *M.* 'Butterflies', a wonderful hybridized creation of Phil Savage. 'Butterflies' showcases large deep yellow flowers. Currently we are in our 3rd year of propagation, exclusively by grafting. All understocks are potted in tree bands 1 year before grafting is done. It is grafted in February on *M. kobus* using a side-veneer graft. The graft is secured by a rubber band and sealed water tight with Parafilm™ wrapped around the union. The versatility of this laboratory film eliminates the need for bench grafting tents. The finished graft is set upright in flats which are placed on top of sand beds in the greenhouse. Bio-therm hot water bottom heat helps to activate roots and stimulate the cambium tissues, thus promoting callus. As with the other magnolias, the newly formed grafts are planted in May into liner beds for 2 years. We choose to cut the rubber bands and Parafilm™ from the union prior to planting, although it is not imperative as the rubber band eventually rots and the growth of the union breaks the Parafilm™. Periodic sucker removal from the understock helps keep all the energy directed to the scion. This year we planted our first field crop and hope to add 'Butterflies' to our catalog in the near future. Stay tuned.

CONCLUSION

Magnolias are a never-ending challenge. Have I master the art of propagating them? Hardly! I have found it to be one of the most humbling experiences in my life. We are who we are by what we learn. The keen power of observation and experience can only be achieved if it is modeled and taught to us. Many times as I look out over the fields from the second floor balcony of my home I am reminded of the people who took the time to teach me the skills I needed to know to learn the industry. To Zophar Warner, Ed Losely, John Ravestein, and Tim Brotzman, this Society, and a host of other folks, I will forever be grateful.

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Sorting Out the Yellow Magnolias

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INTRODUCTION

Magnolia ×*soulangiana* remains the most popular tree magnolia in the northern part of eastern North America in spite of the fact that its flowers appear early enough in the season that they are frequently ruined by frost. Seeking to produce magnolias that would bloom late enough to escape most frosts, plant breeders at the Brooklyn Botanic Garden began a hybridization program in the 1950s that involved the use of a native species, *M. acuminata*, that normally begins to bloom in late May/early June in our area. The results of this work, repeated and built upon by other breeders, yielded a new class of yellow-flowered magnolias that begin to bloom in late April or later, evading the frosts and providing a reliable annual display.

Magnolia acuminata in its most common form bears mostly greenish flowers with some yellow on the inner tepals. Remarkably, when used as a seed parent, it transmits mostly yellow pigment to the flowers of its offspring. *Magnolia acuminata* 'Golden Glow', a clone found in the Smoky Mountains in Tennessee, bears flowers that are much more yellow than the average. *Magnolia acuminata* var. *subcordata* bears smaller flowers of a good yellow and usually reaches less than half the 80 to 90 ft that is the mature height for the species. It has been used in some hybrids where a smaller tree was the desired result.

HYBRIDIZATION

One primary cross brought together *M. acuminata* and *M. denudata*, a Chinese species with white flowers of exquisite form that are usually borne in March or early April, and consequently are very vulnerable to frost. The hybrids are usually in bloom the last week in April or first week in May here, appearing before the leaves expand. The first of this hybrid was 'Elizabeth', introduced by the Brooklyn Botanic Garden in 1976. The flower color, as for many of the other cultivars resulting from this cross, is a clear light yellow, fading in hot weather to an ivory color. Specimens of 'Elizabeth' have already reached 35 ft in height, and considering the ultimate dimensions of the parents, an ultimate height of 50 ft may well be achieved. Other cultivars belonging to this hybrid group are:

'Sundance' - raised by August Kehr, Hendersonville, North Carolina

'Yellow Fever' — selected by Kenneth Durio, Louisiana Nursery, Opelousas, Louisiana

'Yellow Garland' — introduced by David G. Leach, Madison, Ohio

'Ivory Chalice' (Leach) — flowers ivory in color

'Legend' (Leach) — selected because it readily sets fertile seeds when pollinated, principally valuable for breeding.

'Golden Sun' (Leach).

'Golden Gift' (Leach) — compact growth habit. Produces numerous axillary flower buds, leading to a prolonged bloom period.

'Goldfinch' — selected by Philip Savage, Bloomfield Hills, Michigan.

'Butterflies' — (Savage and patented) flowers deeper yellow, tree more compact.

'Sun Ray' (Kehr) — the result of treating 'Sundance' with colchicine to double its chromosome number. Flowers larger than 'Sundance', of heavier texture and slightly darker yellow.

A second class of hybrids was produced by crossing *M. acuminata* with *M. liliiflora*, a shrubby Chinese species with dark purple flowers. Although not reliably hardy in USDA Zone 5, *M. liliiflora* is valued for its highly pigmented flowers and blooming period, which begins in May. Again, Brooklyn Botanic Garden first made this cross, which yielded 'Evamaria', with somewhat bizarre flowers colored a mixture of purple, green, and yellow. Joseph McDaniel of the University of Illinois repeated the cross, and introduced 'Woodsman', of similar color. Although the first generation hybrids have not become wildly popular, they were used in further breeding, where it was discovered that they produced principally yellow progeny. Because both parents flower later in the season, the hybrid does as well, after the leaves have appeared, making cultivars of this group useful in areas that experience very late frosts. This hybrid was given the name *M.* ×*brooklynensis*. Because of the stature of the *M. liliiflora* parent, plants of *M.* ×*brooklynensis* mature at a smaller height than the *M. acuminata* × *M. denudata* hybrids. Except for 'Hattie Carthan' the following cultivars are the result of backcrosses to *M. acuminata*:

'Yellow Bird' — (Brooklyn Botanic Garden) flowers are a clear yellow, scattered repeat bloom in summer.

'Hattie Carthan' — (Brooklyn Botanic Garden) yellow flowers with a crimson stain at the base of the tepals. Resulted from a cross between two *M.* ×*brooklynensis* seedlings.

'Ultimate Yellow' — introduced by Harry Heineman, Scituate, Massachusetts. Tepals yellow with some green. Tree 17 ft in height at 20 years. Flower buds hardy to -30F.

Other crosses that have yielded yellow-flowered magnolias of note:

'Yellow Lantern' (Savage) — *M. acuminata* × *M.* ×*soulangiana* 'Alexandrina' — light yellow flowers hold "tulip" shape well, upright habit.

'Gold Star' (Savage) — *M. acuminata* × *M. stellata* 'Rubra', small, light yellow star flowers on a medium tree. Bronze new foliage.

'Gold Crown' (Kehr) — *M.* 'Woodsman' × *M.* 'Sundance', 8- to 10-inch yellow flowers on a columnar tree. Late flowering.

'Sunburst' (Kehr) — *M.* 'Woodsman' × *M.* 'Gold Star', deep yellow flowers of medium size, floriferous. Late flowering.

PROPAGATION

Some of these cultivars can be propagated from leafy, semi-ripe cuttings in summer, particularly if juvenile material is available. Alternatively, these can be grafted,

with *M. acuminata* and *M. kobus* being the recommended rootstocks in our area (USDA Zone 5 and colder).

Acknowledgements. I would like to acknowledge August Kehr, who provided descriptions and details on origin of his hybrids, and to Pat McCracken of Taylor's Nursery, Raleigh, North Carolina, for providing photographs of the Kehr hybrids.

Pot-In-Pot Tree Production for Municipal Use

Mark W. Bricker
City of Columbus, Ohio Forestry Section, 6993 South High Street, Lockbourne, Ohio 43137 U.S.A.

INTRODUCTION

The City of Columbus, Ohio comprises 135,000 acres: 2050 miles of streets and 202 parks (7000 acres). In 1996, an independent consulting firm accomplished a street tree inventory, concluding that the City had 85,000 trees and slots for 45,000 additional trees.

At that time, the City of Columbus made a commitment, and in my opinion, undertook the most aggressive approach to planting street trees in the United States. In the fall of 1999, the Columbus Ohio Municipal Nursery will be in full production planting 4000 container-grown and 1000 bareroot trees along the streets and in the parks each year.

PRODUCTION

The pot-in-pot system optimizes the growing environment of a tree through highly controlled germination, propagation, and root control methods. The process combines several different production methods that have been developed over the years. The unique combination of these methods and critical timing at different stages during the growth period results in a superior tree.

In the fall, seed is collected locally, specifically from mature trees exhibiting exceptional form, foliage, and resistance to insect/disease/air pollution. Table 1 represents a list of trees that I consistently produce from seed.

After collection, seed is given the proper stratification/scarification treatment and stored in the cooler. Once dormancy requirements have been satisfied, the seed is germinated. By the end of the greenhouse phase, the trees usually produce three flushes of growth and are approximately 18 to 24 inches tall.

Trees are then acclimated under shade and transplanted into 3-gal containers for one growing season. During the 1st year of growth, trees are monitored closely to insure central leaders are maintained and to accomplish selective pruning.

In the fall, some trees will be transplanted into 10-gal containers, while others will remain in the 3-gal containers and overwintered in the polyhouse. Transplanting is dependent upon the size of the tree as well as the species. In the spring, the remaining trees are transplanted into 10-gal containers and will remain there for 2 years. During each phase of production, containers treated with Spin-Out™ are utilized to prevent root girdling.

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Table 1. Trees that are consistently produced from seed.

Acer buergerianum	trident maple
A. campestre	hedge maple
A. tataricum subsp. *ginnala*	Amur maple
A. palmatum	Japanese maple
A. truncatum	purpleblow maple
Aesculus glabra	Ohio buckeye
A. parviflora	bottlebrush buckeye
Carya cordiformis	bitternut hickory
Celtis laevigata	sugarberry
C. reticulata	nettedleaf hackberry
Cercis canadensis	eastern redbud
Cladrastis lutea	yellowwood
Diospyros virginiana	persimmon
Eucommia ulmoides	hardy rubber tree
Fagus grandifolia	American beech
Fraxinus ornus	flowering ash
Gymnocladus dioica	Kentucky coffeetree
Koelreuteria paniculata	panicled goldenraintree
Magnolia acuminata	cucumbertree magnolia
M. virginiana	sweetbay magnolia
Nyssa sylvatica	black tupelo
Ostrya virginiana	American hophornbeam
Phellodendron amurense	Amur corktree
Pterocarya fraxinifolia	Caucasian wingnut
Pyrus fauriei	Korean pear
Quercus acutissima	sawtooth oak
Q. bicolor	swamp white oak
Q. imbricaria	shingle oak
Q. macrocarpa	bur oak
Q. muhlenbergii	chinkapin oak
Q. palustris	pin oak
Q. robur	English oak
Q. rubra	red oak
Q. stellata	post oak
Sophora japonica	Japanese pagodatree
Tetradium danielli (syn. *Evodia daniellii*)	Korean evodia

At the end of the 3rd growing season, trees are adequately branched with central leaders, will stand 6 to 7 ft in height, and will average 1 to 1½ inches in caliper.

Although these elements seem to be rudimentary, desired growth will not be achieved if the schedule is not strictly adhered to. In addition to the timing of certain activities, monitoring the trees and correcting any deficiencies is just as vital.

Successful Production of Difficult-to-Transplant Native Woody Trees

Peter J. White
Earthscapes Inc. 10403 St. Rt. 48 Loveland, Ohio 45140 U.S.A.

For almost 10 years our nursery in southern Ohio has been working on developing a system to produce difficult-to-transplant or taprooted trees so they can be successfully moved to their final destination. The production system we are using today is allowing us to grow and successfully transplant many of the more beautiful natives in a short period of time which here-to-for were nearly impossible to field transplant successfully or at least at any successful ratio that made it a profitable venture. This system has allowed us to go from a seed, to a containerized liner, to a 2-inch caliper tree in 42 months and only 24 to 26 months are spent in the ground.

The demand for trees and shrubs and, in particular indigenous natives, has been extremely high the last couple of years. Our tiny nursery is receiving orders and request in the numbers of thousands. The last 50 to 75 years showed a marked decline in the use of native trees I suspect because of their notorious reputation for transplant difficulty or they may have been considered too "ordinary" for most people to seek them out.

The late Dr. Phillip Kozel of Ohio State University infected me in the early 1970s with a great appreciation and love for the native species. As a young landscape designer fresh out of school, I couldn't wait to start designing landscapes using beech (*Fagus*), nyssa (*Nyssa*), sassafras (*Sassafras*), white oak (*Quercus alba*), etc. Needless to say, I was extremely frustrated when I found that absolutely no one grew these plants. Now 25 years later, I realize what a lot of these reasons were, but we have come a long way to resolving many of these problems with transplant difficulty. There is great interest in the buying public, and I think we know now how to put a good root system on them.

Our nursery has developed a system of growing a containerized liner which when planted in a fertile nursery field in the fall, can produce a 2-inch caliper tree, with a multiple-branched root system that will transplant readily in 2 years. Growing trees in containers is nothing new but before the development of Spin-Out™ and Whitcomb's special 'Roomaker' pots most of the root system was wrapped around the sides and bottom of the container dictating an eventual death sentence for the plant.

Two of the most important factors in this system we developed that help to insure success is by starting with the right plant, (or liner) and fall planting. (Remember, we are talking about native species.) The right plant should be an indigenous native, which means you have to have an idea of the seed source of your liners. Buying seeds or seedlings from and unknown source or from outside your climatic zone is like a crapshoot. The seed of most of our natives is either collected by myself personally or

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received from trusted friends and colleagues in or north of my region.

Once our seed has been collected, processed, and properly stored we begin the process of growing a seedling that contains a fibrous root system rather than a single taproot. This is a particular challenge specific to many of the natives that we consider desirable. Altering the root system at a very early age is one of the keys in this entire system. We have used a variety of methods over the years, but as new products have become available we are constantly testing for improvements. We are currently using containers primarily produced by the I.E.M. Corporation called Tray Masters which produces Spin-Out™-treated trays with quite a variety of cell numbers and cell depths to germinate the seed. What is allowing us to change the root system on these plants is the use of copper inside the cell walls and air pruning.

Except for the fall germinating species such as *Aesculus* and white oak groups, most of the seeds are brought out of the coolers in February or March and placed in the celled flats to germinate typically using bottom heat. Where deep kadon flats are used, the bottom of the flats are covered with landscape fabric coated with Spin-Out™. The celled trays are Spin-Out™-treated on the interior and have a fairly large opening at the bottom to prune the taproot. We feel that the air pruning is just as important as the copper treatment on the sides of each cell. This year the I.E.M. Company double treated our cell trays to help improve the root pruning. My initial reaction is that they need to up the percentage of copper in the paint. Additionally, all of our seedlings trays are inoculated with either endomycorrhizal or ectomycorrhizal preparations produced by Dr. Donald Mark's company Plant Health Care.

Germinating over 200 species of trees is not without its challenges, obviously the seeds need to have been properly stored, stratified, and scarified in order to germinate, but a person could grow old waiting for certain species to germinate. The most difficult problems we contend with germinating the seeds in greenhouses are the growth of algae on the flats, fungus gnats, over watering, and in general fungal diseases. We use a Davis Solar Twelve Mist Controller in our propagation houses for irrigation.

For many years we tried to duplicate Struve's work at Ohio State and tried to produce a usable field liner from seed in one growing season. We were able to do this but it was very inconsistent, as is often the case with seed. So we have settled on a 2-year process of growing a liner. The first being germination and initial growth phase of a seedling ranging from 6 to 30 inches in height and a root system contained in a pot approximately the size of a quart. The seeds are usually germinated in the smallest cell possible for the seed to fit and then transplant into 24-cell trays were they will remain until the following spring; they are then up canned to 1- or 2-gal containers for the 2nd years growth.

When the chance of frost has passed the seedling trays are moved outdoors and grown on raised benches which enhances the air pruning. During the summer growing season the seedlings are graded and culled as we look for genetic impurities or generally weak plants.

The seedlings are overwintered in inflated minimal heat quonset structures and in most cases we allow the winter temperatures to dip to the mid 20s by the dead of winter. In March we begin up canning last years seedlings to either 3-, 4-, or 6-qt containers depending on the species and its general vigor. Whenever possible the 3-qt container is used to save on space and shipping costs once the plants are sold. This

second growing season is extremely labor intensive as each tree needs to be trained to grow perfectly straight on bamboo stakes to the size of a nursery liner, generally 4½ to 7 ft tall, some lightly branched.

Our growing medium is custom blended for us by a neighboring nursery with a mixer and it contains pine bark and rice hulls, municipal sewage sludge and granite pebbles in addition to sulfur, fertilizer, and epsom salt. Our fertilizer is incorporated into the mix because of the labor savings and the problem with our plants blowing over in the wind. Top dressing is generally necessary mid-way through the growing season and keeping the pH of the soil medium low for most natives is very important for our region.

About half of our production is grown inside our 30 ft wide, high-walled greenhouses under 30% shade, the other half is grown on outdoor gravel beds with the wind and frost being major complications. Except for the plants grown in 5- and 7-gal containers, which are all on a drip system, all plants are watered with overhead irrigation from surface ponds.

Growing containerized trees is extremely labor intensive as each plant requires staking and multiple visits to that plant during that growing season to assure that the leaders are still intact and growing straight. In the Cincinnati area, finding labor for this task is usually more challenging than growing the plants.

By Labor Day or mid-September most of our 2nd-year seedlings have reached the salable height of a proper nursery liner and we begin cutting back on water hoping that the fertilizer in the pots is beginning to run low so the plants can harden off. Slowing these plants down and hardening them off before a hard freeze is one of the most difficult parts of this accelerated growth process.

The soil in our nursery fields is prepped around Labor Day and we are ready to begin fall planting of our containerized liners. Before the liners go to the field the root systems are drenched with a bio-stimulant such as "Grower" to aid in transplant shock reduction and all plants are sprayed with a deer repellent. We watch the weather closely and try to time the planting accordingly if rain is forecast, however, we do have drip irrigation and will plant by mid-September whether it rains or not.

The benefits of fall planting in a nursery can not be overstated. Everything works better in the fall than it does when you are planting in the spring. The soil conditions allow the equipment to work as it was designed, the warm temperatures help keep the planting crew in an up beat mood, and you are just plain not as rushed as you are in the spring. We feel that placing an undisturbed root system into warm moist soil in the fall gives us a full years advantage over spring-planted bare-root liners which are usually mudded in into wet cold soil. Usually by Thanksgiving it is very difficult to pull a fall-planted liner out of the soil because so much root growth has occurred by then. This growth of roots in the first fall is what allows us to harvest a 2-inch caliper tree in two growing seasons from transplanting. We feel our first growing season is similar to the second or third season of a bare-root liner in most cases.

First year growth on these liners is usually so extensive that it is necessary to stake the plant. The caliper of the trunk does not usually catch up to the top growth until the next fall and we never trim back lower branches and side growth during the first growing season because it adds so much structural stability. This initial staking is usually done in the winter following the planting of the liner. The second winter many of the branches are headed back closer to the trunk leaving about 3 buds so

that the next season's growth is very full. The second seasons growth is very vigorous as was the first and the development of the caliper continues and with proper pruning being done we have a salable plant by the end of the second season.

We feel that one of the main reasons for this phenomenal accelerated growth is the quantity of roots on the tree. When a tree is spring planted into cold wet soil it has to develop a root system from it's cut roots quickly, which it can not do because of the soil temperatures, while at the same time it is trying to put on top growth. Our fall-planted liners already have roots established.

My observations as a nurseryman for years has been that a tree seems to transplant better if I cut multiple small roots rather than several very large roots; this is exactly the type of root system that develops from a 'Spin-Out™-treated containerized tree. Another advantage of fall planting containerized tree liners is the total elimination of the root pruning process we all go through with bareroot liners. It now takes us less time to plant our entire crop then it used to take just to root prune our bareroot plants.

Genotypic and Environmental Effects on Root Cutting Propagation of *Pulmonaria* Species and Cultivars

Mark Bridgen and Janet Todd
Department of Plant Science, U-67, 1376 Storrs Road, University of Connecticut, Storrs, Connecticut 06269 U.S.A.

INTRODUCTION

Root cutting propagation is the technique in which plant roots are severed from the mother plant, cut into individual pieces, placed under moist, warm conditions, and allowed to develop into new plants after the formation of adventitious buds and roots. The propagation of ornamentals by root cuttings is an economical and efficient technique for some plant species. However, it is a method that is underutilized and should be given greater attention by plant propagators. The increasing costs of cutting production make it worthwhile for propagators to evaluate root cutting propagation as a possible means to increase plant production and decrease costs.

Root cutting propagation has several advantages: it can be carried out with unskilled labor, provides a fast way to multiply clonal material, requires limited propagation facilities, is useful for some plants where other methods have not been found satisfactory, is useful when only one sex of a dioecious plant is required, and can be carried out during the winter when weather is unsuitable for outdoor work. There are some disadvantages — these include limited information on the number of potential plants that can be obtained from stock plants, variability of results from year to year for some species, potential "weed" problems of severed roots that remain in a stock plant area, inconvenience of handling roots from outside stock plants if they are not sufficiently washed, variability in production as a result of the time of year cuttings are made, and the problem of propagating chimeral variegated plants.

Pulmonaria species, commonly called the lungworts, are one of the "hottest" groups of perennial plants for the shade garden. They are low-growing, clump-forming plants that grow best in full to part shade in moist soil. Some *Pulmonaria*

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species produce white or red flowers, but most species produce blue or pink flowers in the early spring; the flowers typically open one color, usually pink, and then turn blue as they age. This flower characteristic has given rise to the common name of soldiers and sailors. Flowers open before the foliage emerges or at the same time. After flowering, *Pulmonaria* species continue to be attractive with dark green, elliptical basal leaves that are covered with a bristly pubescence; many of the most popular cultivars are flecked with white spots.

Pulmonaria species are usually propagated by division, but they can also be propagated by seed for flowering in the 2nd year. The purpose of this study was to determine if *Pulmonaria* could also be propagated by root cuttings.

OBJECTIVES

The objectives of this research were:

1) To determine which genotypes of *Pulmonaria* species responded to root cutting propagation.
2) To learn what time of year is best to take root cuttings from *Pulmonaria*.
3) To discover if distal root cuttings of *Pulmonaria* respond differently to root propagation than proximal root cuttings.

PROCEDURES

There were eight different *Pulmonaria* cultivars that were studied (Table 1). There was one each of *P. longifolia* × *P. saccharata, P. saccharata, P. officinalis, P. angustifolia, P. rubra*, and *P. longifolia.*

Table 1. *Pulmonaria* species and cultivars that were evaluated for root-cutting propagation.

Species	Cultivar
Pulmonaria saccharata	'Janet Fisk'
Pulmonaria vallarsae	'Margery Fish' (syn. *P. saccharata* 'Margery Fish')
Pulmonaria	'Lewis Palmer' (syn. *P. saccharata* 'Highdown')
Pulmonaria	'Roy Davidson'
Pulmonaria officinalis	'Sissinghurst White'
Pulmonaria angustifolia	'Johnson's Blue'
P. rubra	'Redstart'
Pulmonaria longifolia	'Bertram Anderson'

During the first week of each month, for 12 consecutive months, 15 distal and 15 proximal root cuttings were removed from stock plants of each cultivar. Stock plants were maintained outside in a protected hotbed at natural daylengths, winter temperatures did not fall below 0C. Root cuttings were 3 cm long, distal cuttings

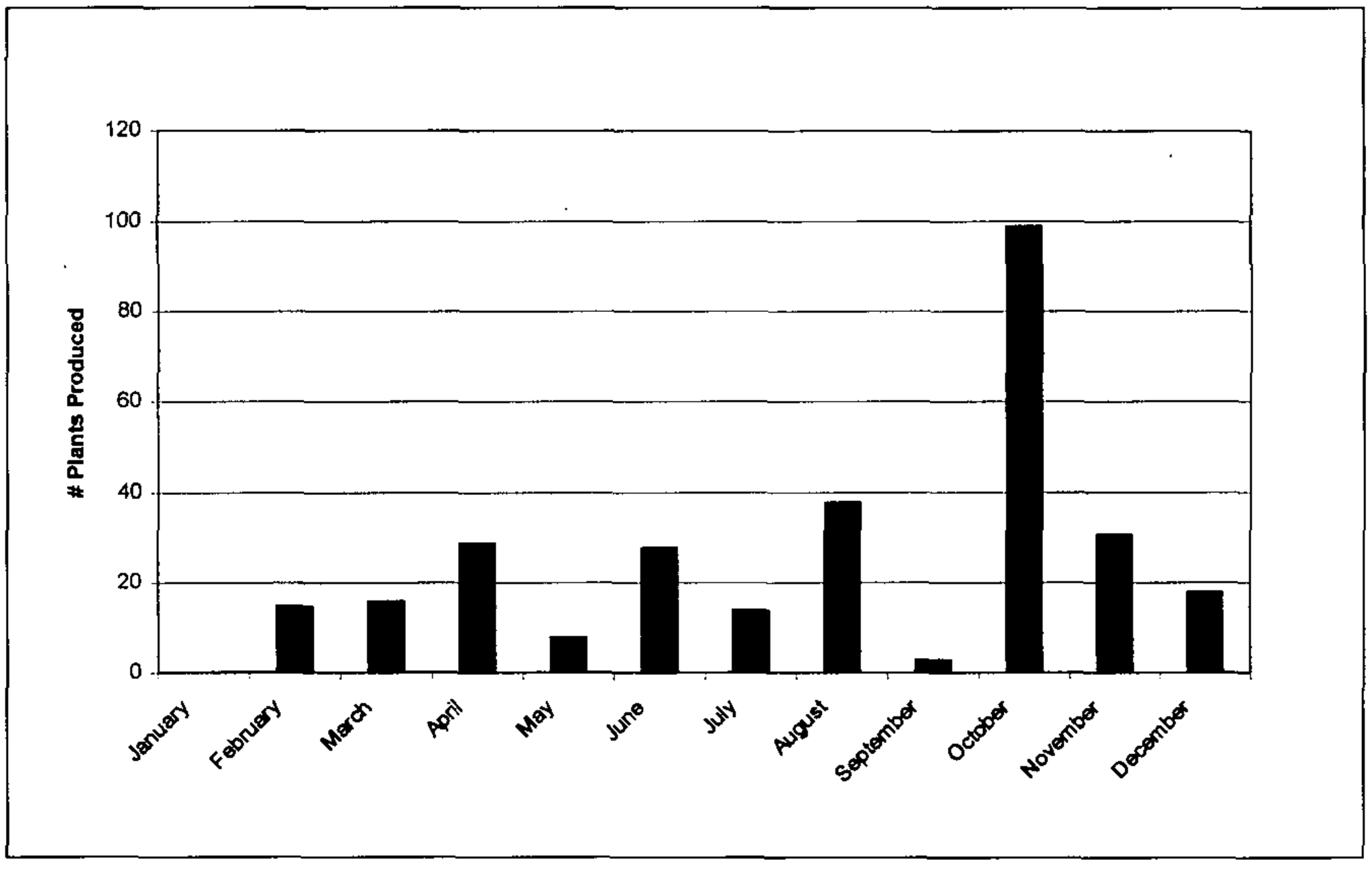

Figure 1. Number of plants produced from root cuttings taken from *Pulmonaria* 'Roy Davidson' over a 12-month period.

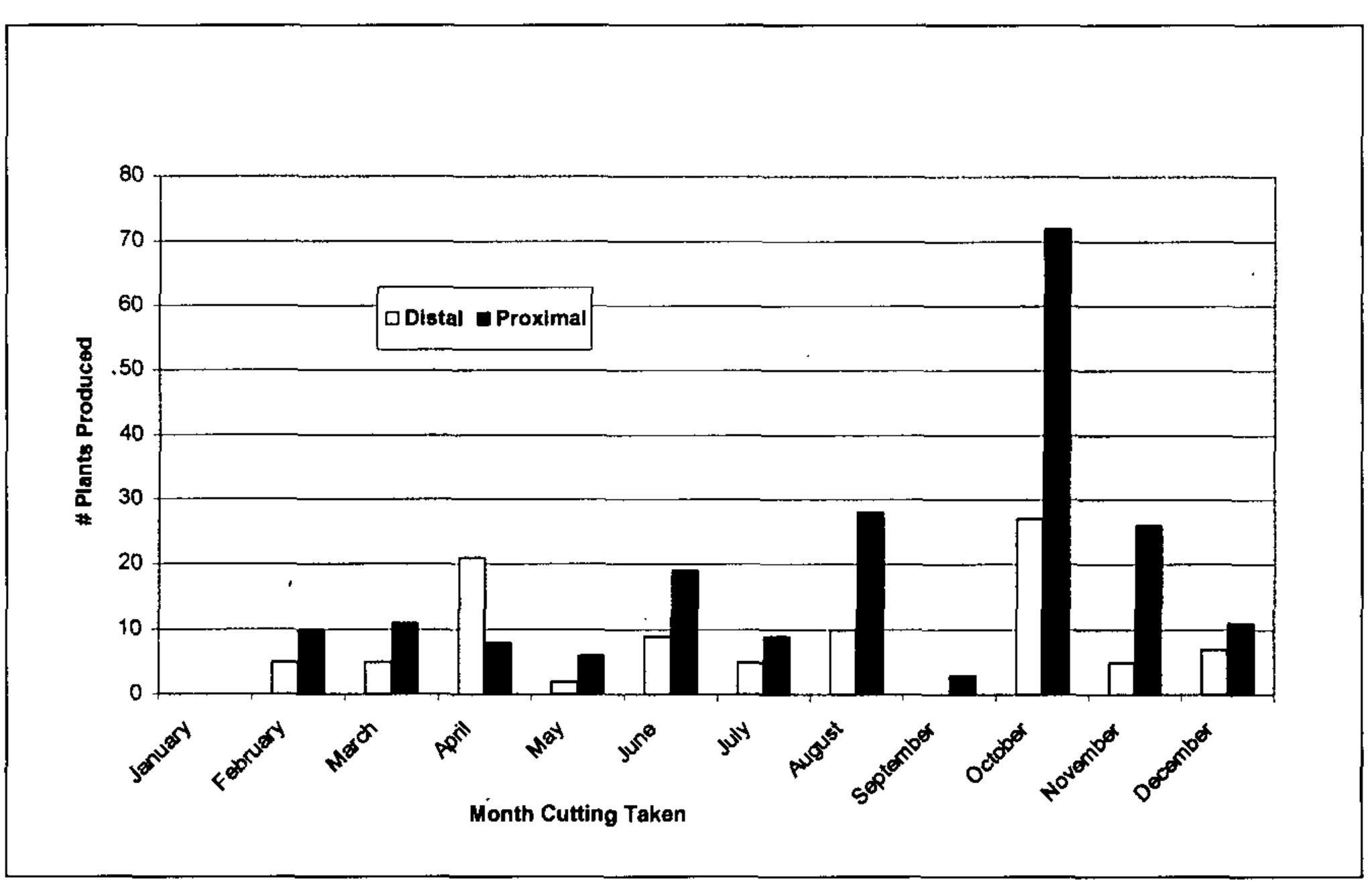

Figure 2. A comparison of the production of plants from distal and proximal root cuttings taken from *Pulmonaria* 'Roy Davidson' over a 12-month period.

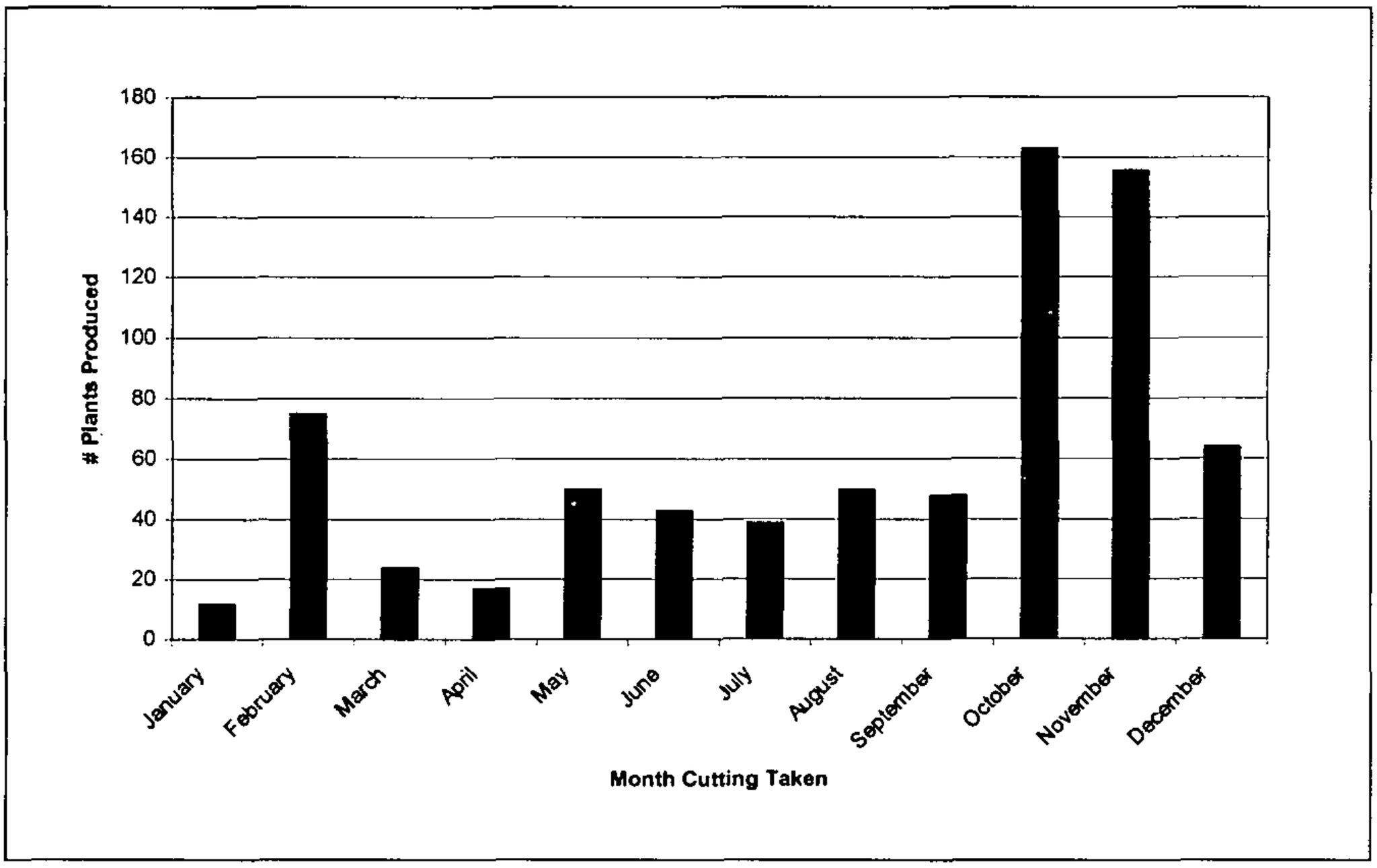

Figure 3. Number of plants produced from root cuttings taken from *Pulmonaria longifolia* 'Bertram Anderson' over a 12-month period.

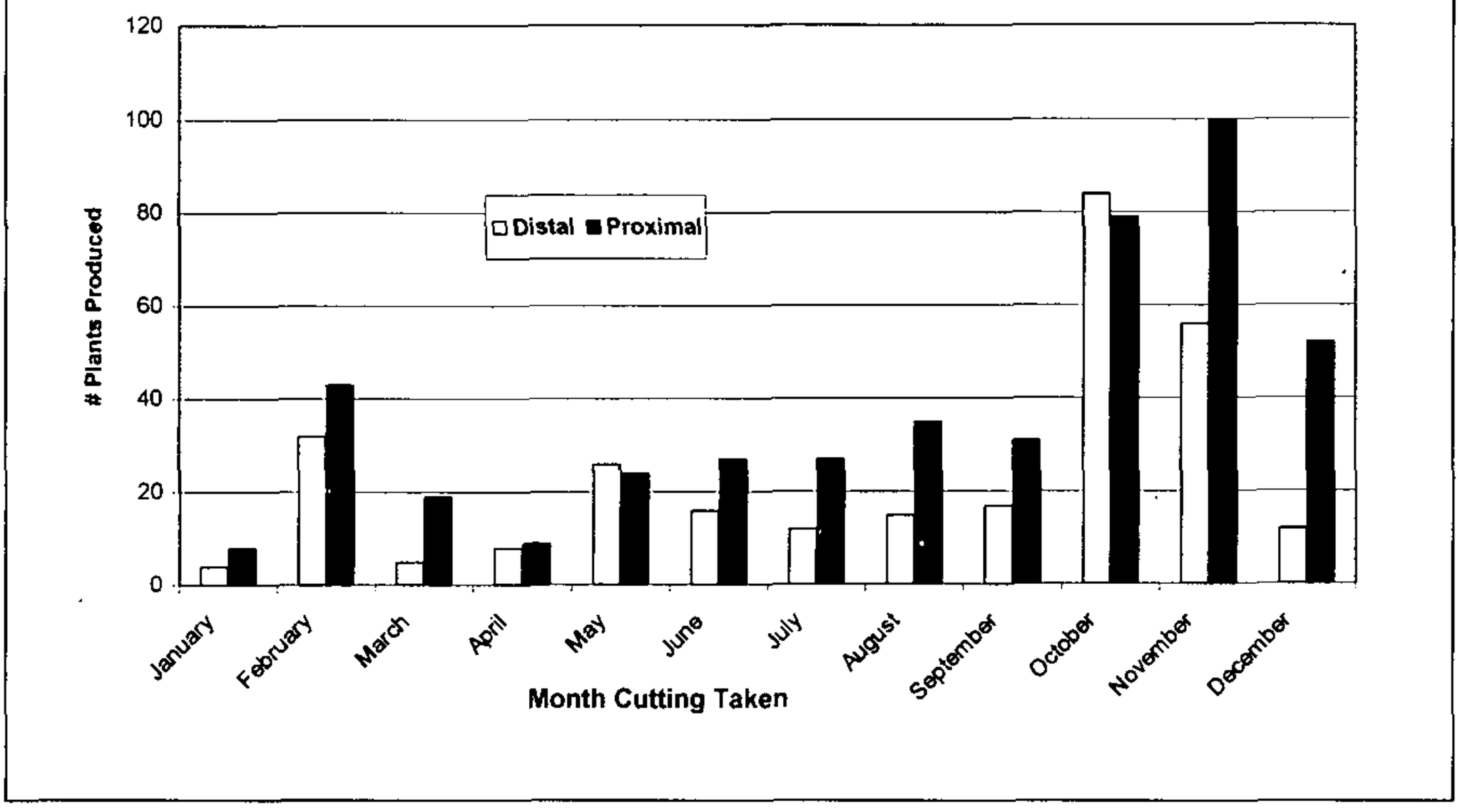

Figure 4. A comparison of the production of plants from distal and proximal root cuttings taken from *Pulmonaria longifolia* 'Bertram Anderson' over a 12-month period.

were approximately 2.5 mm thick at the widest point and proximal cuttings were approximately 3.5 mm thick at the widest point. Root cuttings were placed horizontally, approximately 3 cm deep, into damp Metro Mix 360 medium and maintained in a propagation house at 12C nights. Cuttings were placed in the propagation area in a randomized complete block design over time with five replications per cultivar per month and three samples per replication. The time it took for plants to regenerate from the root cuttings and the number of plants produced per cutting were recorded each week for 16 weeks.

RESULTS

Of the eight cultivars that were tested, the only two to significantly respond to root cutting propagation were 'Roy Davidson' and 'Bertram Anderson'. Root cuttings from the other cultivars produced no or few plants. *Pulmonaria* 'Roy Davidson' produced most of its plants during the months of August, October, and November, with the greatest number being produced in October (Fig. 1). For each month, except April, the number of plants that were produced was significantly greater for proximal cuttings rather than distal cuttings (Fig. 2). A similar response was noticed for *P. longifolia* 'Bertram Anderson'. The greatest number of new plants was produced from root cuttings taken during the months of October and November (Fig. 3). For each month, except May and October, the number of plants that were produced was significantly greater for proximal cuttings rather than distal cuttings (Fig. 4). For both cultivars, the majority of new plants were produced from 4 to 8 weeks after the cuttings were made.

CONCLUSIONS

In this study with *Pulmonaria* species, it became clearly visible that genetics had an effect on the success of root cutting propagation. Of the eight cultivars investigated, the only two to respond, 'Roy Davidson' and 'Bertram Anderson', had the *P. longifolia* genotype. All others failed to produce significant numbers of new plants. Another similarity for both of these cultivars was that the largest number of plants were produced when root cuttings were taken during the fall months of October and November. Evidence was produced that again proves that, for the greatest potential for success, root cuttings should be taken from the larger proximal regions of roots.

Acknowledgments. The authors would like to thank Sunny Border Nurseries, Inc. of Kensington, Connecticut for the donation of plant material.

Propagating Difficult-to-root Roses from Root Pieces

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INTRODUCTION

At the Corn Hill Nursery we have been producing roses from softwood cuttings since 1982. Because of our extreme winter conditions, we grow only the very hardiest types. We have also concentrated on producing those roses that possess good resistance to fungal diseases such as blackspot and mildew. We grow many of the older garden roses including *Rosa ×alba, R. gallica,* and *R. spinosissima* (syn. *R. pimpinellifolia*) taxa. However, the bulk of our inventory consists of *R. rugosa* hybrids and modern shrubs, particularly the roses developed by Agriculture Canada called the Explorer Series, which have used genes from *R. kordesii,* among others.

We take our softwood cuttings as soon as flower bud formation commences in early summer. Cuttings for the day are collected in early morning and stuck in a perlite and peat rooting medium (4 : 1, v/v), usually with a Seradix #2 IBA treatment. Cuttings are then placed in houses that are humidified with a high-pressure fog system. The majority of roses root well using this system, although success rates can vary from 20% to 100% depending upon culitvar, with the average take being approximately 80%.

There are some roses, however, that have defied our attempts to root them. The worst offenders are those having *Rosa foetida* 'Persian Yellow' in their genetic background. These include roses such as 'Harison's Yellow, 'Agnes', and 'Aïcha'. We have tried innumerable formulations of rooting hormones and have adjusted our timing and rooting mediums to see if we could raise our percentages to economically justifiable levels. Results have been discouraging at best. Our best crop of 'Agnes' produced a success rate of approximately 10%. Those that do root usually produce one or two small weak roots that are easily broken when potted or set out in the field.

A few years ago it occurred to me that we may have been overlooking an obvious avenue of exploration. Roses such as 'Agnes' and 'Harison's Yellow', as do many roses, sucker profusely when on their own roots. It seemed reasonable that these plants might be grown from root pieces as we do with such plants as sumac and poplar.

MATERIALS AND METHODS

The biggest stumbling block to this procedure has been the lack of own-rooted stock plants. We have begun to solve this by planting out every cutting that we were able to produce into stockblocks. At present we have stock blocks comprised of approximately 100 'Agnes' and 50 'Harison's Yellow'. We have also set out budded plants with the bud union buried deeply to encourage the cultivar to produce roots of their own. While our stock blocks are still young we have been able to produce enough suckers on older plants in our display gardens to test our theories.

We gather our root pieces in late October and early November just prior to freeze. We have developed shoots on roots collected in spring as well but find that our percentages are higher using fall gathered material. One of the first things we

learned was that pieces taken from the horizontally growing suckers will shoot much more readily than from root pieces taken from the main root system. This seems obvious, as the suckers are a long series of adventitious buds. Pieces taken from the main root system will, however, root and if we have these available we will use these as well.

We cut the roots into pieces approximately 5 cm (2 inches) in length. We use only root pieces having a minimum diameter of 5 mm (¼ to 5/16 inches). Pieces smaller than this rarely produce shoots before rotting. We bundle these in bunches of 25 and set them horizontally in baskets of clean sawdust. These are placed in the cold storage unit at 0 to 1C (32 to 34F). Initially we soaked the root pieces in hydrogen peroxide to destroy any fungi or bacteria. We have since tried storage without this treatment and have not found any difference in storability. If kept at temperatures of 0 to 1C (32 to 34F) we have experienced no storage problems. In the future we may attempt placing the root pieces directly into the flats in which they will develop the shoots.

At present we bring the root pieces out in late March and lay them horizontally in flats. Our flats are 3 inches deep. We fill them to a depth of 2 inches using the same perlite and peat (4 : 1, v/v) rooting medium we use for our softwood cuttings. Small quantities of a slow-release fertilizer are incorporated into the rooting medium as well to encourage growth as soon as the roots have shooted. The root pieces are then covered with another 1 inch of medium, placed on heated beds set at 25C, and kept moist but not wet. The first shoots generally appear within 14 days and by 28 days all the roots have usually shooted. Because these shoots are not propagated in mist or fog, as are softwood cuttings, there is very little time needed for hardening off. Once the root pieces have formed new feeder roots they can be planted into field beds or into containers.

RESULTS

The most important thing we have learned from our trials is that the method works and we are very encouraged by our results. We have successfully produced shoots from a large number of cultivars with varying genetic backgrounds. Generally those taxa that produce suckers readily are the best adapted to this form of propagation. It is our belief that virtually any rose that produces suckers can be propagated from root pieces.

Most of our trials have involved 'Agnes' and 'Harison's Yellow' as these have been the most difficult-to-root roses. Our percentage of success with 'Agnes' has been averaging nearly 90%. Our percentage of success with 'Harison's Yellow' is not quite as high but has averaged near 70%.

DISCUSSION

While we realize that this method is not as economically attractive as budding, it gives us the ability to grow own-rooted plants of rose taxa which are not efficiently raised in a conventional softwood cutting program.

The greatest initial drawback to this system is the time required to develop mature blocks of roses that will provide a crop of suckers. However, once we can develop our program to the point at which we are harvesting sizable crops of these roses, we will be able to harvest roots from our production plants at fall harvest to augment the production from our stockblocks.

We also intend to explore how shoots from the root pieces will root, as it has been our experience with genus *Malus* that rootability can be substantially enhanced by working with shoots from root pieces because these shoots are in a juvenile condition and do not have the physical barriers to root formation present in adult phase material.

Propagation of *Phlox paniculata* From Root Cuttings

Joerg Leiss
Living Carpet RR# 6 Wiarton, Ontario N0H 2T0 Canada

***Phlox paniculata* cultivars can be propagated by division and top and root cuttings. There is, however, a reason to use root cuttings over the other two methods and that is leaf nematodes and fungal diseases are propagated with the propagule while root cuttings are generally free of these pests.**

PROCEDURES

Currently Used Root Cutting Propagation Methods. Before starting I will discuss the different methods that are being used to produce plants from roots. The oldest is simply to dig plants close to the stems, leave most of the roots in the ground, fill in the holes, and then remove the plant sprouts from the ground when they can be handled. Proper labeling and space between cultivars is important to prevent mixing. Depending on the size of the mother plant, this method can yield quite a number of plants for little expense.

The next methods requires a heated greenhouse where temperatures can be maintained at 18 to 22C. Dormant 2-year-old plants are fall dug, retaining all roots, and cold stored until February. Then 1- to 2-mm root pieces 3 to 4 cm in length are planted with their proximal end up at a space of two roots per centimeter into rows 10 to 15 rows per standard flats. Depth of cover is 1 cm. David Beattie (Penn State University, University Park, Pennsylvania) describes a method where root cuttings are bundled and placed into 48- or 72-pocket trays without medium and placed into a grafting case at 68F. Sprouted cuttings are taken out and planted individually.

Another method is to spread the root pieces onto medium and cover with no more than 1 cm of propagation medium; it is best not to disturb the sprouts until at least the second or third leaf stage. The new shoots are very brittle and removing plants disturbs the remaining roots. While waiting for all the roots to develop shoots, the quick sprouting root pieces can be pruned to keep them uniform before transplanting.

With the advent of container growing we see roots becoming smaller and instead of growing down into the ground, circle the container — which end is up? I tried cutting the roots vertically and horizontally, but found that there were no differences in shoot production.

Research Results. I conducted some timing trials on the best time to harvest root pieces. I divided a group of container-grown phlox into three samples. The first group of dormant plants in 15-cm container were brought into the greenhouse, roots were cut into 4-cm slices, placed into a standard flat, and covered with medium. Yield was

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PERENNIAL PHLOX GROWN IN NORTH AMERICA

It surprises me that most North American catalogues only list more or less the same 8 to 10 phlox cultivars; is that all there is? I looked to see what is grown in Europe; *List of Names of Perennials* showed 136 *P. paniculata* cultivars and an additional 20 cultivars were found in *Hardy Herbaceous Perennials*. Powdery mildew is usually the worst disease of *P. paniculata*. At my location night temperatures are usually 8 to 10C lower than day temperatures and with very heavy dew there is no mildew. As an aside *P. subulata* often has downy mildew. When root cuttings developed shoots in the ground, new plants sprouted from the remaining roots and were clean.

Asexual Propagation of *Anemonella*, *Dodecatheon*, and *Trillium*

Leo Blanchette
Blanchette Gardens, 267 Rutland Street, Carlisle, Massachusetts 01741 U.S.A.

INTRODUCTION

North American wildflowers are becoming increasingly popular with our customers. We try to offer named cultivars, double forms, and good color forms. Each cultivar must have uniform color, size, and form. Vegetative propagation is necessary since seed produces wide variation. Like most nurseries, Blanchette Gardens tries to grow plants to blooming size in the shortest possible time. This paper outlines a few methods, and how I have developed them to asexually produce flowering-size *Anemonella*, *Dodecatheon*, and *Trillium* fairly quickly.

PLANTS AND PROPAGATION

Dodecatheon. Shooting star is native to the United States. It has wide smooth leaves with a flowering stalk 10 to 30 cm high depending on the species. The nodding flowers can be white, lilac, magenta, red, or pink. They are primarily woodland plants that go dormant in the summer. While in active growth they enjoy a moist humus soil.

One spring, about 15 years ago, I noticed many flowering dodecatheon in a nursery container. The plants had been divided the previous August to single divisions and I couldn't imagine how one crown had produced so many. I quickly shook the plants free of soil to examine the roots. I found a long single root at the base of each plant with small roots starting to form around the crown. In August, I closely examined another crown and found small buds at the ends of most individual roots near the crown. I separated a few roots with these buds and replanted the original crown to evaluate in the spring. I found that each pot had a plant the following spring. Most were flowering size and each pot only had one plant including the large crown I

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North American wildflowers are becoming increasingly popular with our customers. We try to offer named cultivars, double forms, and good color forms. Each cultivar must have uniform color, size, and form. Vegetative propagation is necessary since seed produces wide variation. Like most nurseries, Blanchette Gardens tries to grow plants to blooming size in the shortest possible time. This paper outlines a few methods, and how I have developed them to asexually produce flowering-size *Anemonella*, *Dodecatheon*, and *Trillium* fairly quickly.

PLANTS AND PROPAGATION

Dodecatheon. Shooting star is native to the United States. It has wide smooth leaves with a flowering stalk 10 to 30 cm high depending on the species. The nodding flowers can be white, lilac, magenta, red, or pink. They are primarily woodland plants that go dormant in the summer. While in active growth they enjoy a moist humus soil.

One spring, about 15 years ago, I noticed many flowering dodecatheon in a nursery container. The plants had been divided the previous August to single divisions and I couldn't imagine how one crown had produced so many. I quickly shook the plants free of soil to examine the roots. I found a long single root at the base of each plant with small roots starting to form around the crown. In August, I closely examined another crown and found small buds at the ends of most individual roots near the crown. I separated a few roots with these buds and replanted the original crown to evaluate in the spring. I found that each pot had a plant the following spring. Most were flowering size and each pot only had one plant including the large crown I

replanted. The small buds did not develop while still attached to the crown. This led me to the following technique to propagate cultivars of *D. alpinum*, *D. hendersonii*, *D. jeffreyi*, and *D. meadia*. I first wash the soil off the root system after the plants have gone dormant in August. Grasping a root with two fingers about halfway down, I gently pull upward causing the root to break off with the small bud. Our form of *D. meadia* var. *alba* is the only form that often needs to be cut with an small, sharp knife as it often doesn't break off correctly. This is repeated until only a root or two remains on the original crown. Each root is then potted into a quart container about 1 cm below the surface. The potting medium used is sand and peatmoss (7 : 13, v/v) with the pH adjusted to between 7 and 8. No growth is seen until the following spring when the plant is saleable.

Anemonella thalictroides. The rue anemone, *A. thalictroides*, is a woodland native of the East Coast of the United States. Its anemone-like flowers appear in early spring in shades of white or pale pink, sometimes in double forms. It grows 15 to 20 cm high. The trifoliate leaves are small and delicate, and disappear in the summer when the plant goes dormant.

After my experience with dodecatheon I checked other plants to see if the same technique could possibly work with them. I noticed that anemonella also have minute eyes on the ends of their thickened roots. Crowns are carefully shaken free of soil and separated in August. They look like tiny bunches of carrots 1 cm long. Roots almost fall off on their own, very little pressure is needed. The shaking often separates a few. I leave at least two roots on the original crown. Each root section is repotted into a quart container just below the surface. The medium is sand and peatmoss (7 : 13, v/v) with a pH of 5.5 to 6.5. The following spring almost all flower. Again, left to their own few attached roots seemed to form new plants, but separated they do develop into nice plants which can be sold the next spring.

Trillium. Different species of *Trillium* are native to different parts of the United States and Asia. These perennials offer color to the shaded garden in the spring. They have three petals, three sepals, and a three-celled ovary. A whirl of three leaves is at the end of an unbranched stem. Colors and heights vary with the different species.

A number of years ago, voles ravaged my garden during the fall and winter. The following spring, I noticed much of my *Trillium* stock had produced small single-leaf proliferations. I dug a few plants to see what had happened. The rodents had taken bites just behind the growing shoots. Now in late July, I lift some plants and cut two wedges 3 to 5 mm deep, 3 to 5 mm wide, and about 7 to 8 mm long just behind the shoot with a sharp knife. These are on the sides to the top of the rhizome and they touch at the top center. Only the top half of the rhizome is wounded. These are then replanted with the shoots just below the surface. Many produce numerous small shoots along the rhizome. The first year they appear, about 90% have only one leaf. After the second growing season, when they all have shown three leaves, they are separated off. Each is planted in quart containers with sand and peatmoss (7 : 13, v/v). The pH is adjusted to fit the needs of each species. It is still takes me on average 4 years from notching to get to flowering size, but seed production takes me 6 or 7 years after germination. I have used this method successfully on 10 different *Trillium* species.

CONCLUSION

Seed has its place in the production of north American natives but the above methods of asexual propagation work well for our nursery operation. In each case blooming-size plants are produced faster than by using seed.

Commercial Propagation of *Trillium*

Stephanie Solt
Trilliums Unlimited, 111 Edgemoor Drive, Burlington, Vermont 05401-1921 U.S.A.

INTRODUCTION

Trillium has a bad reputation. There's a prevailing sentiment among propagators that growing them from seed is difficult. I spoke to a number of you at the Eastern Region meeting in Newport, Rhode Island, in the fall of 1997 and you said, "it takes too long to grow to a saleable size and ties up valuable space in the nursery". When I mentioned vegetative propagation you said, "it doesn't produce the numbers necessary to be worth the effort". I also heard "there's very little demand." Finally, I got the feeling that you thought that no one was propagating trillium commercially.

Trillium doesn't deserve a bad reputation. Growing them from seed is not difficult. They can be brought to a saleable size in a relatively small amount of space in less time than you think. Vegetative propagation is a good method for certain species as well as cultivars and the double-flowered trilliums. A growing number of wholesale nurseries have made the commitment to propagate trilliums. They can't keep up with the demand!

GERMINATION

Understanding the germination process is the first step toward propagation. The seed has an appendage called an aril (or elaisome or strophiole depending on whom you talk to). The aril serves to attract ants and other insects who either eat the aril and discard the seed on the spot or take the seed back to their underground nest for a midnight aril snack eventually discarding the seed in their trash heap. It's been suggested that the aril should be removed prior to planting but that's labor intensive and unnecessary. If you are conducting a seed germination experiment under sterile conditions, it's advisable to remove the aril since a fungus in the aril may interfere with the experiment. The first step in the germination process is the splitting of the seed coat as the cells of the micropylar end of the seed enlarge. The root tip emerges through the enlarged collar followed by the immature rhizome. The root elongates and the rhizome enlarges. The petiole appears next followed by the cotyledon. The seed coat remains attached to the tip of the cotyledon until the cotyledon has absorbed the remaining food supply then drops off. Germination is completed during the first growing season for some species while others may exhibit a need for a subsequent cold period before cotyledon emergence.

FACTORS AFFECTING GERMINATION

A number of factors affect the germination process.

CONCLUSION

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FACTORS AFFECTING GERMINATION

A number of factors affect the germination process.

Moisture. The level of moisture within the seed is important. The germination percentage of the seed lot drops and the remaining ungerminated seed either go into a secondary dormancy or die if the seed are allowed to dry out. Short of soaking, if the seed is kept in constant contact with water, the germination percentage will be much higher. If you sow 100 seed in a flat and 50 come up, don't throw the flat away. Keep the flat moist and, over time, you may get close to 90% to 100% germination.

Temperature. Another factor affecting germination is temperature. Some species need a cold period for embryo maturation. Barton (1944) did research on *T. grandiflorum* and *T. erectum* and concluded that they had double dormancy and required two cold periods for complete germination. An initial cold period was needed for the emergence of the root and another cold period for the emergence of the cotyledon. In my work with seeds of *T. grandiflorum* and *T. erectum* gathered in Vermont I never saw a cessation of growth after the emergence of the root (under experimental conditions). The juvenile rhizome emerged right after the root followed by the petiole and then the cotyledon. The seed coat remained on the end of the cotyledon, shrinking as the cotyledon enlarged and eventually dropping off. As the cotyledon emerged, chlorophyll became evident. No second cold period was needed for complete germination. I suggest that these species have an embryo dormancy with a second cold period needed for cotyledon growth above the soil line rather than emergence from the seed. Patrick (1973) and Jacobs (1997) came to the same conclusion.

Germination Requirements May Vary Among Species. Many references on trillium propagation perpetuate the belief that all species have the same dormancy and that dormancy is a double dormancy. Don Jacobs, in his book *Trillium in Woodland and Garden*, says that while the northern species exhibit the need for a period of cold for embryo maturation, he has observed that other species do not have this requirement. He states, "that while it can be demonstrated that trilliums have a double dormancy and can take 6 to 10 seasons for flowering to commence, this is unnecessarily discouraging and simplistic". He goes on to state that many species germinate the following March after a July sowing at his site in Decatur, Georgia. Apparently one cannot make the assumption that every species of trillium will exhibit double dormancy.

Finally, date of collection and length of time at warm temperatures can affect dormancy. I have observed that *T. grandiflorum* seeds collected while still green but full size (early July in Vermont) will germinate with no cold period in the same season. Jacobs (1997) makes the same observation. Both Patrick (1973) and Jacobs (1997) observed that seeds will germinate if exposed to a sufficient length of warmth (~70F). This could be up to 10 or more months depending on the species.

TIME TO SALEABLE SIZE

Does it take too long to grow to a saleable size? What is a saleable size and how long does it take to attain that size? In preparation for this talk, I interviewed a number of commercial growers of trillium and their idea of what constituted a saleable size varied. A few sell seed-propagated, 4- to 6-year-old, flowering plants. One wholesale grower sells seed-propagated, immature, bareroot, 3-year-old plants while another sells vegetatively propagated, flowering, bareroot, 3- to 4-year-old plants. The key to attaining a saleable size is to maximize water availability and fertility for

optimum growth (Jacobs, 1997). Richard Fraser (1998), from Frasers Thimble Farm in British Columbia, claims to have 3-year-old plants as large as most 7-year-old plants. He recommends fertilizing 3 or more times a month with a weak solution of water soluble 20N-20P-20K fertilizer starting as soon as the plant is in active growth and stopping in July. Bill Cullina, of the New England Wildflower Society in Massachusetts, says that, while trillium benefit from a good water and fertility regime, they will only tolerate a certain amount of fertilizer before they go dormant and overwatering will result in root rot. British Columbia has a long, cool, wet growing season while the growing season in Massachusetts is shorter, warmer, and dryer in comparison. This suggests the location of your nursery will be a factor in determining water and fertility regimes.

VEGETATIVE PROPAGATION

If you want to sell many species of trillium, you have to do some vegetative propagation. Most growers who do seed propagation also propagate vegetatively. Seed of some species is difficult to find so growers have to acquire plants and propagate vegetatively to build up their stock. Up to 20 plants can be propagated from one plant in 3 to 4 years in this manner. If you are selling any of the cultivars or double trilliums, you can command high prices since they are much sought after by collectors. White Flower Farm, in Litchfield, Connecticut, offers a double-flowered *T. grandiflorum* every few years and it's always sold out immediately!

NURSERIES THAT PROPAGATE TRILLIUM

Is anybody in the business of propagating trillium? You bet! In 1995, Van Berkum Nursery in Deerfield, New Hampshire started growing trillium from seed with the eventual goal of selling 3- to 4-year-old preflowering plants. In August, they sow the seed ¼ inch deep in Fafard #2 medium in plastic seedling trays 12 inches × 24 inches. The trays are put outside in a shaded seedling bed under automatic overhead irrigation. In November the trays are covered with a foam mat which is removed as soon as the snow has melted and the temperature is above 0C (32F) at night (April). An upside-down seed tray separates the mat from the soil surface. In 1999 they will have saleable size plants. Peter Van Berkum tells me he doesn't know what price he will ask for these plants but he expects a 20% to 30% margin of profit. Peter Joppe, of Hillside Nursery in Shelburne, Massachusetts, does both seed and vegetative propagation depending on the species. He sells all species in ½-gal containers for $6.40 wholesale and retail for $12.70. His goal is to produce plants from seed to bloom in 4 years. Canada has quite a few wholesalers. Richard Fraser of Fraser's Thimble Farm on Salt Spring Island in British Columbia, sells seed-propagated, bareroot, immature *T. ovatum*. Landscapers buy them in bundles of 100 for woodland mass plantings. He also does a fair amount of vegetative propagation when he can't get enough seed. Majella Larochelle, of Seeds and Plants International, Canada, has hired local people to make an initial collection from their own property. He then teaches them how to propagate vegetatively. He states that there are several benefits from this method. The impact on the trillium population in their landscape is kept to a minimum while a sustainable crop is produced. Larochelle feels that vegetatively propagated plants have stronger root systems, are much healthier, and flower sooner. He then buys from this network of propagators and sells to local retailers while making a profit of 50%.

Tissue culture of trillium has, so far, eluded propagators. However, a nursery in New Zealand has apparently figured out a method. Barry Sligh of Taunton Gardens in Christchurch, New Zealand, is selling tissue-cultured *T. sessile* [however, they may be *T. chloropetulum* according to Jim McClements (1998)]. Heronswood Nursery, in Kingston, Washington is one source of Slighs' plants.

SUMMARY

In summary, commercial production of trillium is possible and profitable. If you wish to propagate trillium from seed, obtain fresh seed and sow it immediately. Maintain a level of moisture for optimum germination and subsequent growth while maximizing soil fertility. Transplant after the appearance of the cotyledon and grow on to saleable size. If you wish to propagate vegetatively, refer to Leo Blanchettes presentation titled "Asexual Propagation of *Dodecatheon, Trillium*, and *Anemonella*" in the 1998 I.P.P.S. Proceedings. For more details and other methods, read either *Trilliums* by Case or *Trilliums in Woodland or Garden* by Jacobs.

I hope I have convinced you to consider propagating trillium in your nursery. Richard Fraser from Fraser's Thimble Farm commented that there's a mind set against trillium propagation. He says, "propagating them is really no more different than propagating peonies or slow hostas". Based on the interviews I've conducted, I suggest that there is a growing movement among the nurseries specializing in native plant propagation to include trillium in their inventory. All express a commitment to nursery propagation for commercial production rather than wild collection. Examine your own mind set to see if you could have a change of heart. Then there truly would be "trilliums unlimited"!

(A list of nurseries which propagate trillium can be provided upon request.)

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RESOURCES

Internet: Trillium Listserve. Send an email to: listserv@nic.surfnet.nl

Type "subscribe Trillium-L, your name (not email name), location and USDA zone or minimum/maximum temperature" in message window.

Commercial Propagation of Hardy Geraniums: Techniques and Recommendations for Successful Production

Beth Weller
White Flower Farm, Litchfield, Connecticut 06759 U.S.A.

INTRODUCTION

My first introduction to hardy geraniums was as a child. In rich woodlands, meadows, and along roadsides in New England, the wild geranium or *Geranium maculatum* is abundant and a great treat for a small child to come across. It was not until my college years, many bouquets later, did I actually realize what a geranium was. The hardy geraniums, most commonly know as crane's bill geraniums, I will talk about today are members of the Geraniaceae family. I want to stress these are not the common tropical *Pelargonium* species, more commonly called geraniums, and that are frequently referred to in most literature as geraniums.

Hardy geraniums range in size from 4-inch specimens of *G. dalmaticum* to *G. psilostemon* that can reach 48 inches. The name, crane's bill, comes from the look of the enlarged seed pods, before they coil away from each other and disperse their seed. At White Flower Farm, I have seen an increased interest in geraniums, by our customers, in the past 5 years that I have been employed there. Much of this is a result of a fairly new horticultural team that has been stressing the merits of geraniums and initiating the trialing of them at White Flower Farm. This alone is not the sole reason for the increased number and changes in species being added to our mailorder catalog. If it wasn't for the interest of our customers, our nursery would not profit from adding new geranium taxa. The interest of gardeners, both experienced and novice, are contributing to the growth in hardy geranium sales. Most geraniums are easy to grow, and provide extended enjoyment for novices looking to try their hand at gardening. For the more advance gardener, the vast quantity of species and cultivars adds new opportunities to add to their collections.

My discussion will concentrate on the commercial propagation of "hardy" geraniums using examples from species I work with at White flower Farm. The majority of geranium taxa, for the commercial market, are produced by the division of "mother plants" with the few exceptions that are produced by basal and tip cuttings. Seed propagation in most circumstances is unreliable as far as germination rates and many do not come true to type. An alternate method of root cuttings is appropriate for select taxa, although yields tend to be lower, and the length of stay in propagation areas tends to increase.

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STOCK PRODUCTION

Healthy and vigorous stock, produced on a timely cycle, is the first step in the successful production of geraniums. I have found that growing geranium stock in small beds or growing frame situations, where more precise weed control methods and good fertilization coverage can be obtained, is most appropriate for geraniums. Large field areas that utilize mechanical planting and cultivation can result in damaged stock as a result of injury to the new growth by this mechanized equipment. Without timely weed suppression or removal, the competition for water and appropriate light conditions can reduce the yields from the mother plants the following fall. At White flower Farm (Zone 5) we plant our geranium stock, for root cutting and division items, in mid May when the most threat of serious frost has passed. I find our stock benefits from the cool weather of May to enable firm root establishment. We find a team of three workers can prep and plant approximately 1800 geraniums during an 8-h workday. These plants are watered thoroughly by hand to set them into the soil. It is important to continue to water these areas daily, thoroughly soaking the root ball and the surrounding soil equally, to aid in the rooting potential of these plants. Drip irrigation supplied directly to the center of each bed, running for approximately 6 to 7 h a day for the first week, provides ample coverage for the newly planted stock. These planted beds have previously been fertilized with a 5N-10P-10K granular formulation and lime is applied at rates determined after early spring soil analyses are performed. By mid June all stock areas are thoroughly mulched with a shredded mixture of bark mulch. Careful application is required to avoid over mulching around the crowns of the plants. Mulching too thickly could result in excess moisture around the plant crowns. As a result disease problems could occur. Once this mulch has been applied it reduces the need for frequent weeding, and it reduces evaporation loss resulting in the need for less frequent irrigation. At this point little care of these plants is needed, until late June or July when another application of fertilizer is applied. Overhead irrigation is required for this process unless an extended period of wet weather has set in. An additional application of fertilizer is beneficial in early September, at which time another treatment of lime is usually necessary because of the reduced pH due to the decomposition of the bark mulch. We tend to see much of the growth occurring after September 1, when our hot dry days of summer have usually ceased. Geranium stock is harvested during the last week of October, at which time it is immediately worked. This stock can only be stored in refrigerated areas for a couple of days, unless they are cleaned and stored in single layers on dry packing material, to avoid decay to the growing tips.

PROPAGATION TECHNIQUES

Division Propagation. Once the geranium stock has been harvested, our propagation staff immediately sets about working these plants. This plant cleaning includes removing all loose soil by gently shaking each individual plant. Foliage is removed usually halfway to its crown, and roots are shortened to 2 inches. Cutting this older foliage aids in successful transplanting due to reduced transpiration. Stock grown on this 1-year cycle will yield varying division pieces depending on the geranium taxa we are working. *Geranium* 'Phillippe Vapelle' is a vigorous grower and will average seven divisions per plant. This species offers a large and somewhat

straight root mass, aiding in the quickness of the division process. This species is very easily divided into single shoots that are suitable for a 3- to 4-inch pot, which is the typical pot size for White Flower Farms mailorder pots. *Geranium sanguineum* has been a very popular species for us. Recently, White Flower Farm has begun to offer *G. sanguineum* 'Alpenglow' which has been widely accepted by our customers. This cultivar is representative of the sprawling open-foliage geraniums we produce. I find the yield is satisfactory after 1 year (4.8 divisions per plant), but if time permits, 2 years in our stock beds will almost double the yield (8 divisions per plant). This is possible provided the cost of stock garden maintenance can be kept at a minimum to avoid increasing the cost of producing the plant. *Geranium sanguineum* var. *striatum* tends to be a much slower growing plant. Yields after 1 year are only 2.8 divisions per plant. Two years in the stock bed is recommended for this variety, at which time a yield of approximately five division per plant can be expected. These single divisions are potted into a well drained soilless potting mixture and placed on propexed floors in minimally heated greenhouses to grow on. Average winter nighttime temperatures hold 50F. Watering is kept at a minimum to avoid root and crown rot diseases. We begin shipping in late February to our southern customers. By this time these geraniums have successfully rooted into their pots. Portions of these plants are kept as stock to restart the cycles.

Root Cuttings. I have had minimal experience with root cuttings of geraniums, but I would like to mention a few points. I have found that root pieces of *G. sanguineum* species, can yield a portion of your crop, if a longer propagation time is allowed. This can generally reduce the quantity of stock planted and save labor and space in the stock growing areas. After the division pieces have been prepared, one is left with a pile of discarded root pieces. If these roots are cut into 2-inch segments and placed horizontally into deep plastic flats about 2.5 inches below soil; ample plants can be produced. After watering these flats in well, we place them in a fog house at about 80% humidity and 70F with bottom heat provided. These flats are watered very infrequently during the short winter months. This process takes approximately 2 months to start to see growth above the soil level. At this time they are removed from the fog house and placed in a cool greenhouse holding around 50F nighttime temperature. In another 3 months these will be rooted adequately enough to be potted into larger pots for later sales. In our situation at White Flower Farm, these plants, maturing at a later time, are not adequate for our mailorder sales. I will utilize these for stock to restart our crop cycles.

Tip Cuttings. Recently we have begun to offer geraniums that benefit from the tip cutting or basal cutting method of propagation. Stock for these species are planted in mid to late May, either in open beds or into growing frames. This stock is used for 3 years, at which time it will be renewed with fresh stock. This stock is grown very similarly to our division stock, with fertilizer and lime applications being applied after early spring soil testing has been done. Cuttings are taken, beginning, in early August after flowering has ceased.

Geranium macrorrhizum 'Ingwersen Variety' is a very versatile geranium. Grown in shade or partial sun, it enjoys a well drained location. This geranium produces long stems emerging from a very woody root mass. These elongated stems make this plant, aesthetically, not suitable for divisions. Basal cuttings are taken with a very sharp knife, being certain to take approximately 1 inch of the dark brown stem,

below the foliage. Foliage is trimmed, leaving only two of the shortest new leaves. We place these cuttings into large cellpacks under mist until rooting starts. When the first roots appear the flats are moved to dry benches in a greenhouse with nighttime temperature of 65F to finish rooting on. These cell packs are fertilized weekly at 100 ppm of 13N-2P-13K liquid fertilizer. Approximately 6 weeks after cutting, these plugs will be ready to go into their 3.5-inch pot. These are placed on the floor in a cool greenhouse for the winter months and will be ready for late February potting.

CONCLUSION

To conclude, I feel hardy geranium species are worthy of our time and effort. The first step in the commercial production of geraniums is to have a customer base to whom you can sell these plants. Secondly, you must have ample stock to supply this customer base, to avoid turning customers away. Thirdly, you should have a knowledgeable production staff to see that each step in the geranium cycle is followed with success. Given adequate soil and environmental conditions, and if appropriate planting and propagation techniques are followed, your customers will be rewarded with healthy, beautiful specimens to add to their gardens and ample stock will be recycled to produce the next years crop.

Top Grafting of *Salix*

Szczepan Marczynski
Clematis Container Nursery, Pruszkow, Poland

INTRODUCTION

Miniature standard willows are attractive small trees, and they lend themselves well to smaller gardens. Because of the varying forms of crowns, as well as, the shape and color of the leaves and flowers (catkins), these miniatures can be part of garden landscape throughout the year.

Small willow standards are produced by top-working the attractive shrubby willows. Most often scions are used from the creeping mountain taxa, and they are grafted onto strong growing willows. Grafted standards have an overall height between 30 and 170 cm and a small crown.

GRAFTED SELECTIONS

Most commonly known grafted standards are *Salix caprea* 'Klimarnock' and *S. integra* 'Hakuro-nishiki'; however, there are over 30 interesting species and cultivars which are propagated as standards.

Salix alpina has weeping shoots, covered with oval, slightly hairy leaves with wavy edges. It naturally grows in the Alps and high parts of the Carpathians. It is a ground-hugging plant among the rocks and is very frost resistant.

Salix arbuscula has short shoots, is strongly branching outward and slightly weeping. Shoots are covered by a densely clustered mass of green, glossy leaves. The average-sized catkins appear in May with the first leaves; in full bloom they are a golden color. This species is very attractive and suitable for planting in rock gardens. The most prevalent disease symptom is stained leaves.

Salix bockii has shoots which spread out over the sides and are covered by small leaves. Leaves are dark green on the top and silvery on the bottom. Plenty of small, spreading gray catkins appear in the autumn. The shoots will freeze at -15C and have to be covered before the winter.

Salix brevipens has free-growing shoots, slightly weeping. They are densely covered by narrow elliptical leaves; dark green on the top and lighter on the bottom. Small, pretty catkins bloom with the first leaves; a slow-growing willow.

***Salix caprea* 'Kilmarnock'**, also known as 'Pendula', has a dignified crown which looks like an umbrella. Its stiff shoots firmly pressed down towards the ground. 'Kilmarnock' is covered by large leaves that are green at the top and grayish green on the bottom. Large silvery catkins (up to 4.5 cm) appear in March long before the leaves. It is a male clone and the stamens are golden yellow in full bloom.

***Salix caprea* 'Curly Locks'**, a sport *S. caprea* 'Klimarnock', is distinguished from the latter by imaginative curly shoots. It looks very nice and has been extremely popular in many countries the last few years.

***Salix cinerea* 'Tricolor'** has upright growing shoots covered by long oval-shaped, green-red-white leaves. It becomes picturesque in the garden. 'Tricolor' is a strong-

growing willow which requires pruning back 3 to 5 times during the growing season. This pruning reduces the surplus growth of shoots and provides favorable conditions for more colorful shoots.

Salix* ×*cottetti has weeping shoots covered by elliptical, dark green, glossy leaves. Only the male clone is cultivated. It produces (before the leaves develop) a mass of medium-sized (1-1.5 cm) golden catkins.

Salix* ×*finnmarchica is covered by small (to 2.5 cm), oval, blue-green leaves and has red hanging shoots. Catkins are small and appear just before the leaves. Only the female clone is cultivated. This plant looks similar to some *Cotoneaster* or *Vaccinium* plants. It is suitable for rock gardens.

Salix foetida has hanging shoots, covered by dark green leaves, with sharp edges. Catkins unfold together with the leaves. This species grows naturally in the Alps and Pyrenees.

***Salix* ×grahamii** has hanging shoots covered by elliptical-shaped, dark green, glossy leaves with wavy edges. Catkins bloom together with the leaves. This natural cross (*S. aurita* × *S. herbacae* × *S. repens*) was found in Scotland.

***Salix hastata* 'Wehrhahnii'** is an upright, slow-growing plant covered at the start by silky, mossy leaves, which turn dark green in the summer. It has beautiful white, cotton-like hair, large (4 to 7 cm) catkins, and when in full bloom is covered by golden stamens.

Salix helvetica is a beautiful plant with silvery leaves, and rising, thick twisting shoots, which in early growth are covered by a silvery nap. Large hairy catkins (3 to 4 cm) appear together with the first leaves. It grows naturally in the Alps and Tatry Mountains. It is very sensitive to rust.

***Salix integra* 'Hakuro-nishiki'** is a plant that grabs one's attention thanks to the white, rose, and green colored leaves. The leaves look beautiful on young shoots, especially in places where there is a lot of humidity in the air (worth pruning often for new growth). The red shoots look nice when they are without leaves. Catkins are small and bloom just before the leaves. During very cold winters the shoots can be injured.

***Salix integra* 'Pendula'** has weeping shoots covered by oval, green, lightly rose-colored leaves when they are young. Its red shoots are attractive before leaves appear. Catkins are small and bloom just before the leaves. During very cold winters the shoots can be injured. This willow has much charm and airy quality.

Salix lanata is a slow-growing, stiffly branched willow. The large (4 to 6 cm), elliptically shaped leaves are covered with nap — very interesting. The winter buds are spherical and covered with yellow glossy scales, quite unusual. The large, yellowish green, hairy catkins (6 cm) bloom in May amongst the leaves.

Salix moupinensis is an exotic-looking plant; thick, red shoots branch out and give the appearance of horns. The winter buds are long, dark brown, and glossy. The leaves are oval, 6 to 20 cm long; when young they are partly purple, later after maturation they become dark green and glossy with a distinctive marked venation. In the spring, long catkins (more than 10 cm) bloom. It is native to China and is frost resistant.

Salix nakamura* var. *yezoalpina is the most beautifully colored willow in the autumn. Weeping shoots are covered with large (up to 8 cm) dark green leaves in the summer changing to golden yellow in the fall. The large (up to 8 cm) male catkins appear with the leaves.

***Salix purpurea* 'Pendula'** is a charming tree with a loose, elegantly weeping crown. It has thin shoots covered with tiny, narrow leaves.

Salix pyrenaica has stems which form a dense spherical crown with lightly hanging shoots. The leaves are rounded, slightly mossy with undulating edges. Catkins are dark green and unassuming. It comes from the Pyrenean Mountains.

Salix repens* var. *argentea has a weeping crown decorated with leaves having a very densely set silvery-blue pubescence.

***Salix repens* 'Bergen'** has thin, strongly weeping spread shoots. It is covered by small, elongated, dark green leaves.

***Salix* 'Boyd's Pendulous' (syn. *S. repens* 'Boyd's Pendulous')** is a male clone, with long weeping shoots, covered by wide oval-shaped green leaves. It produces a very narrow crown.

***Salix repens* 'Iona'** has a nice, wide, crown weeping covered by oval, dark green glossy leaves. Male catkins bloom before the leaves and create a golden halo around the willow.

***Salix repens* 'Voorthuizen'** has thin, weeping, strongly spread shoots. Shoots are covered by tiny silky green leaves.

Salix subopposita has dense foliage and a naturally rounded crown. Leaves are broadly lanceolate glabrous above and glaucous beneath. Small silky white catkins (approximately 2 cm) bloom before the leaves and are decorative for a long time (over a month). The male catkins are especially golden when fully developed. Species is native to Japan and South Korea.

Salix tarraconensis is a slow-growing species. Spreading shoots are covered with interesting leaves which are small and rounded with undulating edges. Catkins are small (0.5 to 1 cm) but very numerous, blooming before the leaves.

PROPAGATION

Propagation of willows is simple and very quick. Even when top grafting willows on a rootstock with no roots, one can obtain a marketable plant in about 5 to 6 months.

The best rootstock for us is *S.* ×*smithiana*. It produces long straight shoots, roots readily, and is compatible with the majority of species, varieties, and cultivars. When seating the mother stock, the hardwood cuttings are made and lined out in the field. In the 2nd year after the lining, provided the conditions are good, shoots sprout over 2 m long which make them perfect for grafting. The mother stock can be exploited at least 5 more years.

One can graft from January until March. Shoots for understocks from the stockbeds are cut 1 to 2 days before grafting. Indoors the shoots are cut again into segments of 60, 80, 100, 120, 140, and 160 cm making every effort to take advantage of the whole shoot. At this time we remove all side branches and cover with a

protective paint containing a fungicide. Shoots are wrapped in plastic and placed in the cooler. Understock are grafted as unrooted shoots.

Scions are prepared just before grafting by cutting 8 to 10 cm from the bases of shoots (without flower buds). Branched scions are excellent since they produce nice crowns sooner.

The height of the understock should be proportional to the strength of the growth, the form of the taxa grafted, and site where it is to be planted. Relatively strong-growing *S. caprea* 'Kilmarnock' should have a understock between 120 to 160 cm in length. The weaker growing *S. repens* var. *argentea, S. purpurea* 'Pendula' and *S. helvetica* look better when they have shorter trunks from understock between 80 and 120 cm. For dwarfs, such as *S. arbuscula*, *S. ×finnmarchica,* and *S. repens* 'Iona' and 'Voorthuizen', it is enough if they have trunks with a height of 60 to 80 cm.

The species with upright-growing branches look nice on shorter trunks of 60 to 100 cm. This is recommended for *S. integra* 'Hakuro-nishiki', *S. subopposita*, or *S. bockii*. Strong-growing species can also be grafted on shorter trunks, if during cultivation they are sprayed with growth retardant.

We side graft using a very sharp Tina knife. The grafts are then tied with rubber strips and the graft union is dipped into hot (approx. 70C, 158F) grafting wax (Rebwachs WF. Stahler Agrochemie GmbH, Postfach 2047, Stade 21660, Germany) which contains 0.1% hydroxichinolin. Once the wax hardens, the grafted shoots are placed in pails or containers with water. They are covered with a thin polyethylene film and placed in a room (it can be dark) at a temperature of 6 to 7C (42F), for about 3 to 4 weeks. During this time, a union occurs and also on the base of understock the roots are initiated.

Before the roots are fully emerged on the understock we stick the grafted material into 2-, 3-, or 5-liter containers in a cold plastic tunnels. The medium is a mixture of peat moss, pine bark, and styrofoam (5 : 3 : 1, by volume); calcium is added to get pH 5.5; as well as, NPK fertilizer mixture at a dose of 1 g liter^{-1}. After potting we thoroughly water and arrange the containers in 2 or 3 layers to make maximum use of the space. Sometimes we cover the entire ridges with a thin polyethylene film and during sunny days we try hard to shade them as much as possible.

Sucker shoots from the rootstocks must be removed before they harden, by delicately breaking them off. The newly sprouting shoots from the scion are cut in half when they reach 5 to 10 cm in length. This operation should be repeated 2 to 3 times to create strong branching in the crown.

Towards the end of May we move the plants outside, placing them in shallow troughs filled with water and tying them to lines stretched between poles. Plants are fertilized with Osmocote 5-6 months at 5 g liter^{-1}.

DISEASES

Rust can occur on the leaves of willows as orange spots which are visible on the bottom of the leaf. *Salix helvetica* is especially sensitive to rust, however, it can also occur on *S. caprea* 'Kilmarnock', *S. ×cottieti*, and sometimes on other species. Spots on leaves most often occur on *S. arbuscula*. Usually it is a matter of simply tearing off the leaves on which the first signs of rust occurs and burning them. You can also spray for the rust by applying rust-reducing fungicides such as Baycor 300EC, Saprol, or Tilt.

SELLING

We begin selling the plants in mid July. Unsold willows are overwintered outside with a bark mulch in November; they are sold in the spring. Some customers purchase them for Easter, keeping them inside the house for a while, and then planting them outside in the garden.

Top-grafted willows can be planted separately or in groups. They are especially nice in rock gardens and planted near a pond or growing in containers. They grow in average soils, but when choosing the place to plant them, remember they love sunlight and that they do not grow well on very dry soils.

Willows tolerate pruning. Branches of the crown should be cut back to give the plant the desired shape. Pruning the branches several times during the year (stop before August) is necessary especially for *S. integra* 'Hakuro-nishiki' and *S. cinerea* 'Tricolor'. Pruning lessens the size of the plant and gives the crowns the right shape. It also induces new shoots, which look better. Other willows should be pruned back once a year in the spring, after the catkins bloom. They should be pruned rigorously, leaving only a few buds at the base of the shoot.

Top grafted willows have a large market potential because they are attractive to garden lovers and also very easily grown by nurserymen.

Creating Separate Environments to Improve the Grafting Success of Specific Evergreen Species

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INTRODUCTION

This paper will discuss in layman's practical terms the separate environments we try to create when grafting junipers, spruce, chamaecyparis, and pines. I will also touch on the similar environments we create to root hardwood cuttings of broadleaf and conifer species.

My observations come from many years experience grafting conifers in the central Ohio region. I am grafting during dormant winter months in double-poly greenhouses. I will be making observations based on practical experience, not extensive testing by scientific methods.

I want to thank you for allowing me to speak on the subject of creating separate environments for grafting selected species of conifers. This fancy title in essence means, "how do we treat grafted species differently after grafting?" I will discuss the different methods used based on the different species. I have learned the painful lesson that I am not nearly as smart as I used to think I was when I was younger. My recommendations are open to criticism and revision as we continually experiment and observe. I fully expect to be making changes should I be lucky enough to reach my senior years.

The reason we create separate environments for different species is painfully simple; the grafts survive with a higher percentage. For a small quantity grafter, it can be very difficult to create the different environments and maintenance conditions best suited for each genus. At our company, we strive to achieve large production numbers within a genus to gain the ease and efficiency of economies of scale. It often takes no more effort to hand mist 50,000 juniper grafts than it does to care for 100 grafts. Small quantity grafters often are forced to treat many different genera in the same fashion, in the same greenhouse, due to logistics. If, however, you have the luxury to adapt your production methods, I would suggest the following treatments.

CONIFER GRAFTING

***Juniperus* and *Chamaecyparis*.** At Decker Nursery, we graft about 50,000 upright juniper cultivars each year. We produce our own understock, *Juniperus virginiana* 'Hetz' (syn. *J. chinensis* 'Hetzi'), by rooted cuttings. The cuttings are stuck as hardwood cuttings in December with bottom heat, rooted, potted in the spring into a 2½-inch plastic pot, grown the entire summer to build caliper and root volume, and grafted the following winter. We produce our own understock as we cannot purchase plants of consistent quality. Understocks are trimmed in preparation for grafting, and warmed in the greenhouse for several weeks prior to grafting.

Juniperus and *Chamaecyparis* are genera that prefer the high humidity and warmth of a classic grafting case. Ours is a grafting bench with a clear plastic sweat

cover with ventilation holes cut into the plastic. In essence you are trying to create the terrarium that we made in grade school with a empty fish tank and a glass cover. During cloudy days and nighttime the holes are covered with plastic flaps. Optimum tent temperature is about 70 to 72F. Heat is provided to the bench via bottom heat — a hot-water system distributed via small black tubes under the flats.

The grafts are mulched with a peat and styrofoam mixture (1 : 1, v/v) to lightly cover the graft when they are placed in the bench. This peat and styrofoam mixture is very important for all our grafting. It is premoistened and provides a high humidity and dark microclimate immediately around the graft union. In addition, in a sweat case it provides the humidity reserve to constantly recharge the relative humidity level within the sweatcase. This high humidity case is kept intact until the scions begin to show about ¼ inch of new growth. At that time we slowly acclimate the grafts to regular greenhouse humidity. Over a 10-day period we gradually cut additional holes in the tent for ventilation and leave these open at night. When we are ready to remove the plastic tent, we begin at several times per day hand misting of the juniper grafts. This is done by a person rather than a time clock, as I prefer human observation to mechanical errors. We have a saying at our company that the true propagators have leaned to "think like a plant". Learning to observe how the plant "feels" is critical to temperature and moisture control.

Pinus. White pine (*Pinus strobus*) cultivars are grafted in January in the same manner as junipers. They are placed in the same grafting benches, mulched, but left uncovered by the sweat tent. We have observed that the pine grafts prefer more air circulation and slightly lower humidity levels. They are hand misted as required to raise humidity levels on bright sunny days. As a side note, these pine grafts are misted on the same schedule as our winter hardwood cuttings.

Because we graft so many plants and root so many cuttings, it is easier for us to assign one person to monitor and be responsible for all misting duties. From our observation, graft care on a small scale can become a nuisance in early April.

Picea. Blue (*P. pungens*), white (*P. glauca*), and Norway (*P. abies*) spruce cultivars are treated differently from other graft crops. The process begins with a plug-produced seedling. We purchase a 1-year accelerated-growth plug seedling, pot into a 3-inch plastic pot, and grow the plant an entire summer to build roots and caliper. We have found plug produced plants very superior in cambium development and quantity over seedlings purchased bareroot. This vigor, juvenility, and cambium quality has resulted in 5% to 10 % improvements in grafting success.

Spruce grafting begins in February with scion gathering. We gather 1-year growth from vigorous, healthy plants. Poor scion quality will condemn you to about a 20% decrease in graft success. Understocks are cleaned and trimmed to clear the stem. A side veneer graft incision is made in the understock. Scions are trimmed of needles, and a matching incision and backcut is made on the scion. The scion is inserted into the understock and tied with a lightweight budding-rubber strip. The plant bleeds sap from the understock and this hardens into a seal which eliminates the need for grafting wax.

The unusual part of the environmental care begins at this point. The understocks are totally dormant prior to grafting, they are not forced in any heat. The greenhouse for post-graft care is an unheated double polyhouse with one white and one clear layer. The goal is to replicate a soft, cool, semishade environment of the floor of a

Pacific Northwest conifer forest. Remember, we are trying to learn to think like the plant. The grafts are mulched and placed on the floor of the polyhouse. Even globosa blue spruce on standards are laid on their sides to keep the graft near the peatmoss-induced, high-humidity microclimate. These are placed upright as soon as healing activity is apparent. Ventilation is by panels in the ceiling because spruce will die if they are in any draft. Never use fans to ventilate a house with grafted spruce. Spruce grafts will advance in time or slightly ahead of the outdoor season. Understocks will flush growth first, will be gently pruned back, and scions will flush growth. Post care on spruce is a delicate dance of spray maintenance for gray mold, gradual understock removal, temperature and moisture control, and judgement. Experience on this issue is critical to decision making concerning care. Expect many failures during a long and difficult road to calling yourself a successful spruce grafter. I am quite proud of the fact that we have averaged about 90% success for the last three seasons. Prior to some changes made 3 years ago, 50% was a typical crop. My family has been grafting spruce for 76 years and I still feel I have much to learn.

SUMMARY

I hope I have shown three distinct environmental climates we create to maximize conifer grafting success. They vary a great deal, and as you can see work best when dealing with large quantities that financially justify the specific care. If you cannot spare the time to have someone physically involved with your plants in post-graft care 7 days a week in the post-graft process, I think you should plan on purchasing your grafts. Grafting success is often equated with the knife skills in making the incisions, but I feel plant materials quality and post-graft care are just as crucial.

Good luck if you try some of the conifers I've discussed. If in doubt, ask yourself, "what would I like if I was a graft?"

Summer Grafting

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The topic I would like to present today is grafting deciduous plants during the peak summer growth period. Typically grafting is completed during the dormant season; however, we have found that in Maryland USDA Zone 6, that grafting deciduous plants during the summer season can be quite successful. As we prepare to go into the next millennium we are forced to improve the use of our time and dollars spent. We also must strive to increase the quality of plants we produce and how we produce them. Our summer grafting program began 20 years ago, working only with *Acer palmatum* cultivars. As time went on we improved our methods of grafting and our quest for the optimum time to graft. Though there are many taxa that can be grafted during the summer, I would like to concentrate mainly on the following groups: *A. palmatum*, *Hamamelis*, *Cercidiphyllum*, and *Cornus kousa*.

Acer palmatum cultivars are one of the easier groups with which to work. Timing is not as limited as one might think. Basically as soon as the current new growth has hardened off the scions are ready to collect and graft. August and September are the best months for us to do our summer grafting. Scions are collected in the early morning before the heat of the day becomes a factor. We take only the quantity needed for that particular day. We have found in the past scions have desiccated if held too long even in cold storage. The leaves are removed with the exception of the petiole. The petiole stub is used as our indicator for callusing. After 5 days you should be able to barely touch the petiole and it will drop from the bud. This is due to the swelling of the bud which is in direct correlation to the callusing taking place at the union. Our scions are now prepared and ready to graft. The understocks are *A. palmatum* 2-year seedlings which were potted in April of that year in 2⅝-inch pots. All lateral buds and branchlets have been removed with only the top ⅓ remaining in leaf. It's very important that the understocks are at a moderate moisture level. Extreme dry or wet soil conditions can cause quick failure. A soft cloth is used to clean the understock at the point of grafting. We use a simple modified side-grafting technique and wrap the union with budding strips. As the grafting takes place the newly grafted plants are hand misted until they go into the greenhouse. When a flat is full it is placed in the greenhouse under automated mist programmed to mist for 6 sec every 10 min. This is a critical point because the mist system can easily overwater the understock, causing graft failure. Even with today's automation we still check the mist conditions every hour during the first 2 weeks. Shading on the greenhouse is 47% and air temperature control is set at 85F. It's important in the first 2 weeks to have high humidity, heat, and sunlight. After 2 weeks we push on the petiole to see if it is ready to drop off of the bud. If it does and callusing of the union is evident, then the mist is slowly reduced. If our unions are healed and white callus tissue is evident, then we begin cutting the understock back. At the end of 4 weeks the understock is cut back to meet the same length as the scion. This gives the graft mechanical support and relieves moving or bumping the new union. At the end of the 5th week the grafts are completely removed from the mist and the houses are cooled down to harden off the plants. They are then removed to an overwintering house where they will remain until the following spring for shipment.

Grafting of *Hamamelis*, *Cercidiphyllum*, and *C. kousa* are completed in the same method as *A. palmatum*. The only exception is that the leaves remain on the scion but are reduced by ½ to ⅔ surface area. We have found in the past that complete removal of the leaves reduced our take by 45%. More attention is paid to the mist system so that the foliage does not desiccate. After 2 weeks we look for callus formation at the union. *Hamamelis* and *C. kousa* have strong fleshy callusing but *Cercidiphyllum* callusing is similar to that of *A. palmatum*. It is not uncommon after 3 weeks to have defoliation take place. If this does happen it should be a result of the scion buds swelling.

In summary, we feel that the quality of the grafts, and the increased percentage rate, as well as and following season's increased growth rate are important factors when considering summer grafting. Summer grafting allows us to take advantage of warm summer temperatures for our heat source, long days for our daylight requirements, and almost total elimination of fungus problems. It has been our choice to go with this program and we feel it has been a great success.

Embryo Excision for Accelerated and Uniform Germination of Hard-to-Germinate Maple Species

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INTRODUCTION

Virtually all fall-maturing maple seeds exhibit some form of dormancy (Browse, 1979). In one respect, this is advantageous for the seeds as it prevents them from germinating at a time when climatic conditions are unfavorable for plant growth and survival. During dormancy, however, the seeds are vulnerable to a number of factors which can reduce their viability: desiccation, fungal infection, and insect and rodent damage. The longer the seeds are in this vulnerable condition, the greater the chance of loss to these factors. The extended period of time some maple species must be exposed to either natural conditions or various stratification treatments in order to overcome dormancy (as long as 3 years for some trifoliate maples; Fordham, 1969) contributes to an already low germination rate in those species. Finding alternate ways to overcome dormancy in difficult-to-germinate species can reduce frustration for hobbyists, and can make additional species feasible for researchers to study and growers to produce.

In the scientific literature there is information about seed dormancy and methods other than stratification that may be used to overcome it. As early as 1955, Heit realized that the germinability of the naked embryo was a truer measure of the viability of a seed lot than that of the intact fruit. Wilson, Hibbs, and Fisher (1979) developed this further and showed the importance of the seed coat, also known as the integuments or testae, in preventing germination. These reports, and others, show that seed dormancy in maples can be caused by two types of conditions that may occur separately or in concert. The physical structures enclosing the embryo may prevent its germination or the embryo itself may be dormant. Stimart (1981), in a very elegant study, investigated how best to overcome embryo dormancy using various concentrations of a number of growth regulators, in combination with light and dark treatments.

In 1993, in an attempt to expedite the process of tree breeding and provide uniform-sized seedlings for physiological studies, I incorporated a number of the techniques recorded in the literature in a seed treatment that was successful on a broad spectrum of maple species (Wiegrefe, 1994). In October of 1997 I received a number of high-value seed lots of maples from a plant exploration trip to China. In most cases, little or no information was available about the seed dormancy types of these species. The current paper reports the results of using the procedures developed earlier to: (1) hasten germination, (2) trigger more uniform germination, (3) maximize germination percentages, and (4) determine the type(s) of dormancy affecting each species.

Materials and Methods. From 29 to 64 seeds were available for use for each of six species (Table 1). The time required for the embryos excisions ranged from 6 to 12 min per seed. Thus, although all of one seedlot were treated in 1 day, the excisions spanned 2 weeks.

Intact fruits were surface-sterilized in 70% ethanol in water for 3 min, then soaked in filtered water for a minimum of 3 min. Very hard, dried seeds were soaked for as long as 2 days to make the tissues more pliable. The pericarp (hard, protective "nutlet" portion of the fruit) was then removed by either: prying open with a vise and small screwdriver (*Acer triflorum*); scoring the corner of the nutlet with a single-edged razor blade, then vertically compressing the nutlet with a needle-nosed pliers until the two halves begin to separate (*A. mandshuricum* and *A. pseudosieboldianum*); or cutting around the periphery of the embryo and peeling open with a jeweler's forceps (*A. tegmentosum*, *A. tschonoskii*, *A. mono*, and *A. ukurunduense*). In most treatments (Table 1), jeweler's forceps were then used to remove the integuments or testae (the thin membrane still covering the embryo). The naked embryos were soaked for 2 days in filtered water to leach out germination inhibitors and allow imbibition to occur. The embryos were then blotted on a paper towel and placed in 10-cm petri plates on filter paper that had been moistened with 2 ml of one of four solutions: filtered water (distilled water can be substituted), 10 ppm benzyladenine (B-3274, Sigma-Aldrich, Ltd., St. Louis, MO), 10 ppm gibberellic acid (ProGibb®4%, Abbott Laboratories, North Chicago, IL), or 1 ml each of the BA and GA solutions for concentrations of 5 ppm each. The plates were sealed with Parafilm laboratory film (American National Can, Chicago, IL) and placed either under florescent lights at 16-h photoperiod or in a dark drawer, both at room temperatures around 21C/70F. The embryos were determined to be germinated when the radicle had grown at least 2 mm and shown a distinct gravitropic curve. Embryos were observed until they deteriorated or germinated. After germination, the embryos were planted and plastic film was used to loosely cover the flat for desiccation protection. The film was removed for increasing durations as the seedlings adjusted to the lower humidities in the greenhouse.

RESULTS

Integument Effects. Only one species, *A. tschonoskii*, was tested for germination without having its testae first removed and the contrast in the results was dramatic (Table 1). No germination occurred for any of the embryos placed on water-or growth-regulator-soaked filter paper if the testae were intact. Once the testae of those same embryos were removed and the embryos were placed on BA-moistened paper on Day 12, 100% germination occurred in 1 week. Naked embryos placed on filter paper on Day 0 with either 5 or 10 ppm BA germinated within 1 week, but naked embryos in contact with water or 10 ppm GA did not germinate in less than 12 days.

Growth Regulator Effects. Benzyladenine, at a concentration of 10 ppm, was more effective than 10 ppm GA or water and equally effective at 5 ppm concentration when combined with 5 ppm GA in eliciting germination in *A. tschonoskii*. Gibberellic acid was only slightly less effective than BA in eliciting germination in *A. pseudosieboldianum* and *A. triflorum* (probably no statistically significant difference), but much less effective in *A. tschonoskii*, where no germination occurred in the 12 days of the 10 ppm GA treatment. In *A. triflorum* treatments, germination began in the water treatment in 3 days (data not shown) and was the only water treatment that was continued unchanged for the duration of the experiments.

Light Effects. Three species were treated to contrasting light treatments (*A. barbinerve*, first 8 days vs. subsequently; *A. mono*; and *A. tschonoskii*: Table 1). No

germination occurred in the 8 days the *A. barbinerve* were subjected to darkness. However, 2 days after being placed in light, germination began. *Acer mono* seeds that differed in the light conditions they experienced for the first 8 days after excision did not differ in their days to germinate. There was little difference in *A. tschonoskii* placed on BA paper in the light or darkness in percent germination, days to germinate, or uniformity of germination. Light in combination with GA or water did not result in germination.

DISCUSSION

Dormancy Observations. Multiple factors were found to contribute to seed dormancy in the species studied. In many of the cases, the impact of the testae on enforcing dormancy was not investigated, thus no conclusions can be drawn on its impact on the germination behavior. The findings for each species are discussed below.

Acer barbinerve. Light was found to promote germination in naked embryos of this species. This is similar to the response of *A. maximowiczianum* (syn. *A. nikkoense*) (Stimart, 1981). The lack of a difference between the water and BA treatments indicate that the growth regulator is not required to stimulate germination.

Acer mandshuricum. The conditions determined by Stimart (1981) to be necessary for successful germination (i.e., removal of all covering structures, low levels of BA, and light) were applied to this very small seed lot with great success — 100% germination in 4 days.

***Acer pictum* (syn. *A. mono*).** Although my previous work on *A. truncatum* had convinced me that this closely-related taxon would exhibit only a testae-imposed dormancy (Wiegrefe, 1994), this study indicated otherwise. Treatment with BA was required to stimulate germination in this seed lot indicating the presence of embryo dormancy as well. It is unclear to me whether this discrepancy in findings is due to taxonomic differences in the plant materials used or whether provenance differences, summer growing conditions, or post-harvest handling influenced the seed behavior. This seed lot was also found to have low vigor, with many embryos deteriorating in the petri plates.

Acer pseudosieboldianum. Growth regulators were found to be helpful in stimulating germination in this species. Gibberellic acid was almost as effective as BA in this respect. The fact that the germination occurred so quickly following transfer of the water-treated embryos to BA indicates that they may have germinated eventually even in the absence of exogenous growth regulators. The thick pericarp is presumed to play a major role in preventing germination of this species.

Acer tegmentosum. The lack of germination of naked embryos on water-moistened filter papers compared to the BA treatment indicates that there is an embryo dormancy present in this seed lot/species. Darkness was effective in promoting germination in this experiment, but previous experience (unpublished data) has taught me that this species is neutral in its light requirement for germination.

Acer triflorum. Naked embryos in all three solutions used (i.e., water, BA, and GA) germinated in less than 3 weeks under lights. The use of either growth regulator reduced the maximum number of days to germinate to 8 and significantly reduced

Table 1. Results of seed treatments given to seedlots of eight Chinese maple species. Abbreviations: DTG = Days to Germination, CBS# = Changbai Shan expedition collection number, X = excised (pericarp removed), TR = Testae removed, BA = 10 ppm benzyladenine, GA = 10 ppm gibberellic acid, BA/GA = 5 ppm each benzyladenine and gibberellic acid.

Acer species	Treatment	No. of Seeds	Germination (%)	Mean DTG	Std. Dev. DTG
barbinerve CBS#018	X + TR + H_2O + dark[1]	5	0/ 60[1]	14	0.0
	X + TR + BA + dark[1]	10	0/ 70[1]	13	1.8
mandshuricum CBS#135	X + TR + BA + light	5	100	4	0.0
pictum CBS#100	X + TR + H_2O + light[2]	11	0/ 82[2]	12	4.2
	X + TR + H_2O + dark[2]	11	0/ 55[2]	12	2.2
pseudosieboldianum CBS# 110	X + TR + H_20 + dark[2]	10	0/ 70[2]	10	3.1
	X + TR + BA + dark	9	100	4	0.7
	X + TR + GA + dark	10	90	8	3.3
tegmentosum CBS#016	X + TR + H_2O + dark[3]	7	0/ 100[3]	12	0.5
	X + TR + BA + dark	8	100	3	0.8
triflorum CBS#108	X + TR + H_2O + light	10	90	10	6.0
	X + TR + BA + light	8	100	8	0.5
	X + TR + GA + light	10	100	7	0.9

tschonoskii CBS#028	X + TR + H_2O + light[4]	7	0/ 86[4]	19	0.0
	X + TR + BA + light	7	100	7	2.6
	X + TR + GA + light[4]	7	0/ 100[4]	17	4.3
	X + TR + BA/GA + light	7	100	7	2.5
	X + TR + BA + dark	7	100	6	1.9
	X + H_2O + light[5]	7	0/ 100[5]	19	0.0
	X + BA + light[5]	7	0/ 100[5]	19	0.0
	X + GA + light[5]	7	0/ 100[5]	19	0.0
	X + BA/GA + light[5]	7	0/ 100[5]	19	0.0
ukurunduense CBS#071	X + TR + BA + light	24	71	5	0.2

[1] Indicates the treatment for the first 8 days, on Day 9 the treatment was changed to (X + TR + [same solution as previous] + light). The first germination percentage reflects the situation on Day 9.

[2] Changed to (X + TR + BA + light) on Day 8. First germination percentage reflects situation on Day 8.

[3] Changed to (X + TR + BA + light) on Day 4. First germination percentage reflects situation on Day 4.

[4] Changed to (X + TR + BA + light) on Day 12. First germination percentage reflects situation on Day 12.

[5] Changed to (X + TR + BA + light) on Day 12. First germination percentage reflects situation on Day 12.

the variation in germination dates. Thus, although the pericarp and/or testae-imposed dormancy (or correlative inhibition, Samish, 1954) is the major factor enforcing the prolonged seed dormancy, growth regulators can further stimulate the naked embryos to germinate.

Acer tschonoskii* subsp. *koreanum (syn. *A. tschonoskii* var. *rubripes* Komarov). With the luxury of many seed to work with, we were able to study this seedlot quite thoroughly. We determined that both a testae-imposed dormancy and an embryo dormancy are present in this species. Unlike in other instances (see *A. pseudosieboldianum* and *A. triflorum*), GA was not effective in stimulating germination. Benzyladenine at either 10 ppm or 5 ppm (the latter with 5 ppm GA) was required. This species was also found to be nonspecific in the light conditions needed for germination.

Acer ukurunduense (syn. *A. caudatum* subsp. *ukurunduense* (Maximowicz) Murray). As no alternative treatments were attempted, I can only state that treatment of the naked embryos with BA and light was successful in triggering rapid and uniform germination. Since growth regulators in the absence of the preferred light condition is ineffective in eliciting germination (see *A. barbinerve* above), we can assume that either *A. ukurunduense* prefers light or is neutral in its light requirements.

Treatment Recommendations. The treatment that was most effective in causing the greatest, fastest, and most uniform germination for all species tested was: the removal of the pericarp and testae followed by a 2-day water soak and placement of the naked embryos on filter paper moistened with 10 ppm BA. The optimal light condition depends upon the species, and some species may be equally satisfied with light or dark during germination provided other conditions are met.

In my previous work, I found that embryos without an embryo dormancy that are treated with BA can develop a club-shaped radical that is slow to elongate and develop root hairs. For this reason, I would recommend placing the naked embryos of a maple seedlot with unknown dormancy type(s) on water-moistened filter paper for 3 to 7 days and transfer to the BA treatment if no germination occurs within your chosen time limit.

SUMMARY

Embryo excision combined with leaching and with or without growth regulators can reliably result in fast and uniform germination of maple seeds. Due to the time involved, the procedure (unless modified) will not be feasible to be used in most commercial nursery situations. However, where high-value seeds or species are involved, it may be very useful. Some of the most valuable applications for the technique are to be found in plant breeding programs, where acceleration of germination and reduced time per generation is desired, and in physiological research, where the generation of uniform-aged and -sized plants are needed. The risk of damaging a few embryos in the extraction process is more than compensated for by the immediate and high percentage of germination.

Acknowledgements. I thank Jim Humbert for his valuable assistance in administering the seed treatments, and data recording, and analysis. Lisa Berg's assistance with embryo excisions and editing the manuscript is also greatly appreciated.

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Perennial Propagation in the New Millennium

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INTRODUCTION

I chose this topic with a sense of excitement, panic, and frustration because in many ways the propagation and production of certain herbaceous perennials on a commercial scale has changed radically in the last 30 years, yet at the same time the methods used for the vast majority of taxa has not really changed much at all. As we approach this upcoming turn of the century mark, knowing the rate of technological change in the world today, one wonders just what we might be growing, say, 20 years from now. Gazing into the future is not an option for the vast majority of us here today, yet it is worth looking at where we have come from and pondering what may lie ahead in the propagation of such a diverse and exciting group of garden plants.

Without a doubt, one of the most revolutionary developments in commercial plant production in past decades was the invention of the plug flat. Hardly a nursery exists that does not make use of these handy things for the production of seedlings or for rooting cuttings of nearly any plant imaginable. Plug flats allow growers to minimize transplant shock by eliminating "pricking out", mechanization of potting is possible, as well as the ability to hold seedlings or cuttings for longer periods of time before they are moved up.

These are all advantages, particularly for easier-to-germinate perennial species. Production on an enormous scale is possible, such as at Raker's Acres in Michigan, so much so that it may be more economical for a nursery to purchase ready-to-transplant plugs of more common seed-grown types, thus utilizing one's limited space for cutting propagation or growing seedlings not available elsewhere.

The plug revolution has been an enormous boon to growers, without a doubt. In recent years, however, as the end consumer — the gardening public — has become more sophisticated, the items many growers used to consider to be "bread-and-butter" plants have taken some radical downshifts in popularity. In other words, gardeners are now wanting something more exciting than seed-grown carnations or shasta daisies, and they have been whipped into a frenzy by our friends, the garden

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media, into demanding an endless supply of more unusual plants such as *Corydalis* 'Blue Panda', or *Heuchera* 'Chocolate Veil'. This in itself is not such a bad thing, so long as growers are able to somehow anticipate and meet this now constant demand for new plants.

This brings us then to ponder, once we have a hunch what the hottest new taxa are going to be, how are they to be propagated in large numbers and eventually made available to gardeners? What, aside from plug flats, are the tools and methods that we as growers have available to help us in this struggle to survive? I would like to review some of the current methods that many wholesale perennial growers are utilizing for perennial production, the advantages and disadvantages that these methods may offer.

SEED PROPAGATION

In many cases this is still the most economical way to produce a wide range of perennial species and cultivars. Despite a certain amount of snobbery that seems to be inherent in the perennial industry towards anything that is not vegetatively propagated, there are some perfectly fine garden plants produced by seed, whether they be species, cultivars, or less stable "strains" or mixtures of colors. Some of the more popular ones that are easy to produce include *Campanula carpatica* 'Weisse Clips', *Rudbeckia fulgida* var. *sullivantii* 'Goldsturm', or *Echinacea purpurea*. For growers, these easy-to-germinate plants usually adapt well to mass production, giving reasonably uniform and predictable results from the germination bench right on into potting, growing, and shipping.

Moving on to the more tricky seed-grown perennials is a difficult leap for a grower to make. Dealing suddenly with a species that has uneven germination, requires stratification or scarification or who-knows-what-else, can make for a difficult mix of seed germination requirements in a facility designed for factory-level output. The sad truth is that most wholesale perennial growers struggle once or twice trying to produce a crop of *Helleborus* or *Meconopsis* from seed, before giving up and leaving it to the specialist grower. Often part of the decision to not even bother with tricky seeds is directly related to the cost of the seed. In other words, some of most coveted and wonderful seed-raised perennials are an unfortunate burden on the grower's time, energy, and pocketbook, with little to show in return. As competition increases, and seed sources become more reliable, this is an area that holds much promise for the grower who is willing to learn a few simple tricks and also learn to be patient.

VEGETATIVE PROPAGATION BY CUTTINGS

Growers who start out raising primarily seed-grown types soon discover a strong demand exists for cultivars that they simply can't raise from seed. Any number of characteristics can only be maintained in certain plants through vegetative means, for example, variegated foliage, unique flower colour or size, or a compact habit. Taxa with very expensive or hard-to germinate seeds can sometimes be more economically produced by cuttings also, as is the case with *Amsonia tabernaemontana*. Fortunately, a good number of herbaceous perennials are easily produced by means of softwood cuttings, but in all cases there is one common requirement that a grower will have to address immediately: acquiring and maintaining a supply of stock plants.

There are several approaches to stock management: some growers maintain in-ground stock beds, which produce cuttings through the spring, summer, and fall.

Another method is to grow stock plants in containers; this can help greatly to make cuttings available for harvesting year-round. A third approach is to harvest cuttings off of existing production, in other words to sneak cuttings from crops that will be ultimately sold.

Cuttings can be a little temperamental about exactly when they will or won't root, and what sort of percentage of successful take might be expected varies widely between taxa. Few good sources of information about cutting propagation of perennials are in existence, so any grower that embarks down this path is well advised to pay careful attention to successes or failures and learn as much as possible through trial and error. *Galium odoratum* is a good example of this; perfectly nice cuttings taken in the heat of summer usually result in very poor rooting, perhaps as low as 5%, yet when taken from stock plants during the cooler winter months, the take may be closer to 95%.

Typically, a grower will harvest tip cuttings in small batches to be stuck into plug flats as quickly as possible. The majority of perennials respond well to a powder-type #1 rooting hormone, although with certain easy-rooters, like *Sedum* taxa, this step is more or less a waste of time. A mist or fog system is very beneficial to successful rooting or perennials, particularly during the warmer summer months. However, as a rule of thumb, plants with silver or grey foliage, like many *Artemisia*, or fuzzy-leafed species will rot easily with too much moisture, so a dryer area in the greenhouse may also be useful. Bottom heat may help to speed up rooting time significantly during the fall or winter months.

Stem cuttings, taken beyond the softer tips, are used with certain plants, like *Lamium* taxa, and in this case a stem with a single set of nodes will initiate both roots and new top growth, a handy means of making efficient use of available stock plants. A few perennials will produce above-ground runners, like *Fragaria*, and these can be removed as soon as new plantlets form at the ends, then treated like tip cuttings.

A method that is probably under-utilized here in North America is the root cutting. European nurseries propagate oriental poppies, *Phlox paniculata*, and Japanese anemone regularly by this means, and with good success. Typically, roots about the thickness of a pencil are taken in late fall or early spring, and often these are trimmings from field-grown plants being dug for cold storage. The root pieces are cut into sections and inserted into plug flats before being placed in a greenhouse with bottom heat.

DIVISIONS

Simple division of perennial roots is a method still used very widely in the industry. This is an excellent way to preserve the special characteristics of a cultivar, and is the method most widely used by home gardeners. In North America we have relatively few commercial growers of bareroot perennial divisions, with the exception of a few genera such as *Hosta* or *Hemerocallis*. By far the vast majority of bareroot divisions used by growers here are field-grown in Holland, dug and cold-stored in the fall, and exported here for growers to pot in early spring. As a North American perennial grower, it is very difficult to compete with the European field growers on price, when it comes to run-of-the-mill selections of *Dicentra* or *Phlox*. There are, however, a good number of hard-to-find plants, for example *Astrantia major* 'Sunningdale Variegated', that are worthwhile producing here at home in order to be assured of a personal supply. Some perennials simply do not take well to the root-washing, heat, and cold-storage treatments incurred with exporting, so

a plant like *Trollius* has good potential as a domestic crop.

Both cutting-propagated and division-propagated perennials share a common problem that we are beginning to learn more about with increasing frequency; there is a high likelihood that any pathogens that are present within the system of the plant will be passed on through vegetatively propagated material. These include harmful nematodes (e.g., *Aconitum*, *Cimicifuga*), or nasty viruses, especially tomato spotted wilt, and possibly a host of others. An example I will give you is *Lamium maculatum* 'Beacon Silver'. During the 1980s this quickly became a top-selling groundcover at nurseries from coast to coast. Cuttings rooted readily in about 3 or 4 weeks with near 100% success, and grew on to be vigorous and healthy plants. Over the last 5 to 6 years, nearly every grower I have talked to reports a tremendous decline in rooting percentage and noticeable lack of vigor both in the nursery and in the garden. Speculation ranges from "downy mildew" to "some kinda virus" to another theory that there have simply been too many hundreds of generations of cuttings taken and the plants have acquired some sort of genetic instability. Whatever the true problem is with 'Beacon Silver', several perennial growers, ourselves included, have simply dropped the plant in favor of newer *Lamium* cultivars.

MICROPROPAGATION

If we could look into the gazing ball, this technology may be the answer to "entering the new millennium" of perennial propagation, but this is hardly groundbreaking news! For 20 years or more, labs have been working with a limited range of herbaceous genera, most especially *Hosta* and *Hemerocallis*. However, increasing demand for new and unusual perennials is going to be the focus of many growers in the near future and tissue culture techniques have already become critical to the rapid increase of *Heuchera*, *Geranium*, *Brunnera*, *Pulmonaria*, *Hakonechloa*, and all kinds of other wonderful plants. All it takes is that special someone at the lab to "crack the code", finding just the right mix of hormones that will unlock the secret, before millions are listening to Martha convince them of the merits of something exciting and new that they must have! Imagine what could happen to a grower's product mix if there were unlimited numbers of *Paeonia tenuifolia* 'Plena', double *Trillium*, or *Cypripedium reginae* available from the labs? Perhaps some of these are pipe dreams that will never come true, but we must have faith in the unknown.

On another level, there is good evidence that micropropagation can offer a way of "cleaning up" any number of genera, helping nurseries to maintain healthy, virus-free stock that grows well in production and performs as it should in the garden. This has been the fortunate circumstance with double *Gypsophila*, and any number of Victorian double *Primula* cultivars, and rumor has it that a major plug producer in the U.S. is in the process of cleaning up *Phlox subulata*. Regardless of the wonders this miracle technology may hold in terms of making the unusual rarities of the plant world more commonplace, as a producer of perennials, I will be happy to see many a good-old plants cleaned up and once again made vigorous and healthy for generations of gardeners to come.

Seed Viability: Procedures Used by Professional Seed Analysts

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INTRODUCTION

The establishment of plugs or trays with 100% stand establishment saves bench space, increases the profit/area ratio of the plants, and saves labor costs for refilling skips. I hope this talk can provide information on the determination of accurate germination testing, vigor testing, and a mathematical expression of seed vigor.

GERMINATION TESTING

Reproducibility using standard methods and conditions is the first consideration of seed germination and vigor assessment. Accurate records are a must. A germination cabinet is the best way to control temperature, light, and moisture of the germinating seed. Samples are run as four replicates of 50 for the most part, although corn is usually done as 2×100 and members of the Cucurbitaceae as 4×25.

Methodology for testing must be standardized and in Canada is dictated by the methods and procedures, as determined by Agriculture Canada. Interpretation of the results is also standardized with optimum methods for germination of individual crops. Replicates must be within the tolerance tables provided, for the results to be considered valid. Germination can be done using blue blotters, silica sand, or rolled towels. All media must be tested for phytotoxicity. Some seed require light, but seedlings must have all essential structures to be considered normal. The AOSA determines the State rules for the U.S.A. State laboratories, and ISTA is an international association of government laboratories. All are working towards a standardized system for testing and common acceptance worldwide. Both ISTA and the AOSA have established methods to test flower and tree seeds, while Canada has methodology only for herbs, vegetables, and field crops.

A pair of cotyledons or coleoptile, stem, and proper root development are necessary to have a normal seedling. Abnormal seedlings, with disease, split hypocotyls, necrosis, etc. are noted but never included in the germination count. The number of dead seeds are also noted. Methodology determines when interim and final count are made.

FACTORS AFFECTING SEED VIGOR

1) Vigor and health of the parent plant.
2) Maturity of the seed during harvest. Immature seed have generally less vigor and loose their vigor sooner.
3) Environmental conditions during seed development and harvest, especially temperature and humidity.

4) Conditions under which seed are stored. Cool, dry conditions decrease respiration and premature aging.

VIGOR TESTING OF SEED

Accelerated Aging. As cool dry conditions preserve the viability of seeds, moist warm conditions act in an opposite manner. Accelerated aging is accomplished by holding a seed sample for a specified time at a specified humidity and then testing for germination and rate of germination. Sample size is usually based on weight not numbers. Monitoring of the aging process requires a thermohydrograph and checking the moisture content of the seed after aging using a moisture tester. A control of untreated seed is required for comparison purposes. Comparison of the germination rate of both samples should give a good indication of the vigor and long-term viability of the original sample.

Stress Test. Corn seed are routinely chilled at 4 to 5C, after moistening, for 7 to 10 days prior to germination at standard temperature and conditions. Again a comparison of chilled and unchilled samples indicates the vigor of the original sample.

Conductivity Test. Brassica seed soaked in 1% sodium hypochlorite (Javex/ Clorox) will release sinapine within 10 min. Leakage from the seed is directly proportional to the integrity of the seed cell wall. Sinapine has a yellowish color under alkaline conditions (> pH 10), so the addition of potassium hydroxide clearly enumerates the percent of abnormal and dead seeds present. An alternate method would be to soak the seed for 4 to 5 h in tap water and add a drop of 2.5% triple phosphate.

Tetrazolium Test. Replicates of pure seed are imbibed and stained with 0.1% or 1% tetrazolium chloride. Seed may require excision before or after treatment with tetrazolium, but always requires some botanical knowledge of how the embryo is located in the seed. The degree of tetrazolium absorption determines the number of viable and nonviable seed in the sample and the percent of normal/ abnormal or dead seed. This method is highly subjective and misinterpretation often occurs.

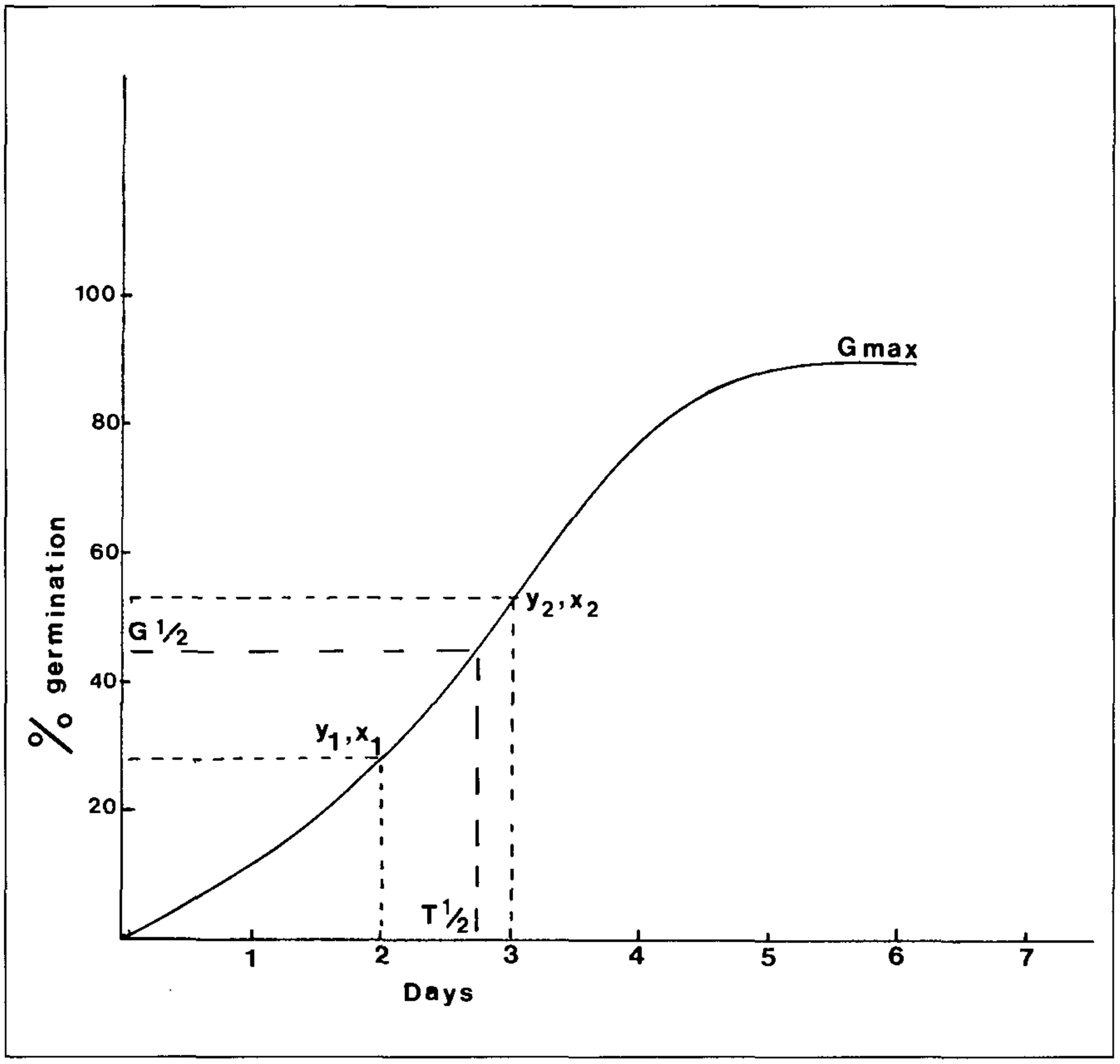
VIGOR DETERMINATION

The simplest way to calculate the vigor of a sample would be to measure the daily emergence of the radicle under the prescribed conditions and time for the species being tested. Plot the percent germination for each day until there is no more improvement in germination. This is the final germination or G_{max}. If the final germination is 90%, then the time to half maximum germination (G 1/2) would be 45%. Drop a perpendicular from 1/2-max germination to get T 1/2 the time to half final germination, measured in days. This is an inverse relationship as the lower the value or time, the faster germination occurs.

Should greater accuracy be required the following formula, developed by Terry McIntee at Stokes Seeds, can be used. G_{max} is the final germination and T 1/2 the time to half final germination. The values x1, y1 are the day and percent germination just before G 1/2, while x2, y2 are the day and percent germination just after G 1/2.

$$T\,1/2 = \frac{\frac{Gmax}{2} - \left(y_1 - \left(\frac{y_2 - y_1}{x_2 - x_1}\right) x_1\right.}{\left(\frac{y_2 - y_1}{x_2 - x_1}\right)}$$

The rate of germination (R 1/2) at T 1/2 is equal to the above denominator y2 - y1/x2 - x1.



This is the slope of the line or percent (%) germination/day.

Calculation of the half time to half maximum germination is an excellent way to judge the vigor of your seeds. Knowing the percent germination does not always give a true measure of the viability of the sample. The advantage in synchronicity and stand establishment are well worth the time required to calculate the true vigor of your seeds.

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Soil Organic Matter Quality and Induced Resistance of Plants to Root Rots and Foliar Diseases

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INTRODUCTION

Nurserymen and landscapers have recognized for centuries that composts can improve plant health. Many factors must be controlled, however, to obtain consistent effects. The degree to which the raw material is heated during composting affects the potential for killing pathogens and weed seeds. The degree to which the organic matter has been stabilized plays a role in disease suppression and plant growth. Furthermore, composts do not always become colonized naturally by beneficial microorganisms and this can lead to failures. Finally, the concentration of salts and the quantity of nitrogen released by composts plays a role in disease suppression. These factors are briefly reviewed here. We also provide some general information on composts widely available to the nursery industry and how best to use such products.

Most beneficial effects induced by composts are due to the activities of microorganisms in the rhizosphere, the area of soil immediately surrounding the roots. Soil organic matter (composts) has a major effect on the types of microorganisms present in the rhizosphere. Some of these microorganisms produce plant growth hormones and stimulate plant growth directly. Others produce natural chelators called *siderophores* that keep iron at a high concentration in available form to plants in soil, even at pH 7.6. Composts also produce water-soluble humic substances, including fulvic acids, which keep iron, zinc, manganese, and other trace elements in solution. This probably explains why growers using composted biosolids can produce "acid-loving" plants such as azaleas at pH 7.4 in container media consisting of aged pine bark (60%), fibrous sphagnum peat or composted rice hulls (20%), composted biosolids (10% to 15%), and silica sand, in regions where the irrigation water is high in carbonates. It is very difficult to grow azaleas in peat mixes in areas with high carbonate water, because trace elements limit growth as the pH of the peat mix increases and their solubility decreases. Peat mixes are too decomposed to support these beneficial effects.

Beneficial microorganisms that control diseases are known as biocontrol agents. Disease control obtained with this microflora is attributed to four mechanisms. The first is competition for seed, root, or leaf exudates (sugars, etc.) that leak out of seeds during germination or root tips as plants grow through the soil. Pathogens swimming to these sources of nutrients must compete with this beneficial microflora in the infection court. This reduces infections and therefore disease. Some biocontrol agents produce antibiotics effective against pathogens. Yet another group parasitizes pathogens. Microarthropods such as springtails and mites actually search out pathogen propagules in soils and devour them. The fourth mechanism involves the induction of systemic resistance in plants by microorganisms present in composts. A few beneficial microorganisms can induce all four mechanisms.

Our group has shown recently that some microorganisms colonizing roots in compost mixes activate biochemical pathways in plants leading to resistance to root as well as foliar diseases. This mechanism explains the often heard statement that plants on "healthy organic soils" are more able to resist disease. It has now been proven that compost can indeed support such effects. Details of our work are described below.

Most of the sphagnum peat sold for use in container media is of a decomposition level that cannot support the growth and activity of beneficial microorganisms. We have determined that such peat mixes are conducive (no suppression) to all diseases tested. In Figure 1 we show plants produced with one half of their roots in one mix and the other half in a second. The plant in the center had both sides in a sphagnum peat mix (H_4 on the von Post decomposition scale). The right side was in a mix infested with *Pythium*, a root rot and damping-off pathogen. Note that the roots of the center plant with both sides in the peat mix were small relative to the others. The rest rotted. The plant on the right had both sides in a composted pine bark mix with *Pythium* on the right side. Note the healthy root system. The plant on the left shows the systemic effect. The right side was in peat, also with *Pythium*, but the left

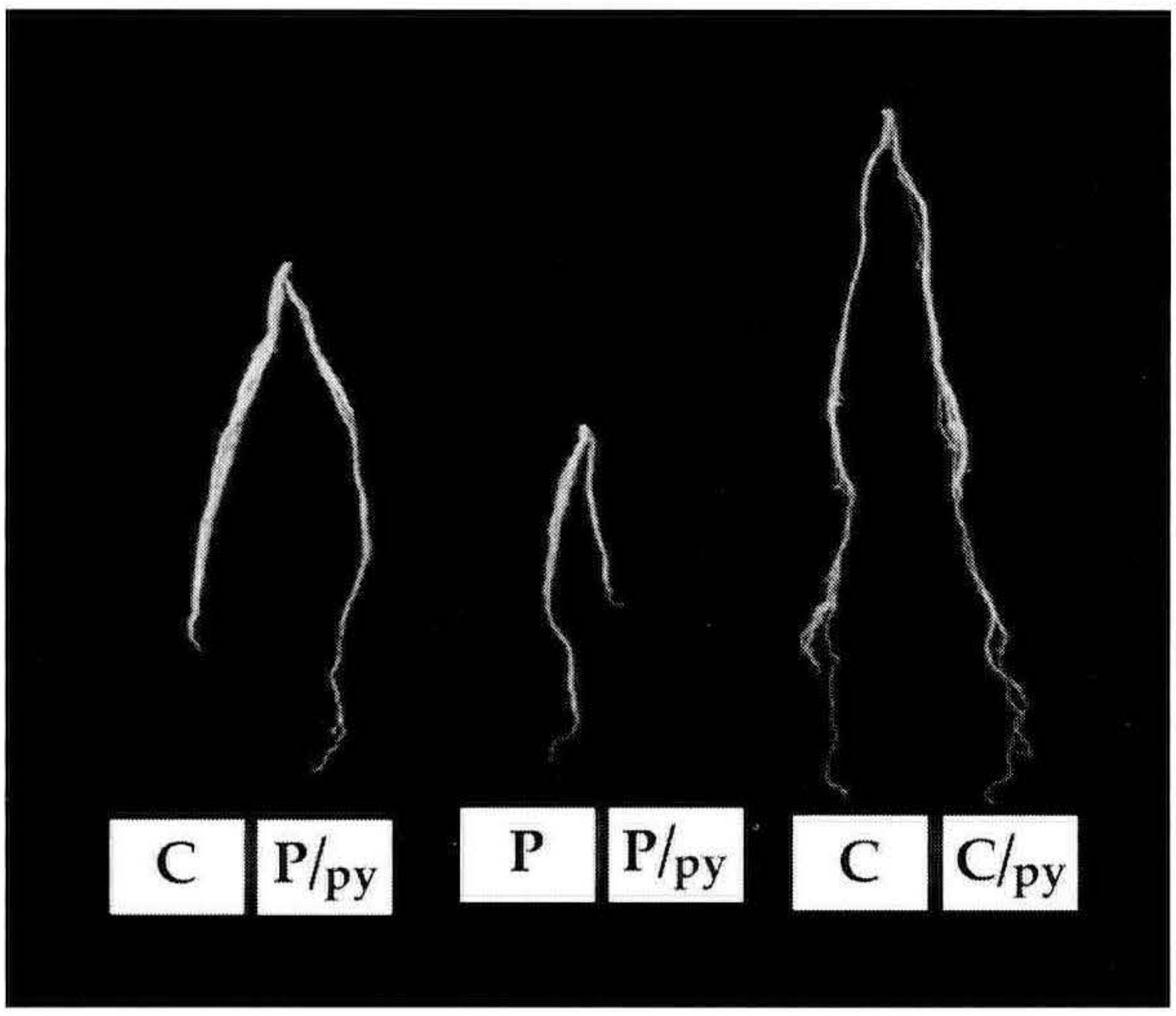

Figure 1. Roots of cucumber plants were transplanted into split-root pots containing a suppressive compost mix (C) or a peat mix (P) conducive to the disease in each half of the pot. The mix in the right half of each pot was infested with the pathogen *Pythium ultimum* (py). Note induced suppression by the compost mix.

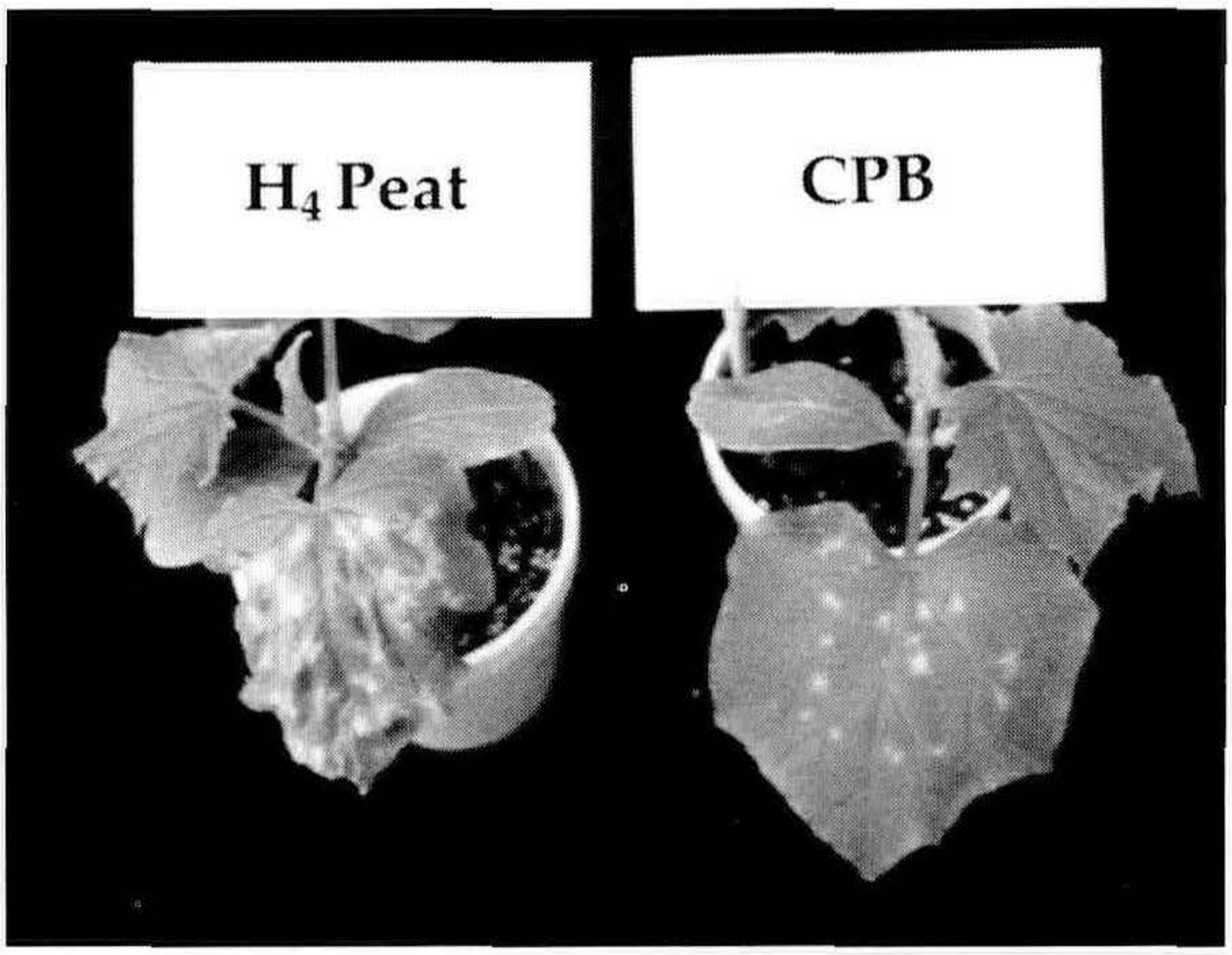

Figure 2. Cucumber plants with anthracnose were grown in pots containing a peat mix (H_4) or a compost mix (CPB). Note the reduced disease severity on the plant grown in the compost mix.

in the compost mix. When the compost was sterilized, it did not control the disease. Somehow, the microflora in the compost seemed to induce factors in the roots on the left that transferred to roots on the right in the peat mix which made the plant resistant to root rot.

In Figure 2, we show an example of control of a fungal disease of cucumber (anthracnose) on the foliage of a plant produced in a composted pine bark mix. The plant on the left, where the disease was much more severe, was grown in an H_4 peat mix. Some bacterial diseases in the foliage of plants can also be controlled in this way with several types of composts in the mix. Sterilized composts do not cause these effects until after they have become colonized by this flora again. This is an important finding because good control procedures for diseases such as fireblight, bacterial blight of lilac, *Xanthomonas* leaf spot on ivy, etc., are not available.

We have now identified some of the microorganisms in composts that can induce this systemic effect. Plants produced in any of several compost-amended mixes tested so far have higher concentrations of an enzyme related to host defense mechanisms. Plants grown in the peat mix that does not provide biological control do not have this elevated level of enzyme activity. In summary, our work shows that plants grown in substrates rich in biodegradable organic matter support microorganisms that induce systemic resistance in plants. These plants have elevated levels of biochemical activity relative to disease control and are better prepared to defend themselves against diseases.

It is important to realize that composts usually do not provide total disease control. When all conditions are favorable, composts offer the potential to reduce many diseases to below critical threshold levels. *Pythium* and *Phytophthora* root rots are

among the most easily controlled diseases. Some foliar diseases such as *Phytophthora* die-backs typically are not controlled at all, particularly when high fertility levels are maintained in the crop.

SELF-HEATING KILLS PATHOGENS BUT, UNFORTUNATELY, ALSO MOST BENEFICIAL MICROORGANISMS

Some landscapers utilize fresh wood chips as mulch. The question is, can this lead to spread of diseases? The answer is yes and such mulches also increase the activity of pathogens already on the site!

C. Ash, formerly at the University of Minnesota, has shown that fresh mulch prepared from maple trees that died from *Verticillium* wilt killed tomatoes mulched with this material. *Verticillium* was recovered from the dead tomato plants. This study demonstrated that pathogens in freshly ground infected trees can indeed cause problems in the landscape. Damping-off of bedding plants has been observed in Ohio landscapes mulched with fresh woody materials. Avocado trees mulched with fresh crop debris also suffer more from *Phytophthora* root rot. *Rhizoctonia* damping-off also occurs in bark mixes used during propagation even though Phytophthora root rot is controlled. How can these problems be avoided?

First of all, pathogens, insect egg masses, weed seeds, etc., are killed when temperatures in compost piles exceed 130F for just a few days. Turning of piles so that all parts are exposed to high temperature ensures that pathogen destruction occurs. Those that are not killed outright are weakened and more susceptible to parasitism. Many technical articles support this statement.

It is important to stabilize organic matter in mulches. Organic matter must be stable enough so that plant pathogens cannot utilize it directly as a food base. Otherwise, the mulch actually increases the population of the pathogen. *Rhizoctonia* is an example of a plant pathogen that can grow on fresh mulches. Another reason for partial composting of mulches is that some beneficial microorganisms grow strictly as saprophytes (as on dead organic material) in fresh mulches. Once the mulch is partially decomposed, these beneficial microorganisms must now compete for nutrients. They now produce several types of competitive products that lead to pathogen kill or inhibition. This does not occur in fresh wastes. Some *Trichoderma* isolates serve as examples of a group of beneficial microorganisms that behave in this manner. In conclusion, application of fresh residues to crops or trees should be avoided when the crop is susceptible to disease. Fall or winter application avoids this problem.

What is the best method to compost fresh wood chip mulches to reach these beneficial effects? After just a few weeks of composting, the organic matter in most materials is already stabilized enough for most diseases to be controlled. The best way to accomplish this quickly with fresh ground brush is to enrich it with nitrogen. Add 1 lb urea per cubic yard, or grass clippings (10% to 20% by volume), composted sewage sludge (10% to 15% by volume), composted poultry manure (10 to 20 lb $yard^{-3}$), or another source of nitrogen to decrease the carbon to nitrogen ratio to within the optimum range for composting. Be certain to add water to the pile to maintain a moisture content of 50% to 60% on a total weight basis because ammonium volatilizes as gaseous ammonia out of the pile when it is too dry. The best procedure is to compost woody materials for 6 weeks before they are used as a mulch. The mulch should no longer give off ammonia odors then and begin to smell like soil.

The procedures proposed above kill pathogens and adequately stabilize most materials for use as mulches. Depending on the material being composted, it may have to stabilize much longer before it is suitable for soil incorporation as compost to avoid nitrogen immobilization.

COLONIZATION OF COMPOSTS AFTER PEAK HEATING BY BENEFICIAL MICROORGANISMS

Very few beneficial microorganisms can survive in the high temperature part of compost piles. Most survive in the outer low temperature layer where they constantly reestablish their populations after turning of windrows if several factors are addressed. First, the moisture content must be above 35% in the organic matter fraction of composts for beneficial microorganisms to colonize the substrate. They actually grow as biofilms on the surface of organic matter, particularly if the moisture content is maintained above 45%. Dusty, dry composts and mulches become colonized by molds that cause a variety of problems. These problems can range from difficulties in wetting of the compost-amended soil or mix because fungal masses repel water, to inhibition of plant growth due to deleterious-to-growth microorganisms (minor fungal pathogens). Some fungi cause problems as toadstools in dry mulches or potting mixes.

Allowing composts to cure while a moisture content of 45% to 55% is maintained reduces the potential for all of these problems. Plant growth-promoting bacteria and bacterial biocontrol agents naturally colonize such higher moisture content mulches and compost after peak heating because a thin layer (film) of water surrounds organic matter particles at this moisture content. Bacteria cannot readily colonize dry surfaces, whereas fungi thrive as long as the moisture content ranges from 15% to 34%.

When all factors are optimized, 20% of the compost batches tested still are somewhat deficient in natural biological control when the moisture content of the compost is kept above 40% on a total weight basis. To maximize disease control, composts must be inoculated with specific biocontrol agents. Commercial inoculants for compost consistently providing these beneficial effects are now being registered with the US-EPA. Mixtures of cultures are better than single strains, and broad spectrum control of soilborne as well as some foliar diseases should soon become possible in practice.

HOW LONG DO DISEASE SUPPRESSIVE EFFECTS LAST?

The readily biodegradable fraction of the organic matter in composts and soils sustains the activity of biocontrol agents. Humic substances do not support this activity; they are too resistant to decomposition to support such activity. The population of beneficial microorganisms steadily declines as decomposition proceeds. Each material has its own properties in this regard. We have characterized these trends for sphagnum peat and cow manure. The concentrations and composition of lignocellulosic substances (lignins and celluloses; not the humic acids) determine this effect. Once these materials are decomposed, the beneficial microorganisms decline in activity, the pathogen population recovers and fungicides must be applied for sensitive crops to remain disease free.

For light sphagnum peat (H_2 to H_3 on the von Post decomposition scale), the beneficial effect lasts 6 to 12 weeks in greenhouse crops. In outdoor containers in hot

weather, the length of time may be reduced 50% because of the higher temperature. Pine bark can support this effect 6 months to 1 year. However, pine bark aged in large piles where pyrolysis or fires occur behaves more like charcoal and offers little disease control potential, even though it still may have ideal physical properties for use in container media to control root rots. Hardwood bark incorporated at 15% by volume lasts two seasons in Ohio. Composted sewage sludges last through 2 years (at 10% to 15% by volume in a mix). Composted rice hulls and coconut coir (husks) also have an effect, but the length of time that the suppressive effects last has yet to be determined. Composted paper mill sludges can also be used for long-term beneficial effects.

Some knowledge is available from field studies also. In general, the same material should last longer in the field because soil temperatures are lower than those in containers. The best results are obtained in the field if the compost is applied as a mulch on the soil surface. Only a small fraction (5 to 10 dry tons acre^{-1}) of the compost should be incorporated into the soil. The remainder (25 to 50 dry tons acre^{-1}) should be applied on the surface after planting. An exception to this general rule is where compost is applied ahead of a vegetable crop planted for an early harvest. Soil temperatures remain lower in mulched soils and this can set back early vegetable crops. The quantity and form of mineral fertilizers applied needs to be adjusted in succeeding years to avoid overloading with nutrients. In general, fine particulate composts should be incorporated. Coarse particles perform better as mulches.

The following examples illustrate control of diseases with composts in field soils. Composted hardwood bark mulch applied to apple trees at planting controlled *Phytophthora* collar rot through 2 years in a 1978-1981 OSU field study where inoculum of the pathogen was used. A recent study by Dr. Funt from the OSU Department of Horticulture and Crop Science revealed that composted yard waste (50 tons acre^{-1}) on strawberry maintained plant stand beyond 3 years whereas plants in control plots declined. In Western Australia, a composted manure is used to suppress Phytophthora root rot of avocado for well into the 2nd year after mulching. Similar results are being obtained in orchards in Southern California today through the work of Dr. J. Menge at the University of California, Riverside. Much more work needs to be done in this field, however, before general advice can be provided.

EFFECTS OF SALINITY AND FERTILITY IN COMPOSTS ON PLANT DISEASES

An increasing number of compost producers with experience in this field realizes that the composition of raw materials, the composting process as well as curing, screening, etc., must be kept constant to produce consistent quality products. Furthermore, soil analysis laboratories increasingly are capable of predicting the fertility values of composts. Nutrient inputs must be balanced against crop needs and the residuals in the soil.

Composted pine bark and peat, because of their resistance to decomposition, do not release or immobilize significant quantities of nutrients. Therefore, essential micronutrients must be incorporated into the mix. Composted hardwood bark immobilizes N early but releases various nutrients, including trace elements, later. Composted sewage sludges available in Ohio release 25% of the total N in the first few months after utilization. Therefore, adjust the incorporation rate to the fertility needs of the crop. Generally, this means do not use more than 10% to 20% of this

compost by volume in a mix, depending upon fertility needs of the crop. Overloading with this nitrogen-rich compost increases fireblight, *Phytophthora* die-backs, and *Fusarium* wilts. All trace elements are supplied adequately by composted sewage sludges, particularly in high pH irrigation water regions. Trace elements do not need to be applied.

Composted leaves also supply trace elements, not much nitrogen, and significant quantities of potash. Composted yard wastes supply some nitrogen if prepared with grass clippings, and may contain up to 1% available potash. All of these composts provide phosphorus, calcium, and magnesium. Most do not have to be amended with lime but addition of sulfur to lower the pH to 5.5 also may not be necessary even though most laboratories recommend it. It makes a lot of sense to blend low nitrogen with high nitrogen composts. Mixtures of composted yard wastes and composted sewage sludges increasingly are preferred in several applications.

Two studies (OSU and Israel) have shown that concentrations of available iron, zinc, and manganese are very high at a soil pH above 7.0 in composted cow manure or sewage-sludge-amended mixes. As mentioned previously, we have determined that plants, including azaleas, grow very well and without trace element deficiencies at pH 7.0 or higher in these mixes because siderophores (natural chelators) and water-soluble humic substances keep them in solution.

All composts can be high in salinity. As composts mature, mineralization proceeds and the concentration of salts increases. Because compost piles often do not leach, salts accumulate with time. Always monitor the conductivity reading of a new batch. Incorporate based on salinity limits, if needed, or apply composts well ahead of planting to allow for leaching. Manure composts now becoming more widely available will have to be monitored most closely for salinity problems. High salinity destroys suppressiveness to *Phytophthora* and *Pythium* root rots. For example, composted sewage sludge was applied to soybeans in Ohio during the early 1980s in an attempt to control *Phytophthora* root rot. The disease was increased in each of 4 years when the compost was applied directly ahead of planting. However, in plots where the compost was applied 3 months prior to planting (February) or in the previous fall, the disease was controlled and the yield increased. The damage done by the compost could be mimicked by an application of salt (NaCl) directly ahead of planting. These factors must be considered carefully in biological control of plant diseases.

The foregoing is a brief synopsis of some of the knowledge available today of compost utilization relative to maintenance of plant health.

REFERENCES SUGGESTED FOR FURTHER READING

Hoitink, H.A.J., Stone, A.G., and **Han, D.Y.** 1997. Suppression of plant diseases by composts. HortScience 32:184-187.

Zhang, W., Han, D.Y., Dick, W.A., Davis, K.R., and **Hoitink, H.A.J.** 1998. Compost and compost water extract-induced systemic acquired resistance in cucumber and *Arabidopsis*. Phytopathology 88:450-455.

The following three papers by Bill Intven, George Okken, and Jack Alexander were part of an evening program titled: Review of Scion/ Understock Compatibilities.

Review of Scion/understock Compatibilities

Bill Intven
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Compatibility is an absolute must for grafting to be successful; however, it is my modest opinion that nursery people know so much about compatibility that they would not be at great risk in this point. However, there are instances where success depends on certain factors other than grafting on the wrong understock under particular circumstances. For years we grafted *Viburnum* ×*carlcephalum* on *V. lantana* where the compatibility is very good.

If this grafting takes place on the rootneck or hypocotyl of *V. dentatum*, there is a great risk that there will be so many suckers on the understock that the shrub is worthless. While *V. dentatum* is very compatible with *V.* ×*carlcephalum* it is also excessively stoloniferous and the resulting shrub will be worthless. Now we use summer-rooted cuttings of *V. dentatum* with only one node at the top. After rooting we cut the understock off below the two-budded node and graft on the rooted part. Thus there is no node left on the understock and there is no suckering.

The reason for our change was that several of our staff complained that the pubescence of *V. lantana* caused considerable discomfort for their eyes, breathing, and skin.

Review of Scion/Understock Compatibilities Results at Okken Nurseries

George Okken
Okken Nurseries, 103 Mountain Ave., Ponpton Plains, New Jersery 07444 U.S.A.

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Genus	Scions	Understock	Success rate
Pinus			
	P. albicaulis	*P. strobus*	19% success
	P. banksiana	*P. sylvestris*	100% loss
	P. banksiana	*P. thunbergii*	10% loss
	P. monophylla (syn. *P. cembroides* var. *monophylla*)	*P. strobus*	10% success
	P. contorta	*P. strobus*	good results
	P. densiflora	*P. thunbergii*	good results
	P. leucodermis	*P. thunbergii*	100% loss
	P. mugo	*P. thunbergii*	2% success
	P. nigra	*P. thunbergii*	80% loss
	P. parviflora	*P. thunbergii*	poor results
	P. resinosa	*P. thunbergii*	poor results
	P. resinosa	*P. thunbergii*	100% loss
	P. rigida	*P. thunbergii*	poor results
	P. sylvestris	*P. thunbergii*	poor results
	P. sylvestris	*P. thunbergii*	100% loss
	P. virginiana	*P. sylvestris*	10% success
Juniper			
	J. rigida	*J. virginiana*	80% success

Genus	Scions	Understock	Success rate
Picea			
	P. jezoensis var. *hundoensis*	*P. abies*	80% success
	P. orientalis 'Atrovirens'	*P. abies*	71% success
	P. orientalis 'Atrovirens' tips 1-year wood	*P. abies*	81% success
	P. orientalis 'Atrovirens' laterals 2-year wood	*P. abies*	14% success
Abies			
	A. amabilis	*A. balsamea*	72% success
	A. cephalonica 'Meyer Blue'	*A. koreana*	good
	A. lasiocarpa	*A. balsamea*	80% success
	A. lasiocarpa 'Compacta'	*A. fraseri*	good
	A. nordmaniana 'Golden Spreader'	*A. balsamea*	81% success
	A. numidica	*A. fraseri*	good
	A. pinsapo 'Horstmann'	*A. balsamea*	90% success
	A. procera	*A. balsamea*	61% success

A Summary of Graft Compatibility from the records of the Arnold Arboretum

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Selecting compatible stock/scion combinations is a challenge for all of us who propagate by grafting. I have frequently referred to Volume 18 of our Proceedings (Nelson, 1968) which contains an extensive list of successful combinations. Sometimes I am asked to graft plants for which I can find no recommended understock listed there or in any other text. At The Arnold Arboretum, we keep detailed propagation records yet these too may not provide the needed information. My standard procedure then is to determine what available understock is most closely related to that scion. I refer first to the Manual of Cultivated Trees and Shrubs Hardy in North America (Rehder, 1940). Taxa listed in this manual are arranged in systematic order. Those considered to be most closely related are grouped together in the text. I simply select as an understock a species that is available and is closely related to the scion. Current taxonomic studies based on DNA more clearly define systematic relationships and are likely to be ever more helpful to us as plant propagators.

From the records of the Arnold Arboretum, I compiled a list of stock/scion combinations that succeeded (Table 1). My original intent was to consider only long-term compatibility and include the number of years that each grafted plant lived, but I soon realized that many successful grafts die due to causes that are not related to stock/scion compatibility. Furthermore, many grafted plants become established on their own root systems and their extensive lives are not indicating a long-term compatibility. The following list of graft combinations survived long enough to be considered successfully propagated. Some of these plants have been dead for years, others are decades old, and some still reside in our nursery.

Table 1. Stock/scion combinations that succeeded

Scion	Rootstock
Abies alba	*Abies concolor, A. balsamea*
Abies alba 'Contorta'	*Abies balsamea*
Abies cephalonica	*Abies balsamea, A. firma*
Abies cilicica	*Abies balsamea*
Abies cilicica ssp. *isaurica*	*Abies balsamea*
Abies concolor f. *violacea*	*Abies concolor*
Abies fargesii	*Abies balsamea*

Abies homolepis	*Abies firma*
Abies koreana 'Prostrate Beauty'	*Abies balsamea*
Abies lasiocarpa 'Compacta'	*Abies concolor*
Abies lasiocarpa	*Abies balsamea*
Abies procera 'Prostrata'	*Abies balsamea*
Abies recurvata	*Abies balsamea*
Abies veitchii	*Abies balsamea*
Abies borisii-regis	*Abies balsamea*
Acer campestre 'Nanum'	*Acer campestre*
Acer ×freemanii 'Armstrong'	*Acer rubrum*
Acer japonicum	*Acer palmatum*
Acer negundo 'Nanum'	*Acer negundo*
Acer saccharum subsp. *grandidentatum*	*Acer saccharum*
Acer saccharum subsp. *nigrum* 'Slavin's Upright'	*Acer pseudoplatanus*
Acer palmatum 'Lutescens'	*Acer palmatum*
Acer platanoides 'Cucullatum'	*Acer platanoides*
Acer platanoides 'Erectum'	*Acer platanoides*
Acer platanoides 'Rubrum'	*Acer erianthum*
Acer platanoides 'Undulatum'	*Acer platanoides*
Acer platanoides 'Walderseei'	*Acer platanoides*
Acer pseudoplatanus f. *erythrocarpum*	*Acer pseudoplatanus*
Acer rubrum 'Columnare'	*Acer rubrum*
Acer saccharinum 'Heterophyllum Laciniatum'	*Acer saccharinum*
Acer saccharinum f. *laciniatum*	*Acer saccharinum*
Acer saccharinum 'Pyramidale'	*Acer saccharinum*
Acer saccharum 'Globosum'	*Acer saccharum*
Acer saccharum 'Newton Sentry'	*Acer saccharum*
Acer truncatum	*Acer platanoides*
Aesculus arguta (syn *A. glabra* var. *arguta*)	*Aesculus hippocastanum, A. flava* (syn *A. octandra*)
Aesculus flava × (*A. pavia* × *A. sylvatica*)	*Aesculus glabra*
Aesculus flava × *A. pavia*	*Aesculus hippocastanum*
Aesculus glabra	*Aesculus hippocastanum*
Aesculus hippocastanum	*Aesculus hippocastanum*

Aesculus pavia × *A. flava*	*Aesculus hippocastanum*
Aesculus sylvatica	*Aesculus hippocastanum, A. flava*
Aesculus ×*carnea* 'Briotii'	*Aesculus glabra, A. hippocastanum*
×*Amelasorbus jackii*	*Crataegus phaenopyrum*
Betula ermanii	*Betula pendula*
Betula grossa	*Betula pendula*
Betula utilis var. *jacquemontii*	*Betula papyrifera*
Betula korshinskyi	*Betula pendula*
Betula papyrifera var. *subcordata*	*Betula ermanii, B. pendula, B. pendula*
Betula pendula	*Betula populifolia*
Betula pendula 'Fastigiata'	*Betula papyrifera*
Betula pendula 'Gracilis'	*Betula pendula*
Betula platyphylla var. *szechuanica*	*Betula papyrifera*
Betula ×*caerulea*	*Betula pendula, B. papyrifera*
Betula ×*intermedia*	*Betula platyphylla* 'Whitespire'
Calocedrus decurrens	*Thuja occidentalis*
Caragana arborescens	*Caragana arborescens*
Carpinus betulus 'Fastigiata'	*Carpinus betulus*
Carpinus betulus 'Heterophylla' (syn. 'Quercifolia')	*Carpinus caroliniana*
Carpinus caroliniana var. *virginiana*	*Carpinus betulus*
Carpinus japonica	*Carpinus betulus*
Carpinus turczaninovii	*Carpinus betulus*
Catalpa bignonioides	*Catalpa speciosa*
Catalpa fargesii f. *duclouxii*	*Catalpa speciosa*
Celtis jessoensis	*Celtis occidentalis*
Celtis laevigata	*Celtis occidentalis*
Cercidiphyllum japonicum	*Cercidiphyllum japonicum*
Cercidiphyllum magnificum 'Pendulum'	*Cercidiphyllum japonicum*
Chaenomeles 'Alba Cincta'	*Chaenomeles japonica*
Chaenomeles 'Alba Plena'	*Chaenomeles japonica*
Chaenomeles 'Alba Rosea'	*Chaenomeles japonica*
Chaenomeles 'Beni Chidore'	*Chaenomeles japonica*
Chaenomeles 'Carnea'	*Chaenomeles japonica*
Chaenomeles 'Euphrosyne'	*Chaenomeles japonica*

Chaenomeles 'Hanazono'	*Chaenomeles japonica*
Chaenomeles 'Nishikichidon'	*Chaenomeles japonica*
Chaenomeles 'Pacific Red'	*Chaenomeles japonica*
Chaenomeles 'Scarlet'	*Chaenomeles japonica*
Chaenomeles 'Shinonome'	*Chaenomeles japonica*
Chaenomeles 'Tani-no-Yuki'	*Chaenomeles japonica*
Chaenomeles 'Wakaba'	*Chaenomeles japonica*
Chaenomeles cathayensis	*Chaenomeles japonica*
Chaenomeles japonica 'Dorothy Rowe'	*Chaenomeles japonica*
Chaenomeles japonica 'Dwarf Poppy Red'	*Chaenomeles japonica*
Chaenomeles japonica 'Pigmani'	*Chaenomeles japonica*
Chaenomeles japonica 'Sargentii' (syn. *C.* 'Sargentiana')	*Chaenomeles japonica*
Chaenomeles speciosa 'Aurora'	*Chaenomeles japonica*
Chaenomeles speciosa 'Brilliant'	*Chaenomeles japonica*
Chaenomeles ×*superba*	*Chaenomeles japonica*
Chaenomeles ×*superba* 'Elly Mossel'	*Chaenomeles japonica*
Chaenomeles ×*superba* 'Etna'	*Chaenomeles japonica*
Chaenomeles ×*superba* 'Fire Dance'	*Cydonia* 'Angers'
Chaenomeles ×*superba* 'Nicoline'	*Chaenomeles japonica*
Chaenomeles ×*vilmoriniana* 'Mount Everest'	*Cydonia* 'Angers'
Cladrastis kentukea 'Rosea'	*Cladrastis kentukea*
Cornus florida	*Cornus florida*
Cornus florida 'Magnifica'	*Cornus florida*
Cornus florida f. *pluribracteata*	*Cornus florida*
Cornus florida f. *rubra*	*Cornus florida*
Cornus kousa	*Cornus kousa*
Cornus kousa × *C. florida* f. *rubra*	*Cornus florida*
Corylus avellana 'Pendula'	*Corylus avellana*
Corylus heterophylla var. *yunnanensis*	*Corylus colurna*
Crataegus compta	*Crataegus phaenopyrum*
Crataegus crus-galli	*Crataegus phaenopyrum*
Crataegus crus-galli var. *arbutifolia*	*Crataegus phaenopyrum*
Crataegus crus-galli var. *bellica*	*Crataegus phaenopyrum*
Crataegus densiflora	*Crataegus phaenopyrum*

Crataegus dilatata	*Crataegus oxyacantha*
Crataegus disperma	*Crataegus phaenopyrum*
Crataegus engelmannii	*Crataegus phaenopyrum*
Crataegus faxonii	*Crataegus oxyacantha*
Crataegus macracantha	*Crataegus phaenopyrum*
Crataegus magnifolia	*Crataegus phaenopyrum*
Crataegus monogyna f. *stricta*	*Crataegus crus-galli*
Crataegus nitida	*Crataegus phaenopyrum*
Crataegus laevigata 'Plena'	*Crataegus laevigata* (syn. *C. oxyacantha*)
Crataegus laevigata 'Plena'	*Crataegus phaenopyrum* (syn. *C. cordata*)
Crataegus laevigata var. *auriculata*	*Crataegus phaenopyrum*
Crataegus phaenopyrum 'Fastigiata'	*Crataegus phaenopyrum*
Crataegus punctata	*Crataegus phaenopyrum*
Crataegus succulenta	*Crataegus phaenopyrum*
×*Crataemespilus grandiflora*	*Crataegus phaenopyrum*
Fagus engleriana	*Fagus orientalis*
Fagus orientalis	*Fagus sylvatica*
Fagus sylvatica 'Rohanii'	*Fagus sylvatica*
Fagus sylvatica f. *tortuosa*	*Fagus sylvatica, F. grandifolia*
Fraxinus angustifolia 'Monophylla'	*Fraxinus pennsylvanica*
Fraxinus angustifolia	*Fraxinus pennsylvanica*
Fraxinus holotricha (syn. *F. pallisae*)	*Fraxinus pennsylvanica*
Fraxinus potamophila	*Fraxinus pennsylvanica*
Gleditsia 'Millwood'	*Gleditsia triacanthos*
Gleditsia triacanthos 'Seiler'	*Gleditsia triacanthos*
Hamamelis ×*intermedia* 'Pallida' (syn *H. mollis 'Pallida'*)	*Hamamelis virginiana*
Hamamelis ×*intermedia* 'Hiltingbury'	*Hamamelis* ×*intermedia* 'Jelena' (syn *H.* 'Copper Beauty')
Juglans nigra 'Laciniata'	*Juglans nigra*
Juglans regia	*Juglans nigra*
Juniperus scopulorum 'Blue Moon'	*Juniperus* 'Glauca Hetzii'
Juniperus scopulorum 'Chandler's Blue'	*Juniperus* 'Glauca Hetzii'
Juniperus scopulorum 'Moonlight'	*Juniperus* 'Glauca Hetzii'
Juniperus scopulorum 'Silver Queen'	*Juniperus* 'Glauca Hetzii'

Juniperus virginiana 'Globosa'	*Juniperus virginiana*
Koelreuteria paniculata 'Fastigiata'	*Koelreuteria paniculata*
Larix sibirica	*Larix leptolepis*
Liquidambar styraciflua 'Aurea'	*Liquidambar styraciflua*
Liriodendron tulipifera × *L. chinense*	*Liriodendron tulipifera*
Maackia chinensis	*Maackia amurensis* (root pieces)
Magnolia amoena	*Magnolia denudata*
Magnolia denudata	*Magnolia kobus*
Magnolia kobus	*Magnolia kobus, M. stellata*
Magnolia salicifolia	*Magnolia stellata* 'Rosea'
Magnolia salicifolia	*Magnolia kobus*
Magnolia stellata	*Magnolia kobus, M. stellata*
Magnolia virginiana 'Milton'	*Magnolia virginiana*
Magnolia ×loebneri	*Magnolia kobus*
Malus 'Donald Wyman'	*Malus* MM 111'
Malus 'Dorothea'	*Malus sargentii, M.* MM 106
Malus 'Helen'	*Malus baccata*
Malus 'Kerr'	*Malus* 'Dolgo'
Malus 'Lady Northcliffe'	*Malus* 'Columbia'
Malus angustifolia	*Malus* MM 111
Malus ×arnoldiana	*Malus pumila, M.* MM 111
Malus ×astracanica	*Malus pumila*
Malus ×atrosanguinea	*Malus* MM 111
Malus baccata 'Columnaris'	*Malus* MM 111
Malus baccata f. *jackii*	*Malus* MM 111
Malus brevipes	*Malus* MM 111
Malus brevipes	*Malus sargentii*
Malus ×dawsoniana	*Malus* MM 106, *M.* MM 111
Malus ×heterophylla (syn. *M. platycarpa*)	*Malus* EMLA 7
Malus hupehensis	*Malus sargentii, M. sikkimensis*
Malus ioensis	*Malus* MM 111
Malus ioensis 'Plena'	*Malus* MM 106, *M. sargentii*
Malus kansuensis f. *calva*	*Malus pumila*
Malus orthocarpa	*Malus* MM 111
Malus prunifolia var. *rinkii*	*Malus sargentii, M. 'Antonovka'* seedlings

Malus prunifolia var. *xanthocarpa*	*Malus* EMLA 7
Malus pumila (either *M.* ×*domestica* or *M. sylvestris*)	*Malus* MM111
Malus ×*purpurea*	*Malus* MM 106
Malus ×*purpurea* 'Lemoinei'	*Malus* MM 111, *M. sieboldii*
Malus ×*robusta*	*Malus baccata*
Malus sargentii	*Malus* MM 111
Malus sieboldii	*Malus* MM111
Malus spectabilis	*Malus* MM 111
Morus alba	*Morus alba*
Paeonia 'Harlequin'	*Paeonia officinalis*
Paeonia suffruticosa 'Hakuo-jishi'	*Paeonia officinalis*
Paeonia suffruticosa 'Hana-kisoi'	*Paeonia officinalis*
Paeonia suffruticosa 'No-kagura'	*Paeonia officinalis*
Parrotia persica	*Hamamelis virginiana*
Phellodendron amurense	*Phellodendron amurense*
Phellodendron piriforme	*Phellodendron amurense*
Picea abies 'Aurescens'	*Picea abies*
Picea abies 'Conica'	*Picea abies*
Picea abies 'Gregoryana'	*Picea abies*
Picea abies 'Inversa'	*Picea abies*
Picea abies 'Pygmaea'	*Picea abies* (syn. *P. excelsa*)
Picea abies (variant)	*Picea pungens*
Picea abies f. *pendula*	*Picea abies*
Picea abies f. *virgata*	*Picea abies*
Picea abies var. *obovata* (syn. *P. obovata*)	*Picea omorika*
Picea asperata	*Picea abies*
Picea asperata var. *aurantiaca*	*Picea pungens*
Picea asperata var. *heterolepis*	*Picea abies*
Picea asperata var. *notabilis*	*Picea abies*
Picea asperata var. *ponderosa*	*Picea abies*
Picea engelmannii × *P. glauca* var. *albertiana*	*Picea abies*
Picea engelmannii × *P. pungens*	*Picea abies*
Picea glauca 'Nana'	*Picea abies*
Picea koyamai (syn. *P. koraiensis*)	*Picea abies*

Picea likiangensis var. *montigena*	*Picea abies*
Picea mariana	*Picea abies*
Picea mariana 'Doumetii'	*Picea abies*
Picea mariana 'Ericoides'	*Picea abies*
Picea mariana (variant)	*Picea abies*
Picea omorika	*Picea abies*
Picea polito (*P. torano*)	*Picea abies*
Picea pungens 'Compacta'	*Picea abies*
Picea pungens 'Hunnewelliana'	*Picea abies*
Picea pungens 'Moerheimii'	*Picea abies*
Picea pungens 'Moerheimii'	*Picea pungens*
Picea pungens 'Pendula'	*Picea abies*
Picea pungens 'Pendula'	*Picea glauca*
Picea pungens (variant)	*Picea pungens*
Picea rubens	*Picea abies*
Picea ×fennica	*Picea abies*
Picea ×notha	*Picea abies*
Pinus armandii	*Pinus strobus*
Pinus banksiana 'Chippewa'	*Pinus sylvestris*
Pinus banksiana 'Neponset'	*Pinus sylvestris*
Pinus banksiana 'Schoodic'	*Pinus sylvestris*
Pinus contorta var. *latifolia*	*Pinus thunbergii*
Pinus densiflora	*Pinus nigra*
Pinus densiflora 'Pendula'	*Pinus resinosa*
Pinus densiflora 'Umbraculifera'	*Pinus sylvestris*
Pinus flexilis	*Pinus resinosa, P. strobus*
Pinus koraiensis	*Pinus strobus*
Pinus lambertiana	*Pinus strobus*
Pinus leucodermis	*Pinus nigra*
Pinus mugo	*Pinus mugo, P. sylvestris*
Pinus mugo 'Prostrata'	*Pinus sylvestris*
Pinus nigra 'Hornibrookiana'	*Pinus resinosa*
Pinus nigra 'Pyramidalis'	*Pinus nigra*
Pinus nigra (variant)	*Pinus nigra*
Pinus nigra var. *pallasiana*	*Pinus resinosa*

Pinus nigra subsp. *salzmannii*	*Pinus thunbergii, P. nigra, P. resinosa*
Pinus parviflora var. *pentaphylla*	*Pinus strobus*
Pinus ponderosa	*Pinus sylvestris*
Pinus pumila 'Glauca' (syn. 'Dwarf Blue')	*Pinus strobus*
Pinus rigida 'Sherman Eddy'	*Pinus rigida*
Pinus strobus	*Pinus strobus*
Pinus strobus 'Contorta'	*Pinus strobus*
Pinus strobus 'Ontario'	*Pinus strobus*
Pinus strobus 'Pendula'	*Pinus strobus*
Pinus strobus 'Reflexa'	*Pinus strobus*
Pinus sylvestris	*Pinus sylvestris*
Pinus sylvestris 'Watereri'	*Pinus sylvestris*
Pinus sylvestris var. *hamata*	*Pinus thunbergii*
Pinus sylvestris var. *lapponica*	*Pinus sylvestris*
Pinus thunbergii	*Pinus thunbergii*
Pinus mugo var. *rotundata* (syn. *P. uncinata* var. *rotundata*)	*Pinus sylvestris*
Pinus ×*holfordiana*	*Pinus strobus*
Pinus ×*hunnewellii*	*Pinus strobus*
Pinus ×*schwerinii*	*Pinus strobus*
Prunus 'Hillieri'	*Prunus serrulata*
Prunus 'Jo-nioi' (syn. *P. serrulata* 'Jo-nioi')	*Prunus avium*
Prunus 'Shujaku' (syn. *P. serrulata* 'Shujaku')	*Prunus avium*
Prunus 'Washi-no-o' (syn. *P. serrulata* 'Washi-no-o')	*Prunus serrulata*
Prunus alabamensis	*Prunus mahaleb*
Prunus alleghaniensis	*Prunus cerasifera, P. avium*
Prunus apetala	*Prunus serrulata*
Prunus armeniaca var. *ansu*	*Prunus americana*
Prunus armeniaca 'Arixpog Alchrod'	*Prunus armeniaca*var. *ansu*
Prunus ×*blireiana*	*Prunus cerasifera*
Prunus cerasifera 'Kok-Sultan'	*Prunus cerasifera*
Prunus cerasifera f. *fastigiata*	*Prunus americana, P. armeniaca*var. *ansu*
Prunus cerasifera subsp. *divaricata*	*Prunus hortulana*

Prunus cerasus var. *austera* 'Plena'	*Prunus avium*
Prunus cerasus var. *frutescens*	*Prunus avium*
Prunus ×*fontanesiana*	*Prunus avium*
Prunus glandulosa	*Prunus avium*
Prunus ×*gondouinii* 'Schnee'	*Prunus avium*
Prunus hirtipes (syn *P. conradinae*)	*Prunus avium*
Prunus kansuensis	*Prunus avium*
Prunus maritima	*Prunus maritima*
Prunus maritima 'Hancock'	*Prunus maritima*
Prunus maritima 'Premier'	*Prunus mahaleb*
Prunus maritima f. *flava*	*Prunus americana*
Prunus maximowiczii	*Prunus avium*
Prunus munsoniana	*Prunus americana*
Prunus nigra (syn. *P. lanata*)	*Prunus americana*
Prunus nipponica	*Prunus avium*
Prunus ×*orthosepala*	*Prunus cerasifera*
Prunus ×*orthosepala*	*Prunus maritima*
Prunus padus 'Watereri'	*Prunus serotina*
Prunus pendula (syn. *P.* ×*subhirtella* var. *pendula*)	*Prunus avium*
Prunus pendula 'Park Weeping' (syn. *P.* ×*subhirtella* var. *pendula* 'Park Weeping')	*Prunus* ×*subhirtella*
Prunus pleiocerasus	*Prunus serrulata*
Prunus sargentii	*Prunus avium*
Prunus sargentii 'Columnaris'	*Prunus sargentii, P. serrulata*
Prunus scopulorum	*Prunus mahaleb*
Prunus serotina 'Cartilaginea'	*Prunus serotina*
Prunus serrula	*Prunus serrulata, P. cerasifera*
Prunus serrulata	*Prunus avium*
Prunus ×*subhirtella* × *P.* ×*yedoensis*	*Prunus avium, P. serrulata*
Prunus tianshanica	*Prunus cerasifera*
Prunus tomentosa 'Geneva'	*Prunus tomentosa*
Pseudotsuga menziesii var. *glauca*	*Pseudotsuga menziesii*
×*Pyronia veitchii*	*Pyrus calleryana, P. communis*

Pyrus betulaefolia	*Pyrus communis* 'Williams Bon Chretien' seedling (syn. 'Bartlett' seedlings)
Pyrus ×bretschneideri	*Malus* sp.
Pyrus communis var. cotinifolia	*Cydonia oblonga*
Pyrus nivalis	*Pyrus communis* 'Williams Bon Chretien' seedling (syn. 'Bartlett' seedlings)
Pyrus ×salviifolia	*Pyrus communis*
Pyrus ussuriensis 'Pin-li'	*Pyrus calleryana*
Pyrus ussuriensis var. *hondoensis*	*Pyrus communis* 'Williams Bon Chretien' seedling (syn. 'Bartlett' seedlings)
Quercus aliena var. *calvescens*	*Quercus prinus*
Quercus coccinea 'Splendens'	*Quercus palustris*
Quercus glandulifera	*Quercus macrocarpa*
Quercus libani	*Quercus acutissima*
Quercus lyrata	*Quercus bicolor*
Quercus pubescens	*Quercus sieboldi*
Quercus ×leana	*Quercus palustris*
Rhamnus imeretinus	*Rhamnus frangula*
Rhododendron 'Bryantville'	*Rhododendron ponticum*
Rhododendron 'Parsons Grandiflorum'	*Rhododendron ponticum*
Rhododendron 'Skyglow'	*Rhododendron* 'Cunningham's White', *R. ponticum, R. ponticum*
Rhododendron fortunei 'Sagamore Bayside'	*Rhododendron maximum*
Rhododendron fortunei (undetermined hybrid)	*Rhododendron* 'Cunningham's White'
Robinia pseudoacacia 'Bessoniana'	*Robinia pseudoacacia*
Robinia pseudoacacia 'Burgundy'	*Robinia pseudoacacia*
Robinia pseudoacacia 'Cylindrica'	*Robinia pseudoacacia*
Robinia pseudoacacia 'Frisia'	*Robinia pseudoacacia*
Robinia pseudoacacia 'Monophylla Pendula'	*Robinia pseudoacacia*
Robinia pseudoacacia 'Semperflorens'	*Robinia pseudoacacia*
Robinia viscosa	*Robinia pseudoacacia*
Robinia viscosa var. *hartwigii*	*Robinia pseudoacacia*

Robinia ×*ambigua* 'Decaisneana'	*Robinia pseudoacacia*
Robinia ×*holdtii*	*Robinia pseudoacacia*
Rosa 'Arnold'	*Rosa multiflora*
Rosa 'Geranium'	*Rosa multiflora*
Rosa banksiopsis	*Rosa multiflora*
Rosa canina 'Inermis'	*Rosa multiflora*
Rosa helenae	*Rosa multiflora*
Sophora japonica 'Columnaris'	*Sophora japonica*
Sophora japonica 'Violacea'	*Sophora japonica*
×*Sorbaronia* × ×*Sorbocotoneaster*	*Sorbus aucuparia*
×*Sorbaronia alpina*	*Sorbus aucuparia*
×*Sorbocotoneaster pozdnjakovii*	*Sorbus aucuparia*
Sorbus 'Hillings Spire'	*Sorbus aucuparia*
Sorbus ×*arnoldiana* × *S. alnifolia*	*Sorbus aucuparia*
Sorbus amurensis	*Sorbus aucuparia*
Sorbus aucuparia 'Asplenifolia'	*Sorbus aucuparia*
Sorbus aucuparia 'Rossica'	*Sorbus aucuparia*
Sorbus decora	*Sorbus aucuparia*
Sorbus discolor	*Sorbus aucuparia*
Sorbus dumosa	*Sorbus aucuparia*
Sorbus esserteauana	*Sorbus aucuparia*
Sorbus ×*hostii*	*Sorbus aucuparia*
Sorbus ×*hybrida*	*Crataegus monogyna*
Sorbus intermedia var. *pinnatifolia*	*Sorbus aucuparia*
Sorbus ×*meinichii* (syn. *S.* ×*hybrida* 'Meinichii')	*Sorbus aucuparia*
Sorbus matsumurana	*Sorbus aucuparia*
Sorbus mougeotii	*Sorbus aucuparia*
Sorbus ×*pseudovertesensis*	*Sorbus aucuparia*
Sorbus sibirica	*Sorbus aucuparia*
Sorbus ×*thuringiaca* 'Fastigiata'	*Sorbus aucuparia*
Sorbus vilmorinii	*Sorbus aucuparia*
Sorbus wilsoniana	*Sorbus aucuparia*
Syringa komarovii subsp. *reflexa*	*Ligustrum obtusifolium*
Syringa vulgaris 'Katherine Havemeyer'	*Ligustrum ovalifolium*

Syringa vulgaris 'Waldeck-Rousseau'	*Fraxinus pennsylvanica*
Syringa vulgaris 'Zulu'	*Ligustrum ibolium*
Syringa ×hyacinthiflora 'Maureen'	*Syringa japonica* (syn. *S. amurensis japonica*)
Syringa ×hyacinthiflora 'Norah'	*Syringa japonica* (syn. *S. amurensis japonica*)
Tetradium daniellii (syn. *Evodia daniellii*)	*Phellodendron amurense*
Tilia americana	*Tilia cordata*
Tilia cordata	*Tilia americana*
Tilia cordata 'Swedish Upright'	*Tilia cordata*
Tilia ×europaea	*Tilia americana*
Tilia henryana	*Tilia cordata*
Tilia heterophylla (syn. *T. monticola*)	*Tilia tomentosa*
Tilia insularis	*Tilia cordata*
Tsuga canadensis 'Nana'	*Tsuga canadensis*
Tsuga caroliniana	*Tsuga caroliniana*
Ulmus glabra 'Nana'	*Ulmus pumila*
Ulmus minor (syn. *U. carpinifolia*)	*Ulmus pumila*
Ulmus minor 'Purpurea'	*Ulmus pumila*
Ulmus monor var. *cornubiensis*	*Ulmus pumila*
Ulmus thomasii	*Ulmus pumila*
Ulmus ×hollandica 'Bea Schwarz'	*Ulmus ×hollandica* 'Christine Buisman'
Viburnum lobophyllum	*Viburnum opalus*
Viburnum lobophyllum	*Viburnum lantana*
Zelkova sinica	*Zelkova serrata*

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The following three papers by H. William Barnes, Gied Stroombeek, and Calvin Chong were part of an evening program: Common/Uncommon Sense Ideas.

Wells for Ideas

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A brief history is in order to fully understand how innovative ideas come about and from what spring they emerge. First is an absolute love and admiration for the business of plant production and for plant life in general. For me plant production and exploration are the most fascinating of all endeavors. This thought is echoed by Dr. J. Artie Browing, noted plant pathologist of Texas A&M. He said "For a plantsman or agriculturist to experience a different climate, environment, and flora is an educational bonus and a justification in itself". I would echo his comments ten fold and fully support his suggestion that education is the gateway towards innovation (Browing, 1998).

I came into horticulture through the back door having a need for a job to finish my degree in biology. The back door was a job in the propagation and production department of a large wholesale nursery in Tampa, Florida. From there I moved on to nurseries in Colorado, Pennsylvania, and Delaware. Combine those years of experience with the more formal education of the University of South Florida and one comes close to what Browing is suggesting. In many ways much of my horticulture background is self taught and I personally feel that is perhaps the best education of all. Self teaching insures an interested student.

To be innovative means building upon existing ideas and then occasionally climbing out on the farthest branch there is. This is not without risk, but on the other hand exciting things can be gained by making the great leap. It is important to be in the outer orbit as fellow colleague Tim Brotzman suggests. My first talk before the I.P.P.S. was in 1986 when I gave a paper on *Use of Glycol as a Solvent for Root Hormones* (Barnes, 1988). Words like wow, crazy, and wildman were a common response to that paper. But as time became the judge my suggestions were heeded and the validity of the approach was confirmed, especially after my colleague Calvin Chong at the Vineland Experiment Station picked up the baton. The important thing to remember is that the procedures outlined do work!

Education for the propagator should not stop at the school door, it should be a life-long process and an never ending passion. It includes the I.P.P.S., formal training, and self-taught instruction, and listening. Listening to others, both experienced and not so experienced is important, as is listening to tall tales and far-fetched stories and truths. It means reading everything in site and it means understanding truths to be valid in so far as the circumstances surrounding the truths are valid. There is a series of books called the Plant Hunters; in one volume of the series there is a recounting of shipping seed from the South Pacific to Kew in England. To accomplish this the explorers packed the seed in honey which allowed the seed to make the long journey home safely. Why honey? It was a desiccant and prevented mold and mildew and it stopped bacterial action. Seed did not dry out. It appears as though honey might be an ideal subject for seed preservation. I am currently working on this for long-term seed storage.

Innovation should not ignore old technology. Many of the ways of our ancestors might have validity today should we chose to investigate them. Early propagation books by Laurie and Chadwick (1931), Kains and McQuesten (1950), Mahlstede and Haber (1957), James S. Wells (1985), and New Creations in Plant Life, an authoritative account of Luther Burbank by W. S. Harwood (1941) should be read and reread. We all should wonder how things were done before the age of computers and the like.

As Browing (1998) suggested travel is a key ingredient for expanding ones mind and focusing on the new. It is important to see how the rest of the world is doing things.

Brent Elliot (1998) of *The Garden Magazine* professes an alternative viewpoint but one that is consistent with this thesis never the less. He suggests in a quote " The best way to appear original at least in your own eyes is to ignore the past" What he is really saying is to ignore the nay sayers and the cannots and go full steam ahead against the odds, for surely there will be rewards for those that do so. A long-time companion and friend and nurseryman, Dick Brady of Canon City, Colorado says to "Create your own luck".

PROGRESS AND NOT SO MUCH PROGRESS

Want to Be's and Duds.

- We have a single plant of a dwarf *Metasequoia glyptostroboides*, but after years of frustration we have not developed a propagation program that does prevent the plant from restoring itself to a normal form. A no go so far.
- *Euscaphis japonica*, a splendid plant with great ornamental features has stonewalled all efforts to become a production item. Great treasures await those who crack the code.
- Witches brooms in *Cornus sericea* and *C. racemosa* are intriguing but they are pathogenic, being caused by a mycoplasma and hence can not be the "Holy Grail of Dwarfs".

Ideas From Others.

- One of my clients uses a giant open-air screened cage that revolves on an axis. They use this to tumble hosta crowns free of soil so that they can successfully and quite easily divide the plants.
- A nursery we visited on an I.P.P.S. trip used barbed wire as a support for hanging baskets, the barbs being strategically placed to prevent slipping of the basket holders.
- One nursery I have seen was growing flats of moss for a specific customer. There seems to be no end to what people will produce or sell.

Things in Process at the Lorax.

- A new introduction after 12 years of study is *Cornus kousa* 'Creme Puff'. A dwarf *C. kousa* with copious amount of flowers.
- We have been looking at *Juniperus virginiana* 'Blue Sentinel' for the last 10 years and we are impressed at its strict narrow upright features and blue juvenile foliage that is accented by bright blue fruit.

- Currently under investigation for production is a seedless sweet gum, *Liquidambar styraciflua*, which we have been watching for close to 7 years. Production and propagation has not been worked out as of yet.
- *Chionanthus virginicus* can be rooted but there are many problems to be solved. However, it can be rooted.
- Studies with oaks have shown similar progress particularly with cultivars of *Quercus palustris*.
- *Viburnum lentago* 'Show Girl' is a variegated *Viburnum* found in southern Vermont. Production has been slow but grafting seems to afford a possible propagation technique.
- *Metasequoia glyptostroboides* 'Silver Splash' is a variegated form of *Metasequoia* that does propagate from cuttings but is slow. More work needs to be done.
- The literature suggests that *Austrocedrus chilensis* is a Zone 9 plant, but plants growing in Martha's Vineyard and in Pennsylvania contest that. It is a strong grower and could be a welcome addition to the upright conifer market.

Success Stories.

- *Lagerstroemia indica* 'Spitfire' has been under development for 10 years and it has stood the test of time and climate and appears to be hardy to at least 0F and maybe lower.
- *Magnolia macrophylla* var. *ashei* is a northern Florida native but is quite hardy and content just North of Philadelphia. It has proven to be a winner after 12 years and has never frozen back or been injured.
- *Cercidiphyllum japonicum* 'Tidal Wave' was found as a weeping variation in a block of seedlings. It is distinctive and quite attractive and is becoming available in the retail mailorder market.
- *Viburnum dentatum* 'Moon Glo' was found as a late-blooming form of the species in a block of seedlings. It blooms later and has both glossy green foliage and wonderful fall color. It is a welcome addition to the viburnum markets.

Inspirations.

- While on a trip to Florida I saw maidenhair fern growing in pure limestone. This is something to ponder, considering the pH in which the fern is growing.
- The inspiration for my talk, *Grasses from Cuttings* (1994), came about from seeing adventitious roots form on corn plants in a field.
- While on another trip in the wilds of Florida I happened upon a large witches broom in a *Pinus elliottii*. Florida and the S.E. coastal states do not have a plant that can be used like mugo pine (*P. mugo*). Perhaps a cultivar could be developed from that plant to fill this niche.
- *Chorisia speciosa* is the world famous kapok tree. The large purple to pink flowers are an inspiration unto themselves.

- At the Henry Leu Botanic Gardens in Orlando, Florida is a large collection of palms, of the many is *Bismarckia nobilis*; perhaps the most stately and artistic of any plant that I have ever seen. A true inspiration to anyone who is a plantsperson.

It is important to " Dare to be Different"!

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The Use of Slow-release Potassium Fertilizer for Hardening off of Holly Liners

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Since the early 1970s, Roemer Nursery has been a licensed grower of the "blue hollies", the *Ilex* ×*meserveae* series. They have become through the years, our main crop.

We decided from the beginning, to grow the holly liners that were earmarked for 3- and 5-gal containers in field beds, rather than shifting them up through our standard container-production program. We plant the potted cuttings rather late during early July. By mid-August these young plants will be growing vigorously and actually accelerate their growth considerably during September into early October. We are located a mile from the south shore of Lake Erie. The lake is the most shallow of the Great Lakes with an average maximum temperature of 78F in August. Current temperature is 74F. This by the way, is one of the reasons many nurseries got established in what is sometimes referred to as the "banana belt of Ohio".

However, from the middle of October, we can expect killing frosts that raise havoc with tender holly liners. The main damage we frequently experienced was large numbers of stem splits at the ground-level.

In the past, we had no choice but to go in March with spray cans of pruning sealant and cover the wounds. This method worked reasonably well and did cut our losses.

In the late 1970s we started to broadcast sulfate of potash fertilizer (farming grade) after Labor Day. We continued this practice for the next 10 years since it reduced the splitting damage considerably. Around 1990 slow-release potash fertilizers became available and we tested two types: (1) a 0N-0P-39K Trikote, coated with sulfur and polymer; and (2) polymer coated 0N-0P-47K. We broadcast this material after mid-August at the rate of 1¼ lb 100 ft^{-2}. This practice has reliably eliminated early winter damage on these holly beds.

I have been told that the constant release of potash binds the water within the cells —visually the stems that were very soft at mid-September are, in mid-October, hard and stiff as pencils. Anyhow, it works for us reliably on hollies.

Will it work for other plants is the next question. I tried it only on boxwood cuttings and it failed. But I still wonder whether application of slow-release potash in late summer might benefit potted cuttings or liners of, for instance, dogwood, magnolia, and viburnum.

Container growers sometimes tend to underestimate the need for potash during the hot summer months. Soil tests in July and August frequently show deficiencies of potash. Roemer Nursery and several other container nurseries in northeastern Ohio utilize these slow-release potash fertilizers in their container operations with good results.

Common/Uncommon Sense Ideas: From Concept to Reality

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INTRODUCTION

My job as a scientist deals with new ideas and innovations. Turning them into practical reality for the nursery industry is a continuing challenge. My investigations cover a broad range of topics — from propagation, container and shade tree culture, composts and wastes in potting mixes to nutrition and nutrient recycling (Chong and Hamersma, 1995). Most ideas I pursue originate initially from industry members who, to a large extent, provide financial and other support needed to pursue them.

In the few minutes allotted to me, I will introduce two innovations and outline how I improved them. Also, I will describe some unproven, untried or "wild" ones that continue to intrigue me and make me continue to think about them. While many ideas seem to appear by "accident", accidents only happen to those in a position for them to happen to. In other words, the process of thinking about an idea or problem makes it more likely to come up with new ones.

THE STYROGRAFT IDEA

Many nurseries routinely propagate hard-to-root species by graftage. Traditional procedures of side-grafting scions of hard-to-root species to rootstocks established in pots require considerable expenditure in time, labor, and greenhouse space, since rootstocks must first be rooted as cuttings or grown from seed and maintained until used for grafting.

In the early 1980s, I experimented with the simultaneous grafting and rooting procedure for speeding production of upright junipers. This procedure, also referred to as the paired-cutting technique, was first described over 60 years ago by Halma and Eggers (1936) and later in the text book by Hartmann and Kester (1968). Although not widely practiced, the technique has been used by several members (Brix and Barker, 1967; Dillon et al., 1962; Teuscher, 1962).

Matched juniper cuttings of scion (slower rooting) and rootstock (easier rooting) grafted along the basal 3 to 4 cm and held together with rubber bands, resulted in successfully rooted paired grafts under mist (Chong 1981a). Depending on the grafter, success varied between 20% and 100%.

The procedure required that both scion and rootstock be of similar size and it was somewhat time-consuming to make, match, and tie the grafts. Therefore, I modified it by using conventional side-grafts (Chong, 1981b). The side graft was held together by inserting it into a styrofoam block (3 cm × 3 cm × 5 cm), prepunched in the center with a nail to facilitate entry of the rootstock. The base of the rootstock was allowed to protrude 0.5 cm out of the styroblock to facilitate growth hormone application.

Insertion of the graft into the styroblock was less time consuming than tying with rubber band. The stryoblock exerted sufficient pressure to keep scion and rootstock

together, and the graft union seemed to heal better than when the rubber band is used. Since the new roots penetrated quite freely through the styroblock, it was unnecessary to remove the block, a feature that facilitated transplanting.

In my comparative trial, I obtained successful grafting and rooting of 75% with stryrograft, 57% with conventional rubber-banded side graft, and 46% with the paired cutting procedure (Chong, 1981b).

During the intervening years, several nurseries had indicated to me only a moderate degree of success in using the simultaneous grafting and rooting technique. Because of the very large cuttings that I used (up to 30 cm in length), I estimate that the procedure could save as much as 1½ to 2 years in production time. The technique deserves a closer examination by propagators.

THE ULTIMATE NON-CHEMICAL, NO-WEED IDEA

Weeds have been one of the biggest problems facing the container nursery industry in Canada. Unlike the U.S., where container nursery growers have a wide assortment of effective herbicides, Canadian nurseries have not been allowed to use any of these chemicals, that is, until quite recently when Devrinol and Ronstar became licensed for container use. However, these two herbicides are only partially effective. Therefore, by necessity our industry was forced to develop nonchemical methods of controlling weeds in containers:

In the early 1980s, Art Vanderkruk of Connon Nurseries (AVK), Rockton, Ontario, was perhaps the first to introduce the weed disc (Weed Guard). The disc is made of a semi-rigid plastic similar to a 45 rpm record. It has a slit so that it can be fitted around the stem of the plant on top of the container mix; small holes allow water to penetrate.

In the late 1980s, limited studies indicated a potential for controlling weeds about 85% (Chong et al., 1989) using weed discs constructed from fabric (Mori Nurseries, Niagara-On-The-Lake, Ontario) or from foam. [We are presently conducting similar tests on "new-generation" weed discs constructed from materials such as pressed peat and cardboard].

In the late 1980s, Braun Nurseries, Hamilton, Ontario, introduced the use of an insulated (THERMAT) blanket cover around the ball of above-ground container-grown trees, both for protection against cold during winter and for preventing weed growth during summer (Chong et al., 1990).

In the early 1990s, Mori Nurseries introduced another method of weed control using a black polyethylene sleeve (weed bag), which is placed around the pot in the same fashion that a florist plant is prepared for market. Small prepunched holes allow water to penetrate. We investigated different ways of applying fertilizer and different ways of applying the sleeves.

During the 1990s, we conducted a variety of investigations (Murray et al., 1996; 1997) with above-ground container (pot-in-pot system) shade tree culture. Producers such as Willowbrook Nurseries, Fenwick, Ontario, began using large plastic weed discs with container-grown trees. Putzer Nurseries, Hornby, Ontario, started to produce trees pot in pot (Chong and Hamersma, 1994).

Based on our experiences with the above innovations, Technician Bob Hamersma (now retired) and I designed the "ultimate" no-weed pot-in-pot tree culture system, which we illustrated previously in a poster display (Chong and Hamersma, 1995).

Somewhat similar to the Mori Nurseries weed bag, we placed a large black garbage

bag around and over the inner 25-gal container of the pot-in-pot grown shade tree (Chong and Hamersma, 1995). The trickle irrigation line and emitter are tucked under the sleeve and held in place by two clothes pins.

The garbage bag (1) was very effective in suppressing weeds, and (2) drastically reduced evaporation of water from the medium and frequency of irrigation. Weeds growing around the containers, or in or between the tree rows, had no effect on the growth of the potted trees. These weeds were periodically cut back with a mechanical trimmer. Furthermore, if the garbage bag (sleeve) is made sufficiently long, it can be pulled upwards and fastened to the trunk (perhaps 30 to 50 cm above the container mix) to prevent against possible rodent or animal damage to the lower trunk during the winter.

In the future, this no-weed technology may become useful for other jurisdictions should herbicides be restricted for use in containers as in Canada.

"WILD" IDEAS

I have had many uncommon or "wild" ideas that are unproven such as this one [rationale and explanation in brackets]:

Give Cuttings Aspirin to Cure Rooting Problems! [Aspirin is derived from salicylic acid which is found in willow, *Salix* sp. (Lord, 1998), known to be easy rooters. Water extracts from *Salix* twigs can enhance rooting (Daigneault and Chong, 1985). Although I did not show that cuttings treated with aspirin solutions rooted better (unpublished results), the idea of giving aspirin to plants — though seemingly preposterous — continues to intrigue me].

Similarly, there are untried ideas that I would like to pursue such as this one:

Shake Your Cuttings Before You Stick Them! [Research has shown that tomato transplants shaken as little as 30 seconds per day over a period of time drastically reduced height. This phenomenon has been observed with trees and greenhouse crops, including chrysanthemums (Hammer et al., 1974; Kellogg and Steucek, 1977). I also have observed it with chrysanthemums grown in pots by students in my floriculture laboratory. Shorter transplants or potted crops are more desirable for marketing and, in these situations, would eliminate the use of growth retardants. The diminutive effect appears to be related in some way with ethylene, which interacts with other plant growth hormones. Could shaking result in better rooting of cuttings than with unshaken ones? Or, could it effectively substitute for certain rooting hormone treatment of cuttings?]

CONCLUSION

It is perhaps "fortunate" that there are restraints on my time and resources. This helps me to focus on developing or improving a few good and innovative ideas, and also to document them carefully for others to use, or build upon in the future.

In the meantime, until I am able to pursue, prove, or disapprove some of the "wild" (uncommon) sense ones, it is very pleasant to dream about turning them into reality.

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Innovation in: Nursery Wagons, Overwintering Techniques, and a Potting Machine

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There are three items I would like to show you this morning.

1) Wagon for the Container Field. We have about 20 wagons, 7 ft wide and 16 ft long, single axle for easy backing up. Each is fitted with a quick hitch for fast hook up and disconnecting. The underside of the wagons have a steel frame with a wooden deck. Each costs about $400 in materials and 1 day's labor.

2) Minimum Heat for Polyhouses. For minimum-heat polyhouses we use regular coldframes, with 2 layers of poly and inflate it. For heat we purchase used natural gas furnaces from a local heating contractor. A 120,000 BTU furnace will give sufficient heat for a 20 ft × 200 ft house. The idea is to keep the worst cold off and we don't have the hassle of thermoblankets. Heating cost on average per year are +/- $400 for approximately 8000, 2-gal containers. We put an 18-inch polytube through the center of the house. It is installed the first week of December and removed the beginning of March.

3) Portable Potting Machine. All our container beds are 48 ft wide with a 3-inch irrigation pipe through the center. Beds are accessible from both ends. We put a JAVO super on a portable platform that's about 8 inches from the ground. The

Figure 1. Portable potting machine.

machine consists of a power unit (engine) with a hydrostatic drive, the platform for the potting machine itself with a roof overtop, and a bin carrier for the containers (Fig. 1).

We drive the potting machine along side of the beds where ever we want to pot. A 20-ft aluminum belt brings the potted plants ¾ the distance into the beds. There are only four people running this machine, one putting pots onto the machine, two people potting, and one person taking the plants off the belt. These four people can do about 1200 to 1500 2-gal containers per day.

Controls consists of steering wheel, throttle, and the groundspeed control (hydrostatic drive). Power is supplied by a 90 hp International diesel engine that runs on idle. It drives the hydrostatic drives and a 15 KV generator. The noise level is very minimal as long as you choose the right generator. The potting mix is supplied with a portable custom-built soil mixer. It brings about 3 yards of soil at a time.

Simultaneous Top Grafting of *Salix* Standards and Hardwood Rooting of the Understock

John Langendoen
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INTRODUCTION

The nursery production of top-grafted standards is one of the most expensive production processes that a nursery incurs. Producing a quality understock may take up to 3 years and it could be another 2 years before a top-grafted standard is saleable after chip budding or grafting.

In a constant effort to reduce production time we have been able to produce top-grafted *Salix* taxa in only 1 to 2 years with excellent results.

MATERIAL AND METHODS

Plant Material Preparation. *Salix* ×*smithiana* understock is collected from field, trying to pick straight 5- to 6-ft stems, and placed in a cooler at 2F until needed, during above freezing weather in early February.

Propagation Medium. One-gal pots with soil mix containing peat moss, pine bark, and perlite (1 : 1 : 1, by volume) and Osmocote 19N-6P-12K fertilizer (slow start) at 7 lb yd^{-3} are prepared. Pots are place in a greenhouse with bottom heat, watered, and covered with clear 2-mil plastic. The soil temperature must be between 60 and 65F and the air temperature held around 45 to 50F.

Grafting.

- Bees' wax is melted and maintained at the desired temperature.
- Scionwood is collected from mature stockplants making sure that it is in good condition and placed in a cooler at 2F until needed; keep the scionwood moist at all times. Store scionwood is kept in wet burlap or in thin plastic bags with holes to provide drainage. This prevents scionwood from becoming waterlogged.

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- *Salix* understock are graded and cut into 4-ft lengths, keep in mind that you need to leave the understock 8 to 9 inches longer than the graded 4-ft length so you can place it into the 1-gal container without affecting your desired height.
- Understocks are grafted using a whip and tongue, machine graft, or veneer graft (method used depends on the size of the understock and/or scionwood) and then tied with an elastic grafting band.
- Grafted ends are dipped into bees' wax and then the opposite ends are placed into a pail of water.
- The grafts are then moved into the propagation greenhouse, dipped in powdered rooting hormone (Stimroot #3), and stuck directly into the pots — piercing the plastic cover in the process.
- The greenhouse is misted two to three times a day depending on the condition in the greenhouse to maintain the humidity level as high as possible. After approximately 3 weeks the plastic is removed from the pots by slitting with a knife down each row of pots along the understock. This usually occurs by the middle of March (depending on the root development).
- By the 1st or 2nd week of April, suckers are removed from the understock starting with the bottom half first; then over the course of 2 to 3 weeks, slowly remove suckers up the understock until there are only 3 to 4 at the top — these are pinched back to 3 to 4 inches in length.
- Approximately 1 month later the scionwood should have started to grow. When the new growth reaches anywhere from 3 to 5 inches it should be tipped back. By the 1st or 2nd week of May all scionwood should be tipped back.
- Once they flush out again and are growing nicely, hardening off is started. Maintain inside air temperature 10F higher than outside air temperature.
- After this hardening off procedure has been implemented for a week or so, start using roll up sides to further harden off the plants so they will be fully conditioned to the outside temperature by the end of May or beginning of June.

Growing On.

- By the end of June or early July, the process of potting the grafts from a 1-gal containers into a 5-gal container starts. Grafts are potted up using a Bouldin & Lawson XL500 potting machine.
- Pots are placed pot to pot in a polyhouse covered with shade cloth (30%) for 3 to 5 days for further conditioning. As the grafts are being potted into 5-gal containers, pruning and removal of suckers is carried out. After the grafts are potted and risk of breaking off the scion is passed, the rubber grafting bands are cut off.
- During August when there is more time available the grafts are staked and tied with custom made stakes. The stakes are stained with a redwood stain to ensure that they will last two seasons. The standards will probably have to have suckers removed two or more times before the end of the season.

- The next time the top will be pruned would be the following year in March and once more during the growing season—depending on the cultivar. Plants are saleable by mid summer of the 2nd year.
- The taxa that we are currently producing with the most success are *S. caprea* 'Kilmarnock' (syn. *S. caprea* 'Pendula') (weeping pussy willow), *S. purpurea* 'Pendula' (weeping purpleleaf willow), and *S.* integra 'Hakuro-nishiki' (variegated pussy willow).

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Gisela® Series: Dwarfing Cherry Rootstocks

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The Gisela® series of rootstocks are important dwarfing cherry rootstocks for sweet cherry and have limited use for sour cherry and Japanese flowering cherries. The initial crosses that lead to the development of these rootstocks started in the early 1960s at Justus Liebig University in Giessen, Germany. The Gisela® series of rootstocks have gone through extensive testing in Germany where they first originated and in Michigan at Hilltop Orchards and Nurseries Inc. for almost 20 years. In addition, for the past 10 years tests as part of the North Central 140 trials (NC-140 rootstock trial plantings) have occurred at 16 locations throughout the U.S.A. and Canada.

The Gisela® rootstocks produce sweet cherry trees which are 45% to 70% or 80% the size of those on mazzard understock. Scions grafted on Gisela® understocks are very precocious and crop in their 3rd year with full crops in the 4th. Typically, in a side-by-side comparison, sweet cherry on Gisela® 12 rootstock will have a heavier bloom and will be in its 4th cropping season whereas grafts on mazzard will just be starting to flower. This earlier and heavier bloom on Gisela® rootstocks has created interest among ornamental nurseries on the potential of grafting Japanese flowering cultivars on these dwarfing cherry rootstocks.

We currently have a 3-acre high-density planting of sweet cherry on Gisela® at Niagara-on-the-Lake with a 6 ft × 14 ft spacing and are planning a 2-acre planting at a 4 ft × 12 ft spacing this coming spring. Rain and hail can be a problem for us with sweet cherries. Because of the dwarfing habit on the Gisela® rootstocks we are working on a simple easy-to-build covering to manage these problems.

Hardiness of the Gisela® rootstocks is good. I have observed damage in a nursery in Washington State where sweet cherry grafted on mazzard cherry showed damage from severe winter cold of -18F with no snow cover. In the same field no damage was observed on Gisela® 6 rootstock.

Gisela® rootstocks will definitely change the production of sweet cherries in Canada, U.S.A., and around the world. The greatest problem is the propagation of these rootstocks in satisfactory quantities. They have been quite difficult to produce in large quantities on a consistent basis. Tissue culture has worked reasonably well

- The next time the top will be pruned would be the following year in March and once more during the growing season—depending on the cultivar. Plants are saleable by mid summer of the 2nd year.
- The taxa that we are currently producing with the most success are *S. caprea* 'Kilmarnock' (syn. *S. caprea* 'Pendula') (weeping pussy willow), *S. purpurea* 'Pendula' (weeping purpleleaf willow), and *S.* integra 'Hakuro-nishiki' (variegated pussy willow).

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Gisela® Series: Dwarfing Cherry Rootstocks

Leno Mori
Mori Nurseries, Ltd., Niagara-on-the-Lake, Ontario, L0S 1J0 Canada

The Gisela® series of rootstocks are important dwarfing cherry rootstocks for sweet cherry and have limited use for sour cherry and Japanese flowering cherries. The initial crosses that lead to the development of these rootstocks started in the early 1960s at Justus Liebig University in Giessen, Germany. The Gisela® series of rootstocks have gone through extensive testing in Germany where they first originated and in Michigan at Hilltop Orchards and Nurseries Inc. for almost 20 years. In addition, for the past 10 years tests as part of the North Central 140 trials (NC-140 rootstock trial plantings) have occurred at 16 locations throughout the U.S.A. and Canada.

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but it to has not been able to provide sufficient numbers. Softwood cuttings have also done reasonably well. This year we took 3-inch softwood tips in June, two-bud cuttings, and 10-inch cuttings. We found that by putting these cuttings all in a polyhouse with extra shading, keeping high humidity with as little watering or misting as possible, keeping the house closed tight with temperatures reaching 110F and higher gave a greater success than by keeping the temperature down with ventilation and more misting. We used a peat and perlite medium for the larger cuttings and a cocoa-mulch medium for the tip cuttings. Gisela® rootstocks are currently propagated in California, Oregon, Washington, Michigan, and Ontario with varying success.

Innovation in Perennial Propagation

Kees Govers
J.E.A. Perennials, 24640 Melbourne Rd, RR#3, Strathroy, Ontario N7G 31-15 Canada

Propagation of perennials by seed is nothing new or innovative. Plugs and plug seeders are not new to the industry either. Many of the large annual plug growing operations around the nation seed bedding plants with highly sophisticated seeding lines. They typically contain automatic flat fillers, dibblers, high-speed drum seeders, watering tunnels, conveyors and sometimes, robots to move plug trays to the bench or the cracking chamber. This equipment is very well suited to bedding material as trays are seeded in lots of several hundred trays. These systems are very fast, very accurate, very sophisticated, and very expensive to set up. Anywhere from $30,000 for the seeder alone to a few hundred thousand for the entire set-up. Only a few perennial plug producers, that I am aware of, utilize this equipment.

If you are a smaller plug producer and typically seed in lots of 5 to 50 plug flats per taxa, the expense of such an elaborate seeding set-up can usually not be justified. Until a few years ago, the next most viable option was a plate seeder. These are very simple pieces of equipment consisting typically of a tray holder, an airtight box holding the seeding plates and a vacuum cleaner with a regulator valve. The plates have holes drilled into them corresponding with the selected plug tray size. Usually three or four plates with different hole sizes are used to cover most seed sizes. Accuracy of seeding depends significantly on the skill of the operator and the number of flats that have already been done that day. Typically the first 20 or 30 are quite good, by the time you hit number 200, your back aches, your wrists are sore, and you are ready to strangle the inventor of this contraption. Of course you conveniently forget the days when plug trays were seeded with a vibrator seeder or a salt shaker.

A decade and a half ago needle seeders made their entrance into the market. Initially rather prone to plugging and somewhat difficult to control, the concept none the less was sound. You put a vacuum across some hypodermic needles to pick up a defined number of seeds from a seed tray, move the needles over a plug tray, release the vacuum and the seed is seeded. In theory you can seed practically any type of seed from cyclamen to walnuts by this method. In practice it was found that more sophisticated controls were needed. Several companies took the initial seeders and added vacuum controls, blow-off switches, vibrating seed trays, and seed retrieval

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systems to come up with the modem needle seeder. The strength of the needle seeder lies in the seed handling capabilities. It is capable of singulating most types of seeds when operated by a skilled person. It works very well for small batches of seed, say 500 to a few thousand, although I still use a plate seeder for smaller quantities.

Here is how it works. You place your seed in the vibrating seed tray and adjust the vibrator to create the effect of seed swimming in the tray. Insert the plug tray under the dibbler and watch the machine do the rest as it seeds each cell row by row. Of course it isn't quite that simple. A few things need to be done first. Picking the right needle size is important. Using a #8 needle to seed *Aquilegia* seed would create some serious plugging rather quickly, likewise using a #41 needle would not have sufficient vacuum to hold the seed. Regular observation and accurate record keeping quickly establishes which needle is appropriate for specific genera. Entering these observations in a database and utilizing it for planning a seeding session greatly decreases the number of needle changes, and increases productivity tremendously. The second variable is the amount of vacuum on the needles. Higher vacuum pressure increases the number of multiple seeds per cell (sometimes desirable), too low and the seeds fall off before they reach their destination. Blow-off pressure can also be important. Too much and the seed bounces out of its cell, too little and the seed sticks to the end of the needle enabling you to seed an entire 288 tray with 12 seeds. Once you've made those adjustments you are off to the races. Finish a seed selection and have seed left over; the seed change-over is quick and painless. Simply suck up the excess seed, put in the new plant and away you go.

Utilizing this machine and my unsophisticated setup a two-person crew is capable of processing between 500 and 800 288-plug trays in an 8-h day. That is roughly 50% faster than with a plate seeder. Adding a flat filler, conveyor, and watering tunnel could double that figure again. The biggest benefit however is reduced operator fatigue.

Innovation in Tree Processing

Todd Baker
Baker's Nursery, RR#2 Bayfield, Ontario N0M 1G0 Canada

INTRODUCTION

Baker's Nursery is a wholesale grower of ornamental deciduous trees and shrubs, cultivating 200,000 pieces of nursery stock, and harvesting and shipping over 25,000 trees and shrubs annually. The bulk of our production is shipped bareroot, without attached soil. Baker's Nursery ships fresh, no stock is retained in cold storage facilities. Trees and shrubs are harvested and shipped immediately during spring and fall digging periods. This restrictive processing schedule leaves us at the whim of nature necessitating an efficient and innovative system of harvesting and processing our nursery stock. The two components of this system, harvesting and processing, will be examined in terms of the modifications made to the equipment and facilities we use and the savings and benefits resulting from these modifications.

HARVESTING PROCEDURES AND EQUIPMENT

Prior to our newest harvesting system, we employed five staff and two tractors to dig only 2000 pieces of nursery stock daily. Today we employ three staff and one tractor to harvest 5000 trees and shrubs daily consuming significantly fewer human and mechanical resources. These savings were accomplished with a few rudimentary and inexpensive modifications to our equipment. An 85-horsepower tractor equipped with a "creeper" gear is used to pull a mechanical shaker digger. To eliminate the need for another tractor and operator, the harvesting wagon was attached to the digging unit by simply welding a tongue directly to the mechanical shaker digger. By attaching the wagon to the harvesting unit, another employee who shuttled trees from the digger to the wagon became redundant. After experiencing the strenuous task of walking behind the mechanical shaker digger in the loose uneven dirt to gather dug stock, it became apparent that a platform also welded and bolted directly to the harvesting unit made sense in terms of safety and physical demands for employees. This harvesting system utilizes human and mechanical resources in this manner:

- One employee operates one tractor that powers a mechanical shaker digger which also pulls a harvesting wagon.
- Another employee occupies the platform mounted on the shaker digger and receives the nursery stock as it is dug.
- The last staff member, situated on the harvesting wagon, gathers the stock from our employee on the platform and loads the wagon efficiently.

Originally, the harvesting wagon was constructed using a standard agricultural chassis with the deck measuring 36 inches off the ground. Now the wagon is built using an implement chassis and the deck is 19 inches from the ground, facilitating nursery stock handling between the platform and the wagon.

PROCESSING AND SHIPPING FACILITIES

Once the stock has been harvested and stacked on the wagon, it is transported directly to the processing and shipping facility. Because we do not process our stock by bundling and tagging in the field, our stock is not subjected to the dry environment characteristic of our field conditions. This temperature- and moisture-controlled facility is equipped with a sunken driveway, allowing machinery and wagons to enter or exit at either end of the building. The drop of this driveway is the same as the height of the wagon deck, making the wagon level with the floor of the facility. The incentive for creating this lower level drive-through system was years of awkwardly and arduously stepping on and off wagons with armfuls of nursery stock. Currently, the unloading of wagons is facilitated by an even step between the wagon deck and the floor of the storage shed. Because the trees are pre-graded in the field, the processing staff can quickly inspect stock for root structure and damage caused by harvesting as it is unloaded from the wagon. Trees and shrubs are processed, tagged, and bundled, directly from the harvesting wagon. This system also eliminates extra labor and space required to unload stock into piles, then pull these piles apart to tag and bundle stock. The savings in storage space that we have realized by changing to this system are significant. Prior to our new facilities, we occupied two storage sheds with a total floor area of 5000 ft^2. Today we process 25,000 pieces of stock annually occupying only 4200 ft^2 of floor space with the ability to process another 75,000 pieces of stock annually. In addition, this drive-through feature eases loading the bundled trees and shrubs onto delivery trucks. "Straight" trucks are able to pull along the drive-through where stock is gathered from either side of the facility and loaded. The system conserves the extra handling required when first loading pick wagons, then using these pick wagons to load delivery trucks. As the delivery truck moves through the shed, the stock to be loaded is never situated more than 20 ft from the truck.

BENEFITS OF THE SYSTEM

The modifications to the harvesting and processing system generated greater safety and efficiency for our staff and healthier conditions for our stock. It requires fewer people and machines to harvest more stock. The reduction in physical demands and moving machinery has created safer and more comfortable working conditions for our employees. Unlike other systems which employ field processing, our stock is transported directly to a moisture- and temperature-controlled facility, eliminating the stress of the field environment for our staff and nursery stock alike. We are able to process more trees and shrubs with a smaller facility. While processing and shipping, the stock is handled less, preventing damage and conserving human resources and time. We are satisfied with the modifications we have made to our systems particularly because they were inexpensive and relatively simple to achieve.

Practical Rooting Trays

Paul Van Der Kroft
Van Der Kroft Nursery, R.R. 2, Strathroy, Ontario N7G 3H4 Canada

We utilize the plastic bulb trays used to ship bulbs from Holland to North America. The bulbs are used in greenhouses for forcing and as it is too expensive to return the trays, they are sold here for $3 (Cdn.) or less. The size of the tray is 60 cm × 40 cm × 18 cm (23.6 inches × 15.7 inches × 7 inches). All of our softwood propagation in the summer is done in these trays. They are filled approximately 9 cm (3.54 inches) with perlite. Depending on the leaf size of the cutting, the trays contain 150, 95, or 75 cuttings.

The cuttings are made about 13 cm (5.1 inches) in length making sure that they do not stick out over the top of the tray. This makes it easier to stack them later. Cuttings are treated with 0.8% IBA powder. Misting is controlled by an electronic leaf sensor. After rooting the cuttings are hardened off.

In November after the leaves have fallen off and the cuttings have been treated with a fungicide, the trays are stacked up to 12 high in a cold storage at 1C; they will remain there until approximately the end of May.

The advantages to using this system are:

1) Inexpensive durable trays;
2) Highly mobile;
3) Light weight;
4) Due to the bottom perforation of the trays the cutting roots are air pruned.

Innovation in Propagation

Dave Bakker Sr.
J.C. Bakker & Sons Ltd., 1209 Third Street, R.R. #3, St. Catharines, Ontario L2R 6P9 Canada

INTRODUCTION

How do you recognize a propagator in a crowd? Among other things, you look at his or her hands, and, on careful examination, you will see scars on their fingers from cuts made when they learned to graft and make cuttings. Upon talking to them further, you will hear of their successes of 200% rooting, and 120% catches!! But also, you will hear of their ongoing battles with certain plants and their undeserved failures.

At one time, we grew tree roses. In order to protect them during the winter, we would bend them down and cover the budded 1.25-m stems with soil. This was cumbersome, but if we could protect the buds from windburn, we would be successful in growing standard roses.

I started with a Kotex® pad, and eventually wound up with a bookmailer — a thick-walled Kraft envelope. The Kotex sanitary pad got a lot of laughs, but later on was used successfully as a moisture-carrying insert in the hot callous tube.

The Kotex pads come pre-glued. They are laid end-to-end on a pipe, and inserted

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The Kotex pads come pre-glued. They are laid end-to-end on a pipe, and inserted

into the insulated hot-callous tube with the slots. The hot callous tube is laid on a slight slant, and water is poured into the end to wet the pads so that they will provide continuous humidity to the callousing graftings in the slots. Pads are sterile, and hold a fair amount of water. This method worked!

GRAFTING

Now, to grafting. We graft a lot — well over 100,000 pieces. You must start to look for improving grafting techniques to cut time, costs, etc.

Rather than tying the scion and stock, I stapled some. It worked, but it is still cumbersome. Then, presto! — an idea. Use Crazy Glue that hardens in seconds!

For the experiment, I used a hypodermic needle to get a very small droplet in the center of the scion cut. But it took too long to set. I called the 3-M Company, the manufacturer of Crazy Glue. They had an accelerator agent. It worked, but the scions didn't take! The accelerator chemical burned the cambiums. Even so, we should continue to look to the medical experts that graft our bones, as well as our dentists, etc. The idea is still good — no rubbers to use, no rubbers to take off.

Salix. Grafting our willows, i.e., weeping pussy willow and hakuro-nishiki willow, is a one-step process. We graft and root at the same time. Early in the spring, we gather sticks of *Salix viminalis* 1.25 to 1.80 m in length with a minimum caliper thickness of a pencil. We graft the tops with *S. integra* 'Hakuro-nishiki', *S. caprea* 'Kilmarnock' (syn. *S. caprea* 'Pendula'), and *S. purpurea* 'Pendula'. We use a polyethylene tape rather than rubbers to tie our scions. The graft is a simple whip graft (no tongue), matching at least one side. The grafted sticks are stuck as a cutting in a 5-gal pot. The cutting grafts are kept in a greenhouse at 20C until outdoor temperatures have warmed up, and then they are moved out. The grafts are next staked through the pot into the soil, thus preventing them from blowing over. They are watered with drip irrigation; willows take a lot of water!!

Aesculus **×*carnea* 'Briotii'.** We graft these onto 1-year *A. hippocastanum* understock growing in 1-gal pots. Because the scions are dipped in wax, the scion buds are sealed, and therefore, are slow to emerge. This allowed rot to set in, causing young emerging buds to damp off, and resulted in poor to mediocre takes. We solved this by capping top buds with aluminum foil before dipping, then removing the aluminum cap and allowing the plant to break through its natural "pitchy" coat.

Euonymus **Standard.** Standards are grafted on *E. europaeus* understock. We used to use seedlings for stems, but they took a long time (3 to 4 years) to get up to 125 to 150 cm. Kris Bachtell (The Morton Arboretum) sent me a selection of *E. europaeus* that is faster growing, and we are now using a fall-potted softwood cutting, grown on in 1-gal pots in a shaded greenhouse which gives us stems of 150 cm+ that are ready in 1 year! These are grafted with a 1-gal-pot rootball.

CUTTING PROPAGATION

Taxus. We root taxus, but, rather than using powdered NAA, we prefer soaking the taxus in a water solution of NAA Rhizopon B (200 ppm) for 24 h. We use a flat with 38 cells to keep the cuttings in an upright position in the water. Each cell contains a bundle of taxus cuttings. The advantage is it's faster! It's hygienic, there are no ties to use, no ties to cut, they're easy to transport, and easy to rinse off prior to sticking.

Our rooted taxus cuttings, or any other cuttings for that matter, are pulled out of the coarse sand medium and put into 2-gal pots which are transported on our roller blade carts overtop the benches. The 2-gal pots are watered and easy to put on a planting machine or into the potting operation.

Prunus. We also root our *Prunus* ×*cistena* and *P. triloba* 'Multiplex' (flowering almond) in boxes in a mixture of fine sand, peat, and perlite. The plants are later field grown, for they do not like container overhead irrigation — they are prone to developing bacterial leaf spot (*Xanthomonas pruni* or shot hole). The cuttings are stuck in fruit boxes, approximately 50 cm × 50 cm × 40 cm in height, containing ¼-inch drainage holes. Cuttings are sprayed with Agrimycin for the leaf spot. The boxes with rooted cuttings are fertilized with 20N-20P-20K liquid fertilizer and grown on to a height of 50 to 60 cm. Rooted cuttings are hardened off and mowed with a sicklebar pruner — levelled down to box height —then leaves and debris are blown out. They are then sprayed with a fungicide and stacked on pallets to be stored in cold storage at 0 to -1C. In the spring, they are shaken out, bundled, and are ready to plant. They are watered only once in the winter while in cold storage. The plants store well, and take off like mad when planted in the field!

Picea. We annually grow *Picea glauca* var. *albertiana* 'Conica' (dwarf Alberta spruce) and *P. abies* 'Nidiformis' (nest spruce) from summer cuttings (described in another paper I gave). I would like to share with you the replacing of our old-fashioned wood sash with 6 ft × 4 ft sheets of double polycarbonate claddings reinforced with aluminum angles. There is no more painting, replacing of glass, etc., but as a bonus, plants are warmer in winter and cooler in summer at cutting sticking time.

Standards from Cuttings. We are now growing many shrubs as standards. This in itself is not a new concept. The difference now is they are container grown from start to finish. A rooted plug is potted and greenhouse grown till June when outdoor temperatures are equal to the greenhouse environment. At this point, they have already reached a height of 125 to 150 cm. They are staked — and will still continue to grow— and grown on for another season into a saleable small tree. For now, we have *Weigela* cultivars, *Cornus alba* 'Elegantissima', and pee gee hydrangeas, giving us even more variety in the small ornamental trees we produce. The pee gee, *Hydrangea paniculata* 'Grandiflora', standards along with *Hibiscus* standards bloom in late summer and into fall, providing beauty and color at a time when most other flowers have peaked.

A New and Inexpensive Rooting Medium Amendment: Paper Mill Biosolids

Calvin Chong
Horticultural Research Institute of Ontario, Department of Plant Agriculture, University of Guelph, Vineland Station, Ontario L0R 2E0 Canada

Paper mill waste (biosolids) was used as an alternative rooting medium amendment in various investigations. With few exceptions, cuttings from a wide assortment of deciduous shrub taxa rooted good to excellent in media consisting of perlite mixed with up to 60% by volume of biosolids in outdoor summer trials under mist. Despite differences in manufacturing processes and end-uses of four sources of biosolids, or in the rooting variability of woody taxa, there was no clear indication that any one of the sources was consistently or substantially better as a rooting medium amendment. Results from parallel winter trials with evergreen cuttings in fog-humidified greenhouses with bottom heat were contrastingly poor due to hardening and shrinking of the biosolids-amended media under these circumstances.

INTRODUCTION

Pulp and paper mills in Canada discard about 10% of the 10 million tonnes of paper mill biosolids generated across North America. Like other industrial wastes, the disposal of paper mill waste is a major concern. Landfilling has been banned or has become prohibitively expensive. Environmentally friendly and sustainable disposal alternatives are needed.

Paper mill biosolids have been used as soil amendment in land reclamation, forestry, and agriculture since the 1950s (Aitkin et al., 1995; Brockway, 1983; NCASI, 1959), and in potting mixes for growing container nursery crops since the 1980s (Bellamy et al., 1995; Chong and Cline, 1994; Tripepi et al., 1996). We have reported an alternate use of paper mill biosolids in rooting medium (Chong and Hamersma, 1996; Chong et al., 1998). This research is herein summarized.

EARLY TRIALS

In two trials conducted during the early 1990s, we attempted to root evergreen shrub cuttings in fog-humidified greenhouses with bottom heat. The media consisted of one source (QUNO, Table 1) of paper mill biosolids (0% to 100% by volume) mixed with peat, bark, or perlite. Few of a wide assortment of taxa rooted fair to acceptable but only in media with ≤30% of the biosolids. With higher proportions, rooting declined rapidly due to increasing hardening and shrinking of the amended media. This condition was apparently induced by the bottom heat and seemed to have restricted water penetration and/or air exchanges in the media.

In a third investigation conducted during summer outdoor under lath (50% shade) and mist, the amended rooting media remained friable and normal in appearance. Six of seven deciduous shrub taxa rooted good to excellent in media with perlite and paper mill biosolids up to 60%, the highest proportion used in this investigation.

DIFFERENT SOURCES

Since sources of biosolids differ in physical and chemical characteristics (Bellamy et al., 1995) and may elicit different rooting responses, a fourth trial under similar outdoor conditions compared rooting with four different sources of biosolids.

Despite differences in characteristics of the four sources due to different manufacturing processes and/or end-uses (Table 1), or to the wide variability in rooting response among six woody taxa, the overall results of the study were remarkably consistent. With few exceptions, there was little or no adverse effect of the four biosolids on rooting when present at levels ≤45%. In fact, as exemplified by data for two of the six species (Fig. 1), some yielded higher rooting percentage, root number, and/or root length with 60% of biosolids. Furthermore, there was no clear indication that any one of the sources was consistently or substantially better as a rooting medium amendment.

Table 1. Source and compositional properties of selected paper mill biosolids.

Atlantic (A)

- 100% recycled deinked newsprint and tissue.
- Combined primary and secondary biosolids; 40% to 60% organic solids (dry wt); ca. 1:1 organic to inorganic solids content.
- Major solid components include: fine cellulosic fibre, calcium carbonate, magnesium silicate (talc), clay (kaolin), ink solids, microbial biomass, and miscellaneous inorganic solids.

Domtar (D)

- Bleached kraft pulp and recycled fibre from old corrugated cartons.
- Combined primary and secondary biosolids; 1.2 : 1 dry wt ratio; 70% to 80% organic solids.
- Major solid components include: cellulosic fibre, calcium carbonate, microbial biomass, and miscellaneous inorganic solids.

QUNO (Q)

- 25% thermomechanical, soft-wood pulp and 75% deinked newsprint and magazines.
- Combined primary and secondary biosolids, 9 : 1 dry wt ratio; 70% organic solids.
- Major solid components include: fine cellulosic fibre, carbonate, talc, and clay (kaolin) filler/coating materials, ink solids, microbial biomass, and miscellaneous inorganic solids.

Thorold (T)

- 100% virgin, market pulp.
  Primary biosolids; 40% to 60% organic matter; ca., 1 : 1 organic matter to inorganic matter content.
- Major solids components include: cellulosic fibres and clay (kaolin) fillers and coatings.

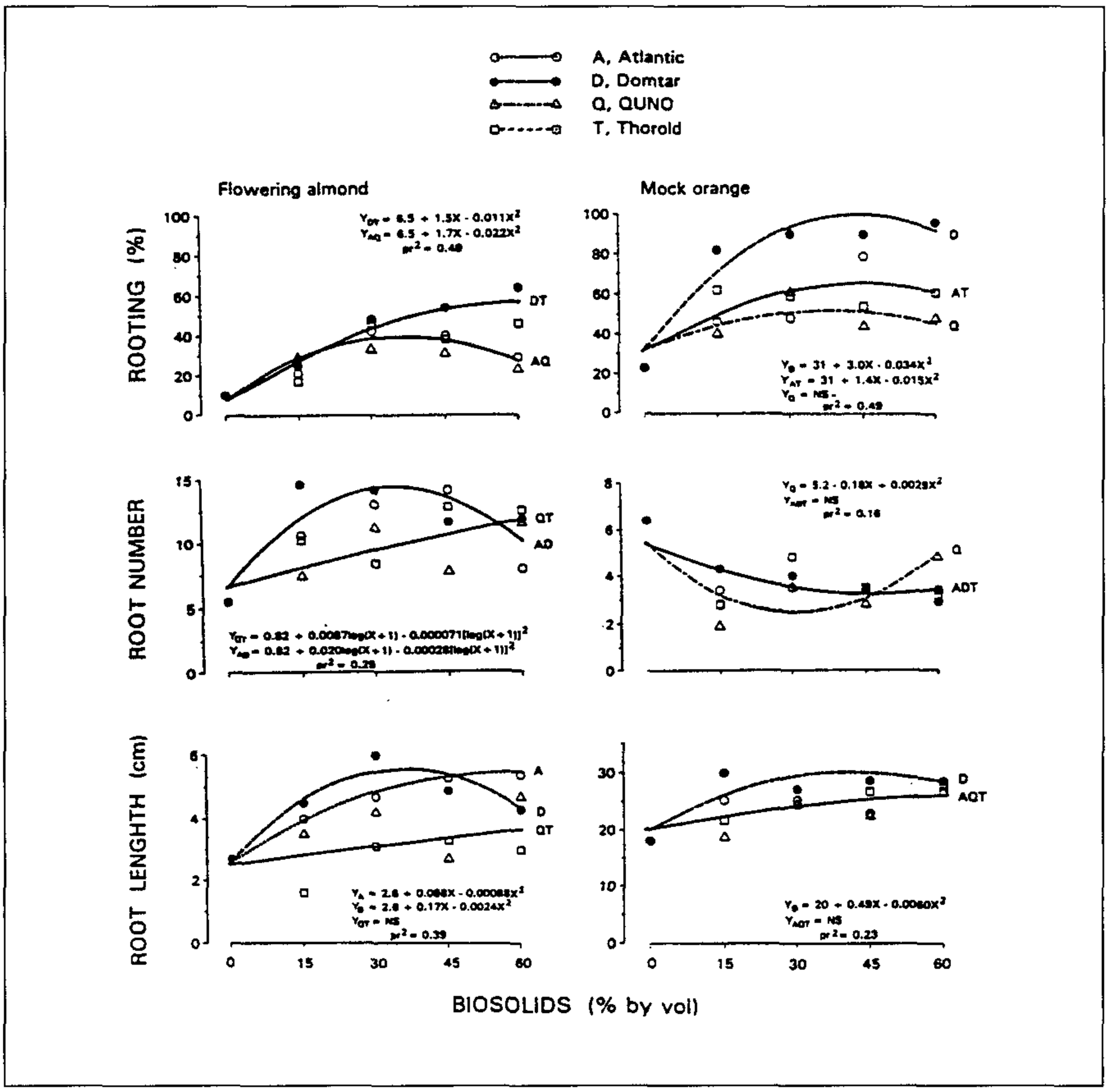

Fig. 1. Percent rooting, root number, and root length of two deciduous landscape shrubs in response to source and level of paper mill biosolids. The regression for each source is represented (broken lines) by Y_A (Atlantic), Y_D (Domtar), Y_Q (QUNO), and Y_T (Thorold). When any two (i.e., Y_{AD}) or more (i.e. Y_{ADT}) regressions were not significantly different at $P<0.05$, a common regression (solid line) was fitted. NS indicates that the slope, curvature, or both, were nonsignificant at $P<0.05$. pr^2 represents the coefficient of determination after removing replication effects.

Except for an excess of Cl^- concentration (136 ppm) with source D, all nutrients in the unamended biosolids were low and the values of EC (a measure of total soluble salts concentration) ranged from 0.2 to 0.7 dS m^{-1} (Table 2). However, the EC in all amended media measured 0.1 dS m^{-1} at the start of the experiment (just after preparation and initial watering in the flats), and $\leq$0.2 dS m^{-1} (the desirable threshold for rooting of cuttings, Chong et al., 1998) at the end, except for those with the Domtar biosolids (0.3 dS m^{-1}, all levels). The pH values of the amended media tended to be similar to those measured in the unamended biosolids (Table 2), changed little or not at all during the rooting period, and had no apparent effect on rooting.

Table 2. Chemical analysis of perlite and four paper mill biosolids before mixing.

Variable	Recommended values[z]	Source of biosolids[y]				
		Perlite	A	D	Q	T
pH[x]	5.5-7.0	7.6	7.8	6.9	7.8	7.3
EC (dS m^{-1})	<1.0	<0.1	0.3	0.7	0.2	0.3
$N0_3$-N[v]	100-200	0.6	52	19	83	5
P	6-9	0.1	1	23	2	1
K	150-200	0.8	2	71	2	1
Ca	200-300	0.3	50	151	66	33
Mg	70-200	0.1	10	27	17	10
Cl	0-50	2.0	27	136	25	19
Fe	0.3-3.0	0.5	0.6	1.2	0.9	0.0
Mn	0.3-3.0	0.0	0.1	1.3	0.1	0.1
Zn	0.3-3.0	0.0	0.4	0.1	0.03	0.6
Cu	0.3-3.0	0.0	0.0	0.03	0.13	0.0

[z] According to recommendations for container growing media (OMAFRA, 1994).
[y] A, Atlantic; D, Domtar; Q, QUNO; and T, Thorold; see Table 1 for description.
[x] pH and EC (electrical conductivity) measured in 1 medium: 2 water (v/v) extracts; mean of three samples.
[v] Concentration of all nutrients expressed in terms of mg $liter^{-1}$; saturated medium extraction (greenhouse) procedure, mean of three samples.

While the bulk densities of the unamended biosolids were 1.3 to 1.8 times higher than that of perlite (0.12 g cm^{-3}), the porosity characteristics exceeded slightly (1.1-1.3 times), or were similar to those of perlite (total pore space, 56%; air pore space, 32%; water pore space, 24%).

CONCLUSIONS

These investigations demonstrated that paper mill biosolids in amounts ranging from 30% to 60% by volume can be used effectively as rooting medium amendment for propagating cuttings under mist. The four biosolids tested showed little adverse effects on rooting. The electrical conductivities of the biosolids-amended media were acceptable (0.1 to 0.3 dS m^{-1}) for rooting of woody cuttings and pore space characteristics were comparable to, or exceeded those of, perlite. As an organic waste product which may be obtained, where available, at little or no cost, raw paper mill biosolids could be more widely used in nursery propagation as an inexpensive rooting medium amendment.

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Field Propagation of *Cercis* and *Hamamelis*

Harald Neubuaer
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My nursery is a small family operation in middle Tennessee located in U.S.D.A. Zone 6. We produce both common and unusual budded and grafted bareroot liners.

Our production fields consist of a rocky, well-drained soil with a pH of approximately 6. I have always enjoyed the challenge of growing difficult-to-propagate plants, such as *Cercis* and *Hamamelis*, which I will now discuss.

CERCIS

There are several methods for *Cercis*. I start with bench-grafting bareroot understock in February/March. As understock I use seedlings of *C. canadensis* ¼ to ½ inches in diameter. When I can match my scionwood to my understock, I prefer to do a 45° graft. If my scion wood is smaller, I do a side veneer graft. Either graft is tied with a rubber band and sealed with a water-soluble coating such as Treecote. The finished grafts are then stored in damp peatmoss until planting time in the spring. With the side veneer grafts, the stub is removed in July using a slanted cut. The success rate can be from 20% to 80%.

A second method I have good results with is T-budding in the spring. As soon as the bark slips on established understock in the field, I cut a small shallow wood bud and attach the bud with a rubber band. I use dormant scionwood which has been stored under refrigeration.

Even more successful is a graft on established understock in the field. The best method is to make a side veneer graft on understock which I cut back to 10 to 12 inches above the ground and sealing the graft with Treecote. This stub must be removed in July or August above the successful graft. The field grafting method is the most reliable for me.

Because spring is such a busy time, I try to propagate redbud in the summer. Due to the zig-zag growth habit of redbud, it is almost impossible to T-bud using a slip bud. When the bud is pulled off the scion wood, the result is a concave surface that will not match the understock. In summer, the best way to bud is chip budding. The bud must be wrapped with budding tape. In late winter of the following year, the plant is cut off above the bud with a slanted cut.

I have found that *Cercis* is a very unpredictable crop. Using the same procedure at the same time of the year, the results range from 0% to almost 100%. My average of saleable plants is about 50%.

Listed below are the main cultivars we grow with a brief description of each.

Cercis:	'Oklahoma'	Glossy dark green leaves and a deep purple flower (syn. *C. reniformis* 'Oklahoma').
Cercis canadensis:	'Appalachia Red'	A cold-hardy, true red flowering introduction from Dr. Max Byrkit.

	'Covey' (PP#10328)	A graceful, fast-growing weeper introduced by Tim Brotzman of Ohio and patented by his nursery.
	'Flame'	Sterile with large double flowers.
	'Forest Pansy'	Dark burgundy foliage.
	'Royal'	Somewhat larger flowers at an earlier age than 'Alba', the most winter hardy (syn. 'Royal White').
	'Silver Cloud'	A Theodore Klein introduction with spectacular variegated leaves on a smaller grower.
	'Tennessee Pink'	Our own selection of a true pink flower.
Cercis canadensis var. *texensis*:	'Texas White'	Glossy wavy leaves, dense growth habit (syn. *C. reniformis* 'Texas White').

HAMAMELIS

One of my favorite plants has always been *Hamamelis*. The fragrant blooms are a standout in the bare winter landscape. The conventional method of propagation — grafting in the greenhouse on potted understock — did not fit in my operation. So I experimented with other methods. One successful technique is bench grafting in the winter. I use 1-year seedlings of *H. virginiana* which I prefer to grow myself. *Hamamelis vernalis* should not be used due to the stoloniferous nature of this plant. If *H. virginiana* is not available, then *H. mollis* or *H. ×intermedia* can be substituted. A side veneer graft should be used but if the scionwood is large, I like to do a 45° top graft tied with a rubber band. Then I do not have a stub to cut back in the summer. After grafting, all exposed cuts are sealed with Treecote. The grafts are stored in damp peatmoss until planting. Some callous will form during this time. The same grafting procedure can be used in early spring on established understock in the field.

T-budding in the summer is also a very good method. The bud is tied in with a rubber band. The following spring, the top of the understock is cut off above the bud. During the growing season, the plants need to have any suckers removed.

Field growing *Hamamelis* cultivars has produced large plants with good root systems. Success rate varies, but I expect to have between 50% to 60% saleable plants.

Cultivars we grow with a brief description of each are listed below.

Hamamelis ×intermedia:	'Angelly'	Yellow flowers on a medium-size shrub with good yellow fall color.
	'Arnold Promise'	Dense fragrant clusters of late blooming deep sulfur-yellow flowers on a vase shaped compact grower.

	'Barmstedt Gold'	A new cultivar with fragrant canary-yellow flowers produced in mid-season on an upright bush.
	'Diane'	Carmine-red flowers in mid-season on a slightly spreading bush with good fall color.
	'Feuerzauber'	Red fragrant twisted flowers in mid-season on a strong upright grower with yellow fall color.
	Jelena'	Fragrant dense clusters of early coppery flowers with wavy petals on a broad and shrubby bush with beautiful bronze, scarlet-red fall color.
	'Pallida'	Large early season fragrant sulfur-yellow flowers on a strong wide-spreading grower. (syn. *H. mollis* 'Pallida')
	'Primavera'	Scented primrose yellow mid-season flowers with violet centers on a wide upright floriferous shrub.
	'Sunburst'	Very abundant clusters of lemon-yellow mid-season flowers with long petals on an upright bush with good fall color, a striking cultivar.
	'Westerstede'	Primrose-yellow late-season fragrant flowers on a strong upright grower.
Hamamelis vernalis:	'Sandra'	Small fragrant bronze-yellow early flowers on a strong upright shrub with red purple new growth and fabulous red to orange fall color.

There are many new cultivars from Europe under evaluation. We have a few in limited numbers.

Growing *Cercis* and *Hamamelis* in the field has proven to be a challenging undertaking, but I believe the effort has been worthwhile. These plants are beautiful, hardy, easy to care for and pest resistant. They deserve a greater role in the landscape.

Clematis Propagation

Szczepan Marczynski
Clematis Container Nursery, Pruszków, Poland

Clematis is the queen of climbing plants and its popularity is constantly increasing. I think it is important that we become aware of the various ways that clematis can be propagated.

SEED PROPAGATION

Seeds of *Clematis* species should be collected after ripening — most often in October — without waiting too long because they can easily be blown away by the wind. Seed tails should be detached and seeds dried indoors.

Most small-flowered clematis seeds should germinate within 6 to 7 weeks. It is best to sow them in early spring.

Large-flowered clematis, as well as, certain small-flowered species (e.g., *C. viticella*) germinate after 6 to 18 months. These seeds should be sown in November. When clematis taxa are propagated on a small scale it is best to sow them in cases or flats filled with sowing medium, adding grit for better drainage. Seed should be sown evenly but not too densely. A space of 1 to 2 cm between seeds is best for most species. Cover the seeds with a thin layer of medium and spread a 5-mm layer of sand or grit on top. After watering they should be placed in a cold greenhouse or tunnel, in a well lighted position, but out of direct sunlight.

The seeds should be protected from mice, checked occasionally, and watered so that the soil is damp but not wet. When the seedlings reach the height of 5 cm they can be transplanted into containers.

The easiest seeds to propagate are: *C. tangutica, C. orientalis, C. flammula, C. alpina, C. macropetala, C. vitalba,* and *C. recta.* Some of these species can be ready for sale in one growing season.

However, it should be noted that clematis propagation from seed is rarely applied in commercial nursery production. It is better for this reason to only propagate from seeds those species that have stable characteristics, such as *C. vitalba* and newly bred hybrids. In other cases better results are achieved by vegetative propagation using cuttings or grafting.

GRAFTING

Grafting was the dominant method 25 to 30 years ago. It was thought that grafted plants were more resistant to disease and their production time was shorter. This method didn't work in practice.

When using the grafting technique, you first have to produce a 1-year rootstock; most often using *C. vitalba.* Secondly, you have to force stock plants 6 to 8 weeks in a warm greenhouse to obtain scions for grafting in January and February. Newly grafted plants are plunged into a moist medium in a warm greenhouse (20 to 22C) and covered by a plastic film. Then a salable plant can be grown in 6 to 8 months following grafting. This method increases the cost of production. Interestingly,

German nurseries use this method. In other cases some nurseries choose cutting propagation which can produce a salable plant in 12 to 16 months.

CUTTING PROPAGATION

Clematis can be propagated by micropropagation, but this is usually more expensive than by cuttings. Clematis taxa propagated by this method are more difficult to strengthen.

Propagation by hardwood cuttings is possible only for certain species such as *C. montana,* for example. However, this is limited and can only be applied in regions with a temperate climate.

Most often the propagation of clematis is achieved through softwood cuttings. One method is to collect cuttings between February and May from maternal plants raised in greenhouse or in plastic tunnels. You can also collect cuttings from May to autumn from plants growing in the open. Cuttings taken before mid-August root the best.

Cut shoots and prepared cuttings should always be moist, and if circumstances permit, kept in the cooler at a temperature between 4 and 7C. Most often single-node cuttings are prepared, making an upper cut 0.5 cm above the node and 3 cm below the node. One leaf is removed and the second leaf, if it is big, can be reduced. In single-node cuttings the bud touches the medium. In double-node cuttings the bottom node is the only portion covered. In our nursery we use only single-node cuttings.

Certain nurseries in Europe and the U.S.A. use cuttings with two nodes, removing both leaves from the bottom node and one from the top. A greater number of buds increases the chance for the cuttings to produce a new plant, but also increases the amount of work and requires more stock plant material.

In Japan the nurserymen do things differently. Cutting are prepared with two nodes cut 0.5 cm below the bottom node and up to 3 to 5 cm above the top node. They do not remove any leaves from the cuttings. These kinds of cuttings are supposedly stronger and a longer shoot protects against infection.

Cuttings can be treated with root initiation stimulators, although many taxa root well without the treatment. We treat the base of the cuttings with a powder containing 0.1% NAA, but also commonly used is the powder containing 0.2 to 0.3% IBA. Thick cuttings and/or hardened ones can be wounded at the base on a segment measuring 1 to 2 cm.

The medium used for cutting propagation can have a diverse composition. We use a mixture of peat moss and perlite (1 : 1, v/v), and sprinkle 2 mm of sand on the surface.

It is not wise to stick cuttings too densely since it increases the potential for disease. Depending on the size and strength of the cuttings and length of the rooting period, we stick between 400 and 800 cuttings m^{-2}.

After watering in the cuttings, it is advisable to spray fungicide which protects against *Botrytis* (we most often use Rovral). The cutting cases are tightly sealed with 0.02-mm milky plastic film. Heavy shading of clematis is used throughout the rooting process. It takes about 4 to 8 weeks to root cuttings. When the cuttings root we harden them and remove the plastic film.

In England various types of plastic film protection systems are used . Cases can vary in height between 50 and 150 cm. Mist is applied manually or automatically. In regions of Japan where there is a high level of humidity, propagators use a white, dense shading material. And as I see it, mist is rarely needed in rooting clematis,

however, some nurseries in Europe, U.S.A., and Japan apply this method successfully.

Clematis cuttings rooted during spring or autumn root best when the medium temperature is between 20 and 23C during the day and 17C at night.

Electrical heating systems are less expensive and simpler to install, however, heated water circulating in pipes costs less to maintain. Heating pipes are placed in sand or concrete and flats are placed on the top for the duration of the rooting. Concrete is easier to disinfect but sand ridges allow for better moisture containment. Additional application of CO_2 into the air (800 to 1000 ppm) provides an environment for better rooting.

In late autumn and winter rooting of clematis, the lengthening of the day through artificial lighting speeds up the rooting. The best way to do this is to interrupt the night every 3 h for 30 min beginning 1 Sept.

In the spring rooted cuttings are planted out until mid June in 1- or 2-liter containers. If roots are established by the end of July, clematis could be planted in 7 cm × 7-cm or 9 cm × 9-cm pots. Later-rooting plants should be planted the following spring.

During summer and autumn propagation, cuttings are kept in tunnels until November; then we lift, clean, grade, and tie them in bundles of 25 plants. The bundles of clematis are lightly covered with moist peat moss, placed in plastic cases, and put in a cooler at a temperature between -2 and 2C. Species sensitive to lower temperatures should be kept at temperatures above 0C: *C. montana* and *C. texensis*. Some nurseries keep cuttings as they were rooted in flats in the cooler throughout the winter.

TRANSPLANTING

In our nursery clematis planting begins in March when the plants are removed from the cooler and potted. The stronger cuttings (those with 3 or more thick roots) are planted in 2-liter pots (14 cm). Weaker cuttings are planted on 0.5-liter pots (9 cm × 9 cm × 9 to 10 cm).

We use a medium composed of peat moss, bark, styrofoam, and sand (5 : 3 : 1 : 1, by volume) with and added 2 kg of dolomite, 2 kg of chalk, and 2 kg of Osmocote, 5-6 month release m^{-3}.

The 2-liter-potted plants are placed outside and staked with 90-cm bamboo canes. When newly grown shoots reach between 40 and 90 cm they are cut at the second node. From those node buds grow 2 to 3 shoots, which are tied 2 to 4 times to the bamboo stick. During the course of 6 to 8 weeks plants reach a height of 90 cm.

MARKETING

Colorful photo labels with the name of the plant are attached and plants are packaged into wooden cases of 25 (40 cm × 60 cm × 25 cm). During summer and fall we sell approximately 60% of the clematis which we produced in containers. The rest of the plants, after overwintering, are sold in the spring.

Throughout the winter the majority of the plants are kept in tunnels, covered with a double layer of transparent plastic. We prepared the plants for overwintering in November. In the nonheated tunnels we apply a 2-cm layer of pine bark on the containers. In the gas-heated tunnels the containers are not covered with bark, but are maintained about -4C. Clematis which cannot be placed in the tunnels due to lack of space are left outside on a well drained, sheltered field. Containers are

covered with 5-cm layer of pine bark. Smaller clematis in 0.5-liter containers (9 cm × 9 cm × 19 cm) are prepared in the same manner, as I mentioned earlier, using bamboo canes 40 cm long. We sell these packaged in plastic bags with large colorful tags or in colorful cardboard packages. We sell these in a box of 24 plants containing six colors of clematis.

I believe that the production of clematis will continue to grow and that the plant has an excellent market potential with appropriate promotion.

Innovative New Plants and Future Trends

John E. Elsley
Wayside Gardens, Hodges, South Carolina 29695-0001 U.S.A.

OBJECTIVES

I will attempt to outline some of the present and future trends in the field of ornamental horticulture in North America and illustrate these trends with a selection of new plant introductions which I personally feel are of potential outstanding ornamental landscape merit. My personal instincts regarding trends have been formulated from information gathered from a range of sources including: commercial growers, professional and amateur horticulturists, and especially from customers of our retail mailorder company.

General Trends in Marketing and Merchandising.

- Past decade has seen an escalating demand at consumer level for more unusual plants of outstanding ornamental merit.
- Consumers are now offered an ever increasing range and diversity of plants from an increasing number of sources—mass retail merchandisers are for example, increasingly emphasizing the importance of diversity and quality of their plant offerings. These mass retail merchandisers are assuming an increasingly important role in the marketing of live horticultural products.
- Consumers are becoming more informed and knowledgeable, requiring products which will fulfill specific needs, combined with the potential of cultural success.
- Increased knowledge combined with a wider choice of sources is creating consumers who are demanding "value for money" (i.e., given products assume a perceived value).
- Improved and increased consumer education is going to be vital as demand for our products increases—ultimate consumer satisfaction and success is critical!
- Education will increasingly be targeted and focused on a more regional and local basis. Cultural methods and product suitability are critical factors in such a vast geographical area as North America, therefore, horticulture is destined to become more regional in many facets.

Specific Trends Related to New Plant Introduction.

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Specific Trends Related to New Plant Introduction.

- Individual plants should, where possible, exhibit extended seasonal ornamental interest. In addition to floral features: habit, foliage, fruits, and bark are important ornamental assets.
- With many landscapes decreasing in size, subjects with a compact growth habit are desirable.
- Resistance to diseases and pests. Subjects should be "environmentally" friendly. I can envisage much tighter regulations on the use of chemicals in both home and commercial landscapes.
- Plants that succeed with reduced maintenance (i.e., pruning and watering) will always be popular.
- From an industry "credibility" standpoint new introductions should ideally be improvements over existing offerings.
- Also from a "credibility" viewpoint it is imperative that as producers we market plants "true to name" — understanding the implications of vegetative vs. seed propagation is critical.

NEEDLE-LEAF EVERGREENS

***Cryptomeria japonica* 'Gyokuryu'.** Performed well in the Atlanta Botanical Gardens conifer trials; tolerant of heat and humidity; handsome dark green foliage.

× *Cupressocyparis leylandii* 'Golconda'. A European selection; intense golden-yellow color, appears to hold color well in winter and very little summer burn.

***Pinus contorta* 'Taylor's Sunburst'.** Selection of the lodgepole pine with golden-yellow new spring foliage; upright growth habit; attractive bark.

***Thuja plicata* 'Spring Grove'**. Selection made at Spring Grove Cemetery, Cincinnati, OH; foliage holds color well in winter; deer and bagworm resistant; very useful sheared; snow resistant; rapid-growing evergreen screen.

DECIDUOUS TREES

***Acer pensylvanicum* 'Erythrocladum'.** Spectacular coral-pink-red stems with distinct white striations in winter; fantastic in winter landscapes; outstanding golden-yellow fall color.

***Acer palmatum* 'Tamukeyama'.** This member of the dissectum group is considered by many growers to be the best of the purple-leaved types on account of its ability to retain its desired purple-red leaf color throughout hot, humid summers.

***Acer palmatum* 'Shaina'.** Originated as a witch's broom on *A. palmatum* 'Bloodgood'; dense compact growth developing a layered outline; dark red leaves densely arranged on truncated shoots; ideal for small gardens.

***Amelanchier* ×*grandiflora* 'Forest Prince'.** A Roy Klehm selection; clear, healthy, leathery foliage plus excellent orange-red fall color; profuse, fluffy pure-white flowers produced along the length of the stems, not just at the tips.

***Betula nigra* 'Little King', Fox Valley™ birch.** Discovered by Jim King, Oswego, IL; dense, compact oval-rounded growth habit with branches down to ground level; glossy, healthy mid-green foliage; exfoliating bark enhances winter ornamental effect; 10 ft high × 12 ft wide in 20+ years with no pruning to achieve its

desired shape; tolerates moist soils; ideal for small gardens and landscapes.

***Cercidiphyllum japonicum* f. *pendulum* 'Amazing Grace'.** Discovered in a seedling population by Theodore Klein, Crestwood, KY; outstanding specimen growing in Spring Grove Cemetery, Cincinnati, OH; mound of gracefully weeping branches clothed in attractive blue-green orbicular-shaped leaves; apricot-orange fall color.

***Cercis chinensis* 'Avondale'.** A New Zealand selection; very prolific bloomer on an annual basis; dwarf compact, upright grower — ideal for small landscapes; tough, leathery foliage.

***Cercis canadensis* 'Cove'.** Selection made by Tim Brotzman, Madison, OH; weeping form with an umbrella-shaped crown; harder than *C.* 'Traveller'; excellent in winter landscape.

***Cornus florida* 'Spring Grove'.** Selection made in Spring Grove Cemetery, Cincinnati, OH; very heavy annual bloom; often blossoms are produced in pairs; disease (Anthracnose) resistant and very hardy.

***Cornus kousa* 'Wolf Eyes'.** Introduction from Manor View Farm, Monkton, MA; possibly the best variegated *C. kousa* selection; shows little, if any, leaf burn; prominent white marginal leaf variegation — very stable; thrives in sun or shade — in sun the leaf assumes an appealing curled appearance; pink-red fall color; heavy blooming with star-shaped flowers; vigorous, spreading growth habit.

***Cornus capitata* var. *angustata* (syn. *C. kousa* var. *angustata*).** Narrow, leathery evergreen foliage — fully evergreen in Zone 7; locate in a protected (wind) site; excellent heat tolerance; numerous smallish, white-cream blossoms.

***Magnolia* 'Butterflies'.** A Phil Savage hybrid (*M. acuminata* × *M. denudata* 'Sawada's Cream'); one of the finest of the new yellow-flowered magnolias; deep yellow color — abundant flowers before foliage emerges; forms a neat, compact small tree and is very hardy.

***Malus* 'Amberina'.** A Father John Fiala hybrid; strong semidwarf tree up to 10 ft tall; creamy white flowers followed by a profusion of persistent bright orange-red fruits; handsome deep green summer foliage turns golden in fall; good disease resistance.

***Quercus* 'Heritage' (*Q. robur* 'Fastigiata' × *Q. bicolor*).** Patented selection by Earl Cully, Heritage Trees Inc.; strong central leader with a dense, uniform, pyramidal crown, vigorous, more hardy than *Q. robur*, leathery, dark green foliage which is mildew resistant.

***Ulmus* 'Morton', Accolade™ elm.** A Morton Arboretum introduction; spontaneous hybrid of *U. japonica* × *U. wilsoniana*; extremely glossy, dark green foliage and rich golden-yellow fall color; good Dutch elm disease resistance together with excellent elm leaf beetle and leaf miner resistance; upright growth habit; excellent cold hardiness.

DECIDUOUS SHRUBS

Aesculus parviflora. An underutilized American native with a graceful airy feeling; ideal as an isolated lawn specimen or mass planting on slopes or banks; grows into a mound shape 8 to 10 ft tall × 10 to 15 ft wide; 10- to 12-inch perpendicular white flower spikes in mid-summer; appealing yellow fall color.

***Buddleja davidii* 'White Ball'.** A recent introduction from Boskoop, Holland; dense, dwarf habit, 4 to 5 ft tall × 5 to 6 ft wide; panicles of white flowers freely produced in mid to late summer, excellent for restricted spaces — a "natural dwarf".

***Calycanthus floridus* 'Michael Lindsey'.** Selected by Allen Bush; lustrous, dark green leaves turn a golden yellow in fall; red-brown flowers emit a strong fruity fragrance; dense, compact, and rounded habit; 5 ft × 5 ft in 10 years; ideal for small landscapes.

***Clethra alnifolia* 'Ruby Spice'.** A Dick Jaynes (Broken Arrow Nursery, Hamden, CT) introduction; fragrant flowers a rich rose color which is retained through the life of the blooms (deeper than 'Pink Spires'); tough, lustrous dark green foliage which turns yellow-gold in fall; salt tolerant.

***Deutzia* ×*hybrida* 'Magicien' (syn. *D. longifolia* 'Magicien').** Large freely produced flowers of a rich red-purple and white-edged petals; "eye catching"flowers.

***Hamamelis* ×*intermedia* 'Angelly'.** European (Dutch) selection; clear lemon-yellow, fragrant blooms in February/March, produced annually in profusion; color "carries" well in landscape.

***Hydrangea macrophylla* 'Tovelit'.** Outstanding clone with a dense and extremely compact habit (2 to 2½ tall); flowers are extremely long lasting, displaying a kaleidoscope of colors from a mid pink transforming to a luscious purple-mauve; attractive leathery, dark green foliage.

Hydrangea macrophylla 'Lemon Wave'. Eye-catching foliage, each leaf colored mid green with yellow and white mottling; beware of reversions.

***Hydrangea arborescens* ssp. *radiata*.** Brilliant white underside to each leaf; especially effective when wind blows, white, lacey fragrant flowers in mid to late summer; excellent woodland plant.

***Hydrangea quercifolia* 'Pee Wee'.** Compact form (2 to 3 ft tall × 3 to 4 ft wide); foliage turns rose purple in fall and remains attractive well into winter; ideal plant for small gardens.

***Rosa* 'Ombrée Parfaite'.** Gallica rose introduced in 1832; intense dark crimson flowers; one of the darkest colored within its group; intensely fragrant; an example of an "old fashioned" rose worthy of reintroduction.

***Rosa* 'Ausham', Geoff Hamilton™ shrub rose**. A recent David Austin English rose introduction; cupped-shaped, highly fragrant blooms; "old fashioned" look; good disease resistance; such characteristics contribute to the popularity of this group of hybrid roses.

***Rosa* 'Meideauri', Leonardo Da Vinci™ rose**. Meilland (France) floribunda of the Romantica group; many petalled, pink flowers of "old fashioned" form; sweetly fragrant; compact growth habit; high disease tolerance.

***Rosa* 'Meilavio', Traviata™ rose.** Meilland (France) Romantica group; large, red "old fashioned" type blossoms; high petal count; ideal for outdoor or indoor decoration; outstanding dark, leathery disease-resistant foliage.

***Rosa* 'Meiviolin' Pierre de Ronsard® rose (syn Eden Rose 88 rose).** Meilland (France); one of the finest climbers introduced in recent years; another Romantica rose; fragrant, pastel-pink "old fashioned" blooms produced in profusion during summer; excellent disease-resistant foliage.

***Rosa* 'Meitosier', Polka™ rose.** Meilland (France); another outstanding new climber within the Romantica group; unusual mandarin-orange color of the "old fashioned" flower form; disease-resistant foliage; tough, robust grower; new climbers are in great demand.

***Rosa* 'Meimodac', Royal Bonica™ rose.** Meilland (France); a recent introduction within the Meidiland group of landscape roses; deep pink flowers are freely produced over the summer months; a group of tough, disease resistant, easy care roses.

***Rosa* 'Meikrotal', Scarlet Meidiland™ rose.** Meilland (France); another recent introduction of a tough, low-maintenance Meidiland landscape rose; fully double, vivid scarlet blooms produced throughout summer and into fall.

***Rosa* 'Morplag', Playgirl™ rose.** An outstanding single, lavender-pink shrub rose from master American hybridizer Ralph Moore of Visalia, CA; blooms from summer to late fall — even till nearly Christmas in the South; excellent disease-resistant foliage; tolerates medium shade.

***Rosa* 'Noatraum', Flower Carpet™ rose.** This carefree landscape rose exemplifies how an intense and focused marketing program can make an "average" rose extremely and widely popular.

***Syring* ×*hyacinthiflora* 'Blanche Sweet'.** A Father John Fiala hybrid (*S. oblata* × *S. vulgaris*); tolerant of heat and cold; large panicles of multipetaled soft whitish-blue, tinged-pink fragrant flowers; flowers at an early age; good disease-resistant foliage; upright, compact grower (10 ft) — ideal for small landscapes.

BROADLEAF EVERGREENS

***Buxus sempervirens* 'Vardar Valley'.** One of the best forms of the species; originally collected in Yugoslavia by Edgar Anderson of the Missouri Botanical Garden, St. Louis, MO; neat, low-growing, flat-topped, mounded form; outstanding blue-green foliage.

***Daphne* ×*burkwoodii* 'Briggs Moonlight'.** Arose in the tissue culture laboratory of Briggs Nursery, Olympia, WA; reversed variegation of the popular D. 'Carol Mackie'; a narrow green margin on each leaf frames a broad and consistent yellow central zone, thus creating a most striking effect; surprisingly strong grower.

***Pieris* 'Flaming Silver'.** A European introduction which was a sport of 'Forest Prince'; young leaves are red with a pink margin which eventually turns a silvery white; a striking color combination which remains effective year round.

***Pieris* 'Bert Chandler'.** Raised by Australian nurseryman Bert Chandler over 60 years ago — a plant which truly deserves wider recognition; outstanding foliage

coloration early in season; leaves emerge a salmon-pink changing to cream and white before assuming a transition from light to a darker green; a spectacular "kaleidoscope of color"; shy in flower production.

***Rhododendron* 'Samoa'.** A David Leach hybrid; one of the breeder's finest red-flowered creations; very compact grower, 2 to 3 ft after 5 years; handsome, healthy dark-green foliage.

***Rhododendron* 'Capistrano'.** Considered by its hybridizer, David Leach, to be probably his best yellow-flowered hybrid; frilled, lemon-yellow blooms produced freely in large, rounded trusses; dwarf, compact habit; healthy dark green foliage.

VINES

***Clematis* 'Piilu'.** Recent introduction from Estonia; belongs to "patens group"; cross between *C.* 'Hagley Hybrid' and *C.* 'Mahrouyi'; handsome, six-tepaled flowers a light purplish-pink with wide, distinct red bars; first flowers are double, later ones emerge as single; heavy bloomer, even on young plants; very hardy growing to 6 ft tall; also good for container culture.

***Clematis* 'Blue Light'.** Double sport of *C.* 'Mrs. Chalmondeley'; large, double flowers are pale blue-violet to pale blue; very free flowering; flowers June through August-September; strong grower to 6 ft, also good in containers.

***Clematis montana* 'Freda'.** Deepest flower color of any *C. montana*; raised and introduced by English hybridizer Jim Fish in 1985; top award winner in Boskoop, Holland, trials; flowers a deep pink with darker pink-red margins to the petals; deep bronze foliage is a perfect foil for the flowers; compact grower which is ideal for container culture.

***Clematis* 'My Angel'.** New cross of *C. orientalis* × *C. intricata*; unique flower color, inside yellow/outside purple with a creamy colored edge; small, nodding flowers in profusion during August, September, and October; outstanding ornamental seed heads in fall and early winter — white fluffy; grows 6 to 8 ft tall.

***Clematis* 'Rogouchi'.** *Clematis integrifolia* hybrid originates from Japan; handsome, elongated, tubular, wax-like flowers of a rich blue-purple are produced all summer long; an ideal subject for scrambling through perennial plantings.

***Campsis* ×*tagliabuana* 'Indian Summer'.** A European selection of the *C. radicans* × *C. grandiflora* hybrid; trumpet-shaped orange-red flowers are profusely produced in large pendulous racemes in mid to late summer; shorter growing than other clones (up to 10 to 12 ft); also makes an excellent flowering pot plant.

***Parthenocissus tricuspidata* 'Fenway Park'.** Discovered by Dr. Peter del Tredici of the Arnold Arboretum, growing as a sport on a building near Boston's Fenway Park baseball stadium; glossy yellow foliage which turns a yellow-green in summer and brilliant scarlet in fall; performs well even in shade.

***Schizophragma hydrangeoides* 'Moonlight'.** A Barry Yinger introduction; striking foliage shaded and mottled a silvery-gray; outstanding yellow fall color; vigorous.

***Wisteria frutescens* 'Amethyst Falls'.** And introduced cultivar by Bob Head of Head-Lee Nursery, Seneca, SC; beautiful, fragrant lavender-blue truss of flowers

are produced even on young plants; much less vigorous than its Asian counterparts and blooms 3 weeks later thus avoiding late frost damage, then intermittently produces flowers throughout summer; good healthy foliage.

PERENNIALS

***Dendranthema* 'Emperor of China'.** Invaluable late flowering hardy chrysanthemum; clusters of silvery, old rose-pink, quilled petalled flowers; foliage suffused with crimson at flowering time; known in English gardens in the late 19th century.

***Echinacea purpurea* 'Leuchstern' (syn. 'Bright Star').** Outstanding clonal selection that must be vegetatively propagated to ensure trueness to name; large, bright rose-pink flowers; a splendid garden performer.

***Cimicifuga simplex* 'Hillside Black Beauty'.** Fred and Mary Ann McGourty introduction; handsome almost black foliage creates a perfect foil for the arching wands of pure white flowers in late fall.

***Delosperma floribundum* 'Starburst'.** An extremely hardy selection with striking purple and white flowers; full sun and easy grower.

***Helleborus* Royal Heritage Strain.** An outstanding seedling strain of the Lenten Rose developed by John Elsley in Greenwood, SC; emphasis on both foliage and flower characteristics; bold, handsome evergreen leaves gives year-round appeal; flowers are well shaped and exhibit a range of sumptuous colors over an extended blooming period from early winter through spring; tolerant of heat and humidity; deer proof; health and vigor are a hallmark of the strain.

***Hemerocallis* 'Rosy Returns'** — A Darrel Apps hybrid exhibiting many of the characteristics associated with the finer daylily hybrids; these characteristics include high bud counts, good flower color and form, repeat blooming, and self cleaning, together with healthy, disease-resistant foliage.

***Hemerocallis* 'Susan Webber'** — An enticing color combination that is usually only found in the southern evergreen-type daylilies; Flowers are an amazing 5 inches across and are a pearly pink with a heavy picotee edge of deep pink; highly sought after.

***Hemerocallis* 'El Desperado'** — A Patrick Stamile hybrid which exhibits many of the fine traits of modern daylilies; large, vibrantly colored flowers are a golden yellow with a burgundy halo and picotee edge; totally dormant daylily.

***Hosta* 'Guacamole'.** This Bob Solberg introduction is a sport of *H.* 'Fragrant Bouquet'; extremely vigorous; unusual avocado green and aqua-blue leaves remain appealing all summer and tolerate high sun levels without burning; prolific flowering of white and highly fragrant flowers.

***Hosta* 'June'.** A recent sport of *H.* 'Halycon' displaying great substance; golden leaves bordered by a blue and green shaded margin.

***Hosta* 'Paul's Glory'.** Recent introduction from Paul Hoffer, Perry, OH; golden leaves are banded by a significant green-blue margin and exhibit a heavy seersucker texture, outstanding!

***Leucanthemum* ×*superbum* 'Beauté Nivelloise'.** An old selection worthy of reintroduction; very large white blooms on extremely strong stems, no staking necessary; bold, leathery dark-green foliage.

***Lilium* 'Orienpet' Scheherazade™ lily.** Group of hybrid lilies resulting from crossing orientals and trumpets; more dependable garden plants than either parent group; summer blooming; large flowers of red-orange.

***Liriope muscari* 'Pee Dee Ingot'.** This recently selected lily turf retains the yellow-green color of its foliage into late summer; the foliage color is an excellent foil for the pale-lavender-colored flowers in late summer; vigorous.

***Paeonia* 'Green Lotus'.** Developed from the joint breeding of William Krekler and Roy Klehm; a new group of herbaceous peonies with general appearance of a parrot tulip; semi-double flowers open in shades of lime green and varying degrees of red candy striping.

***Paeonia* 'Pink Luau'.** An outstanding recent Roy Klehm hybrid which is one of the Estate Series of Peonies; sumptuous semi-double, rich rose-pink flowers.

***Phlox* ×*procumbens* 'Cabot's Blue'.** Early spring flowering clone with unusual colored flowers; extremely long blooming period — between 3 or 4 months; flowers are a striking pastel lavender-blue.

***Phlox maculata* 'Natascha'.** Striking new selection originating from Russia; unusual colored flowers are lavender-purple and white creating a "pinwheel" effect; highly disease-resistant foliage; flowers 3 to 4 weeks before *P. paniculata* clones.

***Pulmonaria* 'Majesty'.** Shimmering silver leaves are edged green; exhibits little if any leaf burn or powdery mildew; cool pink flowers in early spring; a gem for the shade garden.

***Rudbeckia* 'Indian Summer'/*Monarda* 'Marshalls Delight'.** *Rudbeckia* 'Indian Summer' is an annual with large, brilliant yellow flowers; prolific bloomer; may be perennial in some regions. *Monarda* 'Marshalls Delight' is a Canadian selection exhibiting outstanding disease resistance, especially powdery mildew.

***Viola grypoceras* var. *exilis* 'Syletta' (syn. *V. koreana* 'Syletta').** Eye-catching silver and green mottled foliage resembles that of the hardy cyclamen; light purple flowers in early spring; self seeding — an excellent groundcover for the informal shade garden.

INNOVATIVE ANNUALS

***Brugmansia* ×*candida*.** Now available in an increasing range of flower colors, few container plants can create such an impact in the landscape; full sun to light shade.

***Colocasia* 'Jet Black Wonder'.** Few tropical foliage plants can equal the visual impact of this large, handsome plant with almost black foliage.

***Cordyline* 'Red Sisters'/*Ipomoea* 'Margarita'.** An eye-catching foliage combination at the Chicago Botanical Garden; the red leaves of the *Cordyline* are bold and effective with the vigorous lemon-green of the *Ipomoea* foliage.

***Lantana camara* 'Carlos'.** Vibrant red and yellow flower clusters cover this tough, compact growing plant through summer and fall; full sun in beds or containers; thrives in the most intensive heat and humidity.

***Musa acuminata* (syn. *M. zebrina*)/*Caladium* 'White Christmas'.** A simple yet bold and aesthetically pleasing foliage combination for containers or beds in shade.

***Solenostemon* (coleus) hybrids.** An increasing range of vegetatively propagated clones are now available, many exhibit stunning color combinations; ideal for bedding or container usage.

Strobilanthes dyerianus. A vivid metallic sheen with a rich purple venation complimented with a purple-red underside, hardly describes the uniqueness of this foliage; a shade lover of outstanding merit!

***Vigna caracalla* "snail vine".** An impressive, highly fragrant twining climber producing tight clusters of "snail-shell like" white to pink-purple flowers in summer; extremely vigorous.

QUESTION BOX

MODERATED BY RALPH SHUGERT AND BRUCE BRIGGS

RALPH SHUGERT: Question for Mark Bricker. Your have touched a nerve! Why, given the tremendous nursery industry in Ohio, does the City of Columbus have to compete with private industry?

MARK BRICKER: The problem the city has run into the last few years is it has to put everything out to bid. Low bid wins. If we bid for a specific tree we often receive another in its place so the city is not receiving what it wants. With the pot-in-pot production we are growing what we want for our streets. We are really not competing with you because we are growing plants that we often can not get.

RALPH SHUGERT: Question for Mark Bricker. How are finished trees pulled out of the ground?

MARK BRICKER: I pull them with my two arms. We have a Low Boy and our rows are on 15 ft centers. I go down the rows and pull them out and place them on the Low Boy. The trees are premarked as to their final location before lifting.

ROGER FICK: In the state of Illinois a public works director had a similar problem. They obtained an ordinance that allowed municipalities to enter into a 10-year contract for the purpose of obtaining shade trees. In this group there are villages awarding contracts 5 years in advance for specific species.

MARK BRICKER: The City of Cincinnati does not have a nursery and it contract bids for plants.

RALPH SHUGERT: Question for Dave Thompson. Do you wax the *Acer palmatum* summer grafts?

ALAN JONES: No he does not. They callus very quickly during the summer, in 2 to 3 weeks. That is one of the advantages of grafting at that time.

BRUCE BRIGGS: What soil type do *Trillium* species need? Do they need some "real" soil in a container mix?

LEO BLANCHETTE: It depends on the species. In a container I find that *Trillium grandiflorum* does best at a pH of about 7 to 7.5. *T. erectum* likes a more acidic soil. Your really have to look at where they grow in the wild.

STEPHANIE SOLT: I just use a soilless medium, but have not researched soil requirements.

BRUCE BRIGGS: Question for Leo Blanchette. Has the speaker attempted wounding *Hosta* to promote eye development?

BILL BARNES: You can do several things with hosta. You can decapitate them and spray them with 2000 ppm of benzyladenine to stimulate bud break. When buds break fertilize heavily to stimulate bud growth. When the shoots are 3 to 4 inches long cut the shoot off, place it under mist and it will root in about 5 days, do not use hormone treatment.

BRUCE BRIGGS: Question for Joerg Leiss. You mentioned that propagation by root cuttings of *Phlox paniculata* can help reduce powdery mildew problems. Could you elaborate on this further?

DICK BIR: Joerg lives in a much cooler place and his comment on not seeing it in Europe is also related to the optimum temperature for growth of the organism.

CHARLES HEUSER: He also pointed out to me that he received more moisture on his leaves and that washed the spores off.

DICK BIR: It is humidity not rainfall that is the problem. I know one individual who washes down his phlox to reduce the mildew and it works.

DAVE BAKKER: One year we had a very wet summer and we had no mildew on roses. The rain washed it off. In the fall the rain stopped and mildew developed.

BRUCE BRIGGS: Question for Leo Blanchette. How do you overwinter the notched pieces of trillium crowns?

LEO BLANCHETTE: The notch is made on the top half of the rhizome with one notch on one side and one on the other just behind the shoot. The notch is very small. The rhizomes are then grown on.

RALPH SHUGERT: Question for John Bakker. Can you subdivide your large propagation facility for smaller quantities of specialty crops? I understand you can vary bottom heat, but what about top temperature, humidity, watering, shading, or sun?

DAVE BAKKER: Yes. All the misting lines are zoned, heat lines are zoned, and we can use drop sheets to divide the greenhouse in additional spaces.

RALPH SHUGERT: Question for John Bakker. With your new technological propagation facility in place for the past 4 years, do you feel you have reached a level of profit where this facility has paid for itself with improved rooting percentage, growth, savings on labor, etc. Also do you have data that supports its success?

DAVE BAKKER: Yes we do. As an example, because the greenhouse opens up we do not have to do any shading in the field when we plant them out — that is a labor savings that runs into the thousands of dollars because we no not have to move screens.

RALPH SHUGERT: What are the advantages and disadvantages of Nurticote? Does anyone incorporate slow-release fertilizer into their propagation medium?

DAVE BAKKER: We have found in our northern colder conditions that it does not work well; however, in Florida they love it. It is a temperature factor.

GAIL BILLINGSLEY: In the winter time, no; however, in the summertime yes we use it with our softwood cuttings. We direct stick in 2½ to 4-inch pots and use Nutricote 18N-6P-8K (type 140 to type 180). The temperatures in our houses in the summer run around 85 to 90F.

BRUCE BRIGGS: What herbicides can and can not be used on rootstocks for conifer grafting?

BRUCE BRIGGS: I know in the west we have had some problems with Surflan on peaches. I can not answer on conifers.

BRUCE BRIGGS: Has anyone had consistent success rooting *Daphne cneorum* 'Eximia"? What about growing it on in containers?

BRUCE BRIGGS: We have rooted it. Cuttings should be taken off of mature plants with hard wood in late August to September. Soft cuttings just do not root. *Daphne* ×*burkwoodii* 'Carol Mackie' can be rooted from softwood cuttings.

RALPH SHUGERT: Question for Charles Tubesing. Can you recommend hardy yellow magnolias that will grow in the Ottawa area (Canadian Zone 5a)

CHARLES TUBESING: I would recommend the *Magnolia* ×*brooklynensis* types such as 'Yellow Bird' and 'Ultimate Yellow'.

RALPH SHUGERT: Question for Charles Tubesing. There was a magnolia in the auction several years ago named 'Goldfinch', where does it fit? Which cultivars would you consider commercially available? Which would you recommend propagators work on?

CHARLES TUBESING: 'Goldfinch' is a Savage hybrid, upright in habit, and with light yellow flowers. It is one of our earlier flowering yellow types.

As for the cultivars to grow, I would recommend 'Elizabeth', 'Yellow Lantern', 'Butterflies', and 'Gold Star'.

RALPH SHUGERT: Question for Mark Bridgen. With *Pulmonaria*, what propagation medium is used, how deep are the root cuttings buried, and what is the moisture level?

MARK BRIDGEN: For our research purposes we use Metro Mix 360, and place the root pieces 1 inch deep.

RALPH SHUGERT: Question for Mark Bridgen. With *Pulmonaria* root cuttings is there any preventive fungicide program and what are typical response times?

MARK BRIDGEN: They respond in 4 to 8 weeks. We typically use a fungicide dip with root cuttings.

BRUCE BRIGGS: Question for Brian Decker. How do you remove the needles from spruce scions without damaging the scions?

GEORGE OKKEN: With spruce grafts we just use the back of the knife and scrape them off. Keep the scraping to a minimum and as light as possible.

BRUCE BRIGGS: What causes dieback in *Juniperus scopulorum* 'Wichita Blue' and what is the answer for control?

RALPH SHUGERT: The control was benlate, but we don't have it any more. Cleary® 3336 with three applications 20 days apart. If you prune it off, disinfect after each cut.

BRUCE BRIGGS: Is anyone in the room using a system where by you have something in the water that will kill fungi and water molds before they germinate. You want something like Clorox but which is not toxic to plants and can be constant in the water.

GEORGE OKKEN: We treat all our wood benches with copper napthanate every year.

BILL BARNS: The best thing that I know is ozone generators that inject ozone into the water lines. It interacts with the water and controls this problem.

BRUCE BRIGGS: In the west some work is being done with ZeroTol® (common name = hydrogen dioxide) that looks promising.

The Ethics of Plant Exploration

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INTRODUCTION

Throughout recorded history, man has collected plants from foreign lands and utilized them in agriculture, industry, medicine, and for garden uses. Indeed, worldwide, most of our crops originated in places other than where they are being cultivated. In the U. S.A. for example, wheat has a center of origin in western Asia, and soybeans, little known until this century, have a center of origin in China. Similarly, many of our most important landscape plants originated in foreign lands. Frank Meyer first introduced the callery pear in the early 1900s (Cunningham and Meyer, 1984). The original Kurume azaleas were first shown in this country at the 1915 San Francisco Exposition Japanese Pavilion. Today, introduced plants are a critically important component of landscapes, particularly in urban and suburban areas. Without introduced plants our cities and suburbs would be far bleaker and more hostile environments. Thomas Jefferson wrote in 1790, "The greatest service which can be rendered any country is to add useful plants to its culture." Allan K. Stoner, leader of the Agriculture Research Laboratory, states, "No one country or even one continent has all the genetic resources necessary to sustain crops at the level that is needed today. Conditions and needs continue to change, and collecting genetic diversity is how you have the genetic resources to deal with them." (Kaplan, 1998.)

Today the widespread destruction of forests worldwide makes the conservation of plants through plant exploration and ex situ cultivation in gardens all the more urgent. In China, a population of 1.3 billion people continues to press into more remote areas and few natural or semi-natural refuges remain. Some potentially important species like *Eucommia ulmoides*, are nearly extinct in the wild and only exist in cultivation. *Eucommia* is not only a highly drought-resistant urban street tree candidate, but it is also the source of medicine which has been widely used for many purposes in China and is currently being evaluated in the west. Insuring the survival of species likes *Eucommia* is likely to involve plant exploration and cultivation in curated gardens.

Throughout the 19th and 20th century, most plant exploration has been done under the auspices of institutions like the Arnold Arboretum, the Royal Botanic Gardens, and the U.S. Department of Agriculture. Historically, difficulties resulting from politics, communication, and travel have made plant exploration dangerous, expensive, and time consuming. For the most part, only education and research institutions could make the long-term commitment needed for a successful program. However, with the advent of instant worldwide communication, the breakdown of political barriers and inexpensive and convenient air travel, the opportunity to collect plants is more widely available. With this opportunity also comes the responsibility to collect in an ethically responsible manner.

PLANT EXPLORATION

International Protocols. Today, a myriad of laws can govern the collection of plants and the genetic resources of plants. "A new reality has come to those of us who collect, cultivate and study the exotic—people no longer have unchallenged and inherent rights to take plant material from the wild" (Folsom, 1996).

The genetic material of plants is property of the host country. Before any collecting is done, permission of the host must be granted. Usually, before permission is granted a formal exchange agreement must be executed with an institution within the host country. Often this includes a long-term commitment to scientific and educational exchange. Most countries will not give this privilege casually to private individuals.

The *United Nation Convention on Biological Diversity*, a legally binding treaty, opened for signature at the 1992 Rio Earth Summit. It is now international law in roughly 170 nations. Countries that have signed the Convention agree to facilitate scientific access to genetic resources, while users agree to share the benefits from the use of those genetic resources with the source country. Though the U.S. has not signed this convention, the U.S.D.A. and most U.S. institutions are committed to following its spirit. Exactly how that is interpreted continues to evolve (Galbraith, 1998). However, equitable sharing of commercial benefits of plants should be an important goal for any ethical plant explorer.

Field Protocol. The collection of seed and other genetic material in the field should be done in a professional way and thoroughly documented with notes and herbarium specimens. Sound field documentation is critically important to any long-term evaluation program. Often colleagues and students in the host country are not fully aware of modern documentation methods. Therefore, teaching current techniques is one way to help the host country build its conservation program. Likewise, all genetic collections, voucher specimens, and data should be freely shared with hosts.

Collectors must comply if certain areas or taxa are declared off-limits by the host. Of course, no collecting should be done that in any way endangers or compromises a natural population (USDA/ARS, 1998).

Importation Protocols. The danger of inadvertently introducing an insect pest, disease, or noxious weed through the importation of plants is well documented. Gypsy moth, Dutch elm disease, and kudsu are all reminders of the disasters that are possible if proper procedures are not followed.

To help prevent pest introduction, most countries have laws controlling the importation of plants and seeds and the ethical plant explorer abides by the law. Collectors must contact appropriate regulatory officials in advance for information and assistance on specific regulations. It is always necessary to meticulously clean and examine all collections and is usually best to pack cleaned seeds in clear polyethylene bags for ease of subsequent inspection. Plants and seeds must always be declared to customs officials at the port of entry. CITES regulations should be observed regarding the international transfer of endangered plants.

Post-trip Activities. It is important to remember and acknowledge the assistance and hospitality provided by the foreign hosts and credit should be given to them in papers and talks that result. It is imperative that collectors be respectful of local customs and traditions. Not only would disrespect be impolite, but in this age of

instant communication, word of your indiscretions is likely to get back to the host country. Most importantly, collectors need to follow through on commitments for exchange and fostering ongoing relationships.

Sound evaluation is a critical part of any plant exploration program. Plants must be evaluated for adaptability and landscape merit. It is not fair to customers and your good name to rush plants to market that have not been fully evaluated. Furthermore, plants that have any potential to become weedy invaders must be allowed to reach sexual maturity and evaluated for their invasive potential. If found to be invasive these weeds must be controlled or eliminated.

CONCLUSION

Though the world is shrinking and the difficulties of travel and communication are easing, in many ways today's conditions are more complex than ever to the plant explorer. The need for conserving and wisely utilizing plants has never been greater. However, conservation goals and human needs for plants need to be balanced with economic fairness, political realities, and environmental appropriateness.

Plant exploration continues to play a critical role in conservation but must be done in a scientific, professional, and ethical manner. What constitutes ethical practices is still being debated and defined. It is clear that grabbing a few plants abroad and smuggling them into your home country is simply not ethical both legally and environmentally.

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Propagating in The Information Age: Does Our Nomenclature Provide Enough Information?

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Do your customers really know what they are buying? Are we doing a good enough job of describing our products? Are there opportunities awaiting those who better educate their customers, thereby building loyalty and increasing value?

First we'll discuss problems with the prevailing nomenclature and catalog description practices. In the perennial trade it seems that nearly everyone grows *Penstemon* 'Husker Red'. For the first few years after we acquired the plant, we propagated it vegetatively and everyone was happy. I then found out from a customer that most growers were growing theirs from seed, as the lovely seed flats they sold me testified, they were doing fine from seed, as the plants had consistent good deep red color. All went swimmingly for a few more years until our seed batches became inconsistent. We had to "rogue" the seedlings out, but the results were more inconsistent than we would like. As of this year, we're growing them vegetatively, letting our customers know that, charging more for a superior product, and differentiating ourselves in the marketplace. This gives you and your customers "bragging rights", they know they're getting the genuine article. Casting doubt on others undifferentiated products is just an unanticipated positive consequence.

Other problems come in where a given plant has a very wide native range, covering several climate zones. I remember well hearing J.C. Raulston give a talk entitled "The Importance of Provenance" at the native plants conference in Cullowhee, North Carolina. He used *Acer rubrum* as an illustration. It grows from Florida to Maine. If you just list as *A. rubrum*, does a distant customer have the information to make an intelligent decision? Will a plant from Alabama thrive in Massachusetts? All I'm suggesting is that we list the information and let our customers make up their minds. You know the old expression "no one has ever lost a dime underestimating the taste (intelligence?) of the American people. Well that may hold some water, but I would rather have a business that operates on the other end of the spectrum and recognizes and appreciates an increasingly sophisticated market.

I also think that other anecdotal information helps one's catalog and hence helps the business distinguish itself .When the full story of the origin of a selected plant is told, several good things are set in motion. The customer learns more from you than from your competitors, you and your business are looked upon in a more favorable light as more authoritative and knowledgeable, and the person who introduced the plant is recognized. This is often a great thrill and a trust builder. Does it do me any good to pretend that *Aster novae-angliae* 'Purple Dome' was a North Creek introduction? Even though we were the first to have it, I think that we're much better off telling the customers that it was a Mt. Cuba introduction. That's good company to keep and Dr. Lighty was also happy to get us early divisions of a few other introductions as well. When we create and tell stories about plants we are adding something extremely valuable to the product-information, knowledge, and goodwill. When I visited Coen Jansen, a Dutch plant breeder and small retailer and showed him my catalog, listing him as the source for *Nepeta grandiflora* 'Dawn

to Dusk', he treated me like a king! I had published him in North America! He promptly gave me several more new goodies that we hope will be introductions in the future.

Most all other trades describe their products much more fully. Imagine all of the available info for a car, computer, or house. These markets grow in part because they are constantly innovating, describing those innovations, and setting themselves apart. So I believe that developing more "intellectual capital" is a part of the maturation of our industry.

There is a growing market for "green" lumber that is not harvested from old growth forests, an exploding market for organic and whole foods, both developments that I applaud. The reason that they get more for their products is that they enumerate the differences and appeal to the intelligence and desires of their customers.

Several segments of the market are demanding more information. Lots of ecologically minded landscape architects are specifying regional plant provenances that are also open pollinated. This market is not for everybody and it's tricky, but what's the harm in them specifying your material? By giving out a bit of info, you can occasionally be the supplier of choice!

We at North Creek have developed our own little codes to give out the genetic information about the plants that we offer — not necessarily exactly how we propagate them.

- **VEG**. This is a true cultivar. A single selected plant named and propagated vegetatively. All plants are genetically identical (hopefully). These we do from cuttings or divisions.
- **SCL**. A code we made up. We wanted to distinguish between identical plants—genetically—and a very similar populations that do have some variability. A seed cultivar is either a deliberately bred and commercially available cultivar like *Echinacea purpurea* 'White Swan' or a true-from-seed cultivar with distinct differences from the species, like *Aquilegia canadensis* 'Corbett'. These plants have consistent ornamental characteristics with a bit of individual variability. Both the "veg" and the "scl" are cultivars in taxonomic terms, but nonetheless, very different animals.
- **OP**. This is a plant that is open pollinated, and quite genetically variable (variety is the spice of life). I prefer to list it as "OP" rather than say seed propagated because I may need to make 2000 out of 1000 by cutting or divisions, after all a propagator always needs access to his full bag of tricks.
- **TC**. A plant propagated by tissue culture. At this point, we don't use this in our catalog, but we will when we add more "TC" crops. A funny things happen — have you seen those advertisements that offer *Hemerocallis* 'Happy Returns' and mention specifically not "TC" produced!, i.e. have not mixed up the true plant. I know that this might not make the "TC" producers happy, but for better or worse, at least at this early stage in the development of the technology, there have been problems and variability, particularly in *Hemerocallis* and *Hosta*. Indeed, with *Hosta*, "TC" is often the source of the variation that leads to new cultivars.

These symbols are just my suggestion, but they're simple and convey a lot of valuable information. I recognize that not all nurseries will feel that this system is for them. It is particularly valuable for those of us in the starter business. With provenance, listing that information will be more helpful to a regional than a national grower. I think that we have to remember that our goal is for our plants to succeed in gardens and landscapes, giving the ultimate customer a successful experience. Just selling plants that look good in the container, but will not necessarily be well adapted in the customers region is a phyrric victory, making profits now but perhaps not sowing the best seeds for the future.

It would also be helpful if all new introductions would be registered listing propagation info so propagators like myself will know how to propagate it. I know that it takes time, and I must admit that we've named three cultivars and have not registered them. Even our esteemed former Executive Secretary Darrel "The Good Dr." Apps confessed in a moment of weakness that he had introduced a named form of *Astilbe* and not gotten around to registering it, considering it just a perennial and not a *Hemerocallis*, with which he has assiduously registered.

Finally, I think that the International Plant Propagators Society is the best place to have this discussion, and look forward to your comments.

A Diversity of Hydrangea

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The genus *Hydrangea* is one of the richest and most diverse group of plants known to horticulture. In the most recent taxonomic review 37 different species and 17 subspecies were identified. L.H. Bailey had the count at roughly 80 species. As you can clearly see taxonomists tend to lump, while horticulturists prefer to split. In any case the classification of *Hydrangea* is muddy at best. Please forgive me if my classification differs from yours.

My intention today is to give you a very brief overview of the genus *Hydrangea* and those species that have the greatest potential as landscape ornamentals. For each species I will discuss several of the more interesting cultivars to show the wonderful diversity available for horticultural use.

Hydrangea anomala* ssp. *petiolaris (eastern Asia, Zone 4) is a beautiful vine that climbs by aerial rootlets. It has glossy, heart-shaped leaves and white lacy blooms (corymbs) in early summer. It can be grown as a shrub, groundcover, or as a vine depending upon culture. You have not lived until you have seen this plant in full bloom climbing a tall tree. It is very happy on a north facing or otherwise shady brick wall. I know of four cultivars, but the availability on all is quite limited. 'Skylands Giant' is a selection with very large blooms; 'Cordifolia' is a selection with very small leaves, and I have seen a very nice unreleased and unnamed variegated selection.

Hydrangea arborescens (eastern U.S, Zone 3), is a wonderful, hardy plant that blooms in midsummer. It has the great advantage of blooming on the current seasons wood. This results in very reliable blooming regardless of frost or winter injury. The species is not a spectacular plant with its small mostly fertile flowers, but there are some noteworthy cultivars. 'Annabelle', introduce by Joe McDanials of Champaign, Illinois, is the most commonly grown cultivar. One is hard pressed to find any other cultivar of *Hydrangea arborescens* being sold today. There are some nurseries unknowingly selling *H. arborescens* 'Grandiflora' as 'Annabelle'. True 'Annabelle' has very large, perfectly symmetrical blooms, while the blooms of 'Grandiflora' are often quartered and irregular. 'Annabelle' is very showy, but due to the mammoth size of its blooms it often collapses under its own weight. There is a need for more selections of *H. arborescens.* I would like to see a sturdier mophead than 'Annabelle' and I feel there should be more lace-caps in the trade. I personally find *H. arborescens* subsp. *discolor* which has light downy hair beneath the leaves and *H. arborescens* subsp. *radiata* which has snow white coloration on the leaf underside more graceful and delicate than 'Annabelle'. We are searching for improved clones of *H. arborescens* and hope to find one worthy of introduction.

Hydrangea aspera (Asia, Zone 7) is a large 10 to 12 ft woody plant with rough and bristly leaves. The flowers are attractive lace-caps ranging in color from a light mauve to violet with white- to lilac-colored outer florets. The flowers appear in mid to late summer. *Hydrangea aspera* subsp. *sargentiana* is a large plant, 6 to 12 ft tall, with thick wood and very large, densely pubescent leaves and long internodes. It was

discovered by Ernest Wilson in 1908. The plant attracts much attention when it is covered with pale purple and white lace-cap blooms in mid summer. If you have a large, well protected, shady space in your garden this plant is a treasure to grow.

Hydrangea heteromalla (China, Himalayas, Zone 4) is a little known, variable species that may have great unrealized potential as a hardy landscape shrub or as a small tree. Listed in some books as hardy to Zone 7, the hardiness of the species is most likely based on an individual plant's provenance. I have found the plant growing happily in Minnesota, so I know this plant can be very hardy. While it is reported to grow 30 ft tall, the tallest plants I've seen have been closer to 15 ft. In many ways it looks like a *H. paniculata* but with flat lacy corymbs. It also blooms on the current seasons wood which is a great asset. The white flowers appear in midsummer before *H. paniculata* and fade a brick pink to an orange brown. The bark exfoliates with age and can be quite attractive. The cultivar 'Nepal Beauty' (perhaps the same plant as 'Yelung Ridge') has striking blood-red leaf petioles and red young leaves. There are several cultivars being sold, but we are still evaluating the possibilities of this plant.

Hydrangea involucrata (Japan, Taiwan, Zone 7) is a worthwhile ornamental just for its flower buds alone. The terminal flower buds look like large round white marbles. The buds are unique for *Hydrangea* in that they are protected by four large bracts, hence its name. This is a fine plant, roughly 2 to 3 ft tall, with a mounded shrubby habit. Its small, lace-cap blooms are a light blue which fade to mauve with age. The cultivar 'Hortensis' has double white flowers which change to pink. This plant is worth consideration for milder climates.

Hydrangea macrophylla (Japan, Korea, Zone 5, syn. *H. macrophylla*) is a maritime climate plant that prefers ample moisture and filtered shade. Flowers may be either mopheads or lace-caps depending on the cultivar. A few plants have intermediate flowers. The flower color is variable depending upon the cultivar and the availability of aluminum ions in the soil. Acid pH frees up available aluminum ions and results in blue flowers, while alkaline pH and/or phosphorous binds aluminum and yields pink flowers. Some cultivars have more or less stable coloration. Container growers often have a difficult time getting blue flowers. This happens even at low pH levels because of a lack of aluminum in most potting mixes and the presence of phosphorous. In container production aluminum must be supplied and phosphorous must be limited to produce blue flowers

Hydrangea macrophylla forms its flower buds in the autumn and overwinters them to produce the next year's flowers for this reason, flowering is often diminished if the plant is hit by a early autumn frost, a late spring freeze or untimely pruning. The cultivars 'All Summer Beauty' and 'Vindool', DOOLEY^{TM} hydrangea have gained popularity because growers have reported reliable blooming. These plants may have either the ability to produce spring flower buds, or they may be producing an adequate number of buds lower on the stems or near the soil line where they are more protected. Either way, growers are reporting reliable flowering.

There are several dwarf or compact cultivars. 'Pia' (syn. 'Winning Edge', 'Pink Elf') is a very popular dwarf selection with deep pink flowers. It matures under 3 ft, but can occasionally revert into a taller plant. Another good compact selection is 'Masja'; it grows 3 to 4 ft tall, and has attractive dark shinny leaves and red flowers. One of the smallest cultivars is 'Hornli'. It has orange-red flowers and grows only 1 to 2 ft tall.

Four of the most unique cultivars are 'Nigra', 'Ayesha', 'Domotoi', and 'Hanabi'. 'Nigra' has dusty pink flowers and dramatic black stems. 'Ayesha' often called the silver slipper hydrangea, has silvery blue to silvery pink flowers that are uniquely cupped. 'Ayesha' has very large, glossy leaves that give it added appeal. 'Domotoi' and 'Hanabi' are both double-flowered, Japanese selections. 'Domotoi' is an irregular mophead with highly doubled blue or pink sepals. 'Hanabi' is a long-blooming, white lace-cap with doubled, elongated sepals.

While the most popular cultivars are big mopheads (hortensias), lace-cap plants (normalis) are becoming more popular. They are more delicate and interesting than the gaudy mopheads. 'Blue Wave' is a strong growing plant with large, lacy blue flowers. Some of the most beautiful of the lace-caps are the so called Teller Series with their extremely large blooms and wonderfully bright colors. Although often sold as Teller Rot (syn. Teller Red), 'Libelle' (syn.'Teller White'), Teller Rosa (syn. Teller Pink) and so on, this group actually represents over thirty cultivars hybridized in Switzerland for the floral industry. Caution should be used with these plants to be certain you are getting the correct cultivar. Many of these cultivars are tender and do not make good garden plants unless you live in a mild climate. Others have been reported to be perfectly hardy.

One of the most exciting groups of *H. macrophylla* are the variegated types. These beautiful plants are not reliable bloomers, but who cares. 'Maculata' (syn. 'Variegata') has blue green leaves with a creamy white margin. 'Lemon Wave', which is similar if not identical to 'Quadricolor', is a wild mixture of green, yellow, cream, and white. These plants are every bit as nice as a variegated *Hosta*. As more and more forms are selected, I expect these plants will be as popular as *Hosta* some day.

As noted earlier, *H. macrophylla* will not bloom if the buds are damaged. We have several customers as far north as Maine that gets blooms every year. This is accomplished by protecting the plants just as many people protect hybrid roses. Plants are covered with mulch or leaves in early winter and carefully removed after any chance of frost. It may be extra work but to many people this is well worth the effort.

There are literally hundreds of different cultivars of *H. macrophylla*. Many are difficult to distinguish at first glance. The plants I have shown you represent some of the best diversity of the group.

Hydrangea serrata **(syn. *H. macrophylla* subsp. *serrata*).** (Japan, Korea, Zone 5) is native to mountainous regions and for this may be hardier plants in some respects. *Hydrangea serrata* tends to be a more diminutive plant with finer branching, lace-cap flowers and pronounced serrated leaf margins. They often show wonderful hues of red autumn color, while *H. macrophylla* has none at all. 'Bluebird' is the most common selection available. It looks similar to 'Blue Wave' but its light blue sepals rarely overlap. 'Blue Billow' is a low, broad mounded selection introduced by the Mt. Cuba Center. It has good hardiness and nice red fall color. 'Coerulea Lace' is one of our most reliable bloomers. It is an early bloomer with blue and white lacy flowers. It has exceptional fall color!

Hydrangea paniculata (Asia, Zone 3) is a wonderful, hardy species that blooms on its current seasons wood in late summer to early fall. 'Grandiflora' is the most commonly grown cultivar. It has large floppy white panicles. Superior cultivars are now making their way to market. Most of these plants were developed by Robert and

Jelena DeBelder of Belgium. One of the best is 'Unique', a superior plant with extremely large sepals. 'Kyushu' is an early booming selection with pure white, lacy blooms. It is very similar to 'Tardiva' but because it blooms earlier you can enjoy the blooms for a longer time. The cultivar 'Pink Diamond' is one of the best new plants with large upright panicles and very large sepals. The blooms open white and then transform to a rich pink. The extent and quality of pink may vary depending upon climate. Regardless 'Pink Diamond' is a beautiful plant. The cultivar 'Peewee' (perhaps the same plant as 'Diminutive Form') is a nice lacy-flowered plant, but not as small as the name would indicate. I suspect that it is small only in relationship to the larger cultivars. The cultivar 'Burgundy Lace' is a lacy flowered plant with very few sterile florets. It turns a rich burgundy-pink in autumn. 'White Moth' is unique in that it has large globular flower heads comprised of large florets. Unfortunately it is a wild-growing plant with long, snake-like branches. Another nice lace-flowered form is 'Brussels Lace'. The flower panicles are long and narrow and contain numerous green fertile flowers. The sparse sterile florets often nod down to create a distinct effect. I have seen numerous other cultivars, both named and unnamed. We are currently evaluating these plants but want to make certain that they are distinct and worthy of introduction. The USDA has been attempting to cross *H. paniculata* and *H. macrophylla* in order to create a hardy, reliably blooming plant with interesting colors. Time will tell if this effort is successful.

Hydrangea quercifolia (south eastern U.S, Zone 5) know as the oakleaf hydrangea is a course-textured plant with oak-like leaves. It has beautiful white panicles in midsummer and excellent red fall color. 'Snow Queen' is perhaps the standard in which to judge all cultivars. It has large, upright panicles with large sepals and deep red fall color. *Hydrangea quercifolia* 'Flore Pleno' Snow Flake™ hydrangea is a beautiful, double-flowered selection with large, pendulous panicles. The sepals age to purple even as new white sepals emerge to create a beautiful contrast. 'Harmony' has curious globular blooms. 'Alice' is a Mike Dirr selection with large panicles, good red fall color, and extremely vigorous growth. Here too, we are evaluating other new selections that may warrant introduction.

As you can see, the genus *Hydrangea* is wonderfully diverse. I have only touched on a few of the species, and have shown you just a handful of cultivars. If you wish to learn more I highly recommend the following books: *Hydrangeas, Species and Cultivars* a two volume set by Corinne Mallet; *Hydrangeas, A Gardeners Guide*, by Toni Lawson-Hall and Brian Rothera; and *The Hydrangea* by Michael Haworth-Booth. I also recommend joining the American Hydrangea Society, P.O. Box 11645 Atlanta, Georgia 30355. The very best way to learn more about hydrangea is to grow them. They are fun plants that offer the best in color, form, texture, and diversity.

Production and Marketing of *Ilex Opaca* for the Northern Market

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Our search for the most cold hardy cultivars of *Ilex opaca* (those which could withstand -15F temperatures) took us to many midwestern and eastern nurseries, arboreta, and private gardens. We encountered over 200 named culitvars and discovered that only a handful were in commercial production in the eastern United States.

The limited commercial offerings of American holly may be attributable to the following:

1) Limited container adaptability.
2) Introduction and overwhelming acceptance of the *I.* ×*meserveae* hollies.
3) Slow growth pattern in the north (only one flush per season).

We still feel that *I. opaca* cultivars are worthy of consideration in the marketplace because of their handsome conical shape, tolerance of urban settings, soil adaptability, and deer resistance, not to mention their traditional role as a holiday plant.

The *I. opaca* cultivars we find most acceptable for Zone 5a (-15 to -20F) are the following: Arlene Leach, David Leach, Carnival, Arthur Pride, Clarissa, George E. Hart, Mary Holman, Cardinal, Emily, Christmas Carol, Pride of Butler, and Santa Claus. This is not to say that other cultivars will not survive in Zone 5. Many of the above mentioned were just coming on to the marketplace in the early 1960s when the holly market went, literally, South.

All of the aforementioned cultivars share some admirable characteristics. Large leaves, dark green in color; natural central leader; pyramidal shape with little trimming; above average fruit set; orange to carmine-red fruit color, and tolerance of extreme cold (-20F). Like all hollies in general, *I. opaca* taxa will not tolerate desiccating winter winds and need protection, either natural or artificial, to prosper.

We begin the propagation of *I. opaca* culitvars in late August and early September where we make the best use of natural heat and light. Hardwood cuttings with terminal buds (only branch ends and vertical and top growth) are taken. The length of a finished cutting is 5 to 6 inches. We may only be able to take 50 to 100 pieces per tree, hence the search for known trees continues. Cuttings are stripped to 3 to 4 leaves, double wounded, and dipped into an Hormex powder (1.6% IBA). The cuttings are stuck in a 40 tray that has been coated with Spin-out™. This is our 1st year using Spin-out™. A fungicide drench of Cleary 3336 is applied at this time and the trays are placed under mist.

Cuttings taken in late summer will initiate rooting in 4 to 5 weeks. At this time they are taken off mist and placed in a low heat house to finish rooting over the winter. Success rate is usually 95% to 100%.

Cuttings taken after 1 Oct. through 1 Dec. without benefit of a heavy freeze tend to have a lower/slower yield (75%) and take about 8 weeks to root.

Those taken from 1 Dec. to 1 Feb. or into full dormancy receive bottom heat at 72F with air temperature maintained at 45 to 50F. Success rates climb with this method

to over 90% and rooting time is very quick, often less than 30 days. Cuttings are ready for spring shipping after March 1. We generated 20,000 *I. opaca* culitvars cuttings last year and could have sold many more.

We try to hold back 50% of the cuttings and move them up to 2-qt Spin-Out™ containers. These are the best size and quality for the wholesale buyer because there is no loss and they can be shipped any time during the season. Those plants not potted up (approx. 20%) are placed in beds in the field. When they are 18 inches to 2 ft the bedded plants are placed in rows and left to grow on as finished stock. We now have a steady continuum of 3 ft plants available and hope to get to a good supply of 6 ft plants in the next few years.

We market our hollies through advertisements in national publications, catalogue mailings, trade shows, and the Internet. We ship nationwide with 80% to 90% of our plants going to the Eastern United States.

The problems associated with marketing and promoting hollies are primarily based on misconceptions. The image of *I. opaca* culitvars is that they grow in a limited area, they are a disease-ridden plant, and they are just too much effort for the commercial grower. In reality, hardy *I. opaca* culitvars will grow from Nova Scotia to Florida westward into Iowa and Missouri. Leaf miner is indeed a minor problem. It is a pest easily controlled with a spring application of a systemic insecticide. Once under control plants generally will stay clean and need to be sprayed only every 2 or 3 years to keep the leaf miner at bay.

Prospective buyers often call our nursery and tell us that they have had little success with hollies in the past. When quizzed, it is apparent that nonhardy *I. opaca* culitvars have been shipped into areas where they are difficult if not impossible to grow. No one had grown Pride cultivars and other hardy cultivars in years. These plants sell themselves once customers learn that they can withstand Zone 5 winters.

For the commercial grower, the time factor of 6+ years to produce a finished plant can be daunting. From my survey of the market, the growers who have finished product cannot meet the current demand, and therefore name their price.

With the advent of Spin-Out™, we may well be able to grow large container *I. opaca* cultivars, thus eliminating another market hurdle.

We hope that with our interest in hollies we can help educate and inform many others as to the merit of this remarkable plant. *Ilex opaca* cultivars do not fit into a cookie-cutter approach to plant production; they are special plants intended to be grown for their individual qualities, perhaps that is why we like them so much and think they should be produced by more growers.

NEW PLANT FORUM

Compiled and Moderated by Jack Alexander

PRESENTERS:

Jack Alexander, The Arnold Arboretum, Jamaica Plain, Massachusetts 02130 U.S.A.

***Parthenocissus tricuspidata* 'Fenway Park'**

Dale Hendricks, North Creek Nurseries, Inc., R.R. #2, Box 33, Landenberg, Pennsylvania 19350 U.S.A.

***Aster oblongifolius* 'October Skies'**

***Oenothera fremontii* 'Lemon Silver'**

***Panicum virgatum* 'Shenandoah'**

Don Merrick, Monrovia Mursery Co., 13455 SE Lafayette Hwy. Dayton, Oregon 97114 U.S.A.

***Hosta* 'Eola Salad Bowl'**

***Hosta* 'Hottsy Tottsy'**

Claude Richer, Agriculture Canada CRDH, 430 Boul Gouin, Saint-Jean-sur-Richelieu, Quebec G1K 7P4 Canada

***Rosa* 'AC De Montarville'**

***Rosa* 'AC Marie-Victorin'**

***Rosa* 'AC William Booth'**

Tom Ward, The Arnold Arboretum, Jamaica Plain, Massachusetts 02130 U.S.A.

Poliothyrsis sinensis

Timothy Wood, Spring Meadow Nursery, Inc. 12601 120th Ave. Grand Haven, Michigan 49417 U.S.A.

***Euonymus fortunei* 'Interbolwji', Blondy® euonymus**

***Itea virginica* 'Sprich', Little Henry™ dwarf sweetspire**

***Spiraea betulifolia* 'Tor'**

***Weigela florida* 'Alexandra', Wine & Roses ™ weigela**

***Aster oblongifolius* 'October Skies'**. A shorter, bushier, bluer sister of 'Raydon's Favorite'. A strong-growing low mound of bushy 18-inch-tall foliage spreading 18 to 24 inches. Highly tolerant of drought and poor soils. An excellent groundcover potential native plant hardy in Zones 3 to 7.

***Euonymus fortunei* 'Interbolwji', Blondy® euonymus.** A bold new shrub with big, bright yellow splotches in the center of the leaf and bright yellow stems. Very popular in Europe,where it has literally replaced 'Sunspot'. Discovered by Bolwijn

Nursery in the Netherlands as a sport of 'Sunspot'. Great impulse color provides year-round color.

***Hosta* 'Eola Salad Bowl'.** Eola salad bowl plantain lily is a *H. sieboldiana* seedling, selected at Monrovia by Steve Hottovy. The actual parentage is not know as it resulted from seed collected from open-pollinated named cultivars. 'Eola Salad Bowl' is hardy to Zone 3 (-40 to -30F). Size is 24 inches high by 8 to 10 inches wide. This unique miniature hosta has wavy leaf margins with a curled mid-rib and chartreuse green to yellow foliage that becomes brighter yellow with more sun.

Small pale lilac flowers appear on spikes in June. It is a clumping tight miniature which can be used in a border with other hostas and perennials or as a container planting. When grown in a container this hosta looks like a bowl of your favorite bib salad and is sure to catch the eye of hosta enthusiasts around the world.

***Hosta* 'Hottsy Tottsy'.** Hottsy tottsy plantain lily is a perennial originating as a *H. sieboldiana* seedling, selected at Monrovia by Steve Hottovy. The actual parentage is not know as it resulted from seed collected from open-pollinated named cultivars. It is hardy to Zone 3 (-40 to -30F), 24 inches tall, and 3 ft wide. Yellow leaves are larger than *H.* 'Golden Prayers' and the golden color performs well in the full sun without burning. Flowers are pale lilac appearing on spikes in June and July.

It has a clumping form and develops into rounded full specimen. Performs well in the landscape as a border, mixed with other hostas and perennials or as a container planting.

***Itea virginica* 'Sprich', Little Henry™ dwarf sweetspire.** Sweetly scented, pure-white flowers shoot like fireworks in the early summer horizon from this plant. A low mounded, compact stature which is perfectly suited for flooding large banks, beds, and borders. If burning bush has good fall color, then this plant is a wildfire. What more could you want in a plant. Developed by Richard Feist at Hummingbird Nursery in Kentucky.

***Oenothera fremontii* 'Lemon Silver'.** A day-blooming evening primrose with low, silver, lance-shaped foliage, and plenty of light, clear-lemon flowers of tissue paper texture. Flowers from June to September and is happiest in hot, bright, dry well drained spots. Height is 6 inches.

***Panicum virgatum* 'Shenandoah'.** The brightest red *Panicum* by a long shot. Experienced horticulturists have mistaken it for *Imperata cylindrica* 'Red Baron' at first glance. It colors up by June and the flowers are also red. The shortest of the group at 3 ft and also the slowest grower, perhaps due in part to its lack of greenness. Introduced by Dr. Hans Simon of Germany. At native species hardy in Zones 4 to 9.

***Parthenocissus tricuspidata* 'Fenway Park'**. This unique cultivar of Boston ivy (*P. tricuspidata*) produces yellow-green foliage. The plant originated as a bud-sport mutation on a specimen that was growing on a west-facing wall of an apartment complex in the vicinity of Fenway Park, Boston, Massachusetts. Arboretum staff member Peter Del Tredici discovered the plant in August 1988 while on his way to a Red Sox baseball game with his son. The evening sun was setting and the top portion of a mostly green plant seemed to glow in the fading twilight. Upon closer examination, it was discovered that the upper part of the vine was producing bright yellow leaves. With the cooperation of the superintendent of the building, cuttings

of the mutant portion were collected and subsequently propagated in the greenhouses of the Arnold Arboretum.

The outstanding characteristic of this new variety is the coloration of its leaves during the growing season, which, depending upon the amount of light they receive, are various shades of yellow to chartreuse. When grown in full sun, leaf coloration comes close to Royal Horticultural Society (RHS) yellow-green 151A to C. When grown in shade, the leaf color is a uniform lime green (RHS 154D). The coloration of the leaves of 'Fenway Park' is stable throughout the growing season. In the fall they turn brilliant shades of orange, scarlet, and yellow. In full sun, the distal portion of many of the large leaves may lose their chlorophyll altogether, making their tips susceptible to sun-scald during hot, dry summers. For this reason, the plant is best grown on a north- or west-facing wall. 'Fenway Park' is hardy within U.S.D.A. hardiness Zones 4 through 9, and is useful as a climbing vine to brighten up walls, fences, or buildings, that are located in dark, shady places.

Poliothyrsis sinensis. This plant was unknown to horticulture in the U.S. until E.H. Wilson collected it for the Arnold Arboretum in 1908, form central China. The present plants we have growing on the grounds come from seed sent to us from the Shanghai Botanical Garden in 1981. At 18 years of age the plants are vigorous, large, multistemmed shrubs, reaching at this time to 15 to 18 ft in height and 8 to 10 ft in width. In its native habitat this plant has the potential to develop into a tree of moderate size. The foliage is dark green and very lustrous , turning a consistent butter-yellow color each fall. Its flowers are borne each year on that seasons new wood and appear in late August to early September. The inflorescence is made up of numerous small, yellowish-white flowers. The flower shape and fruit capsule are similar in structure to that of *Syringa vulgaris*. We have had no insect or disease problems with this plant, while also seeing that it has good drought tolerance. It propagates easily from seed and softwood cuttings. Seed is available upon request from the Arnold Arboretum.

ROSES — EXPLORER™ CULTIVARS

Agriculture and Agri-Food Canada's winter-hardy roses from the Explorer™ cultivar-group are hardy, require minimal care, are environmentally friendly (minimal sprays), yet offer beautiful bloom through the summer and are fast becoming the preferred rose. They are hardy down to -35C with only snow as winter protection, are disease resistant, flower repeatedly throughout the summer, require only minimal pruning and come in a range of colors and sizes.

Characteristics of three new winter-hardy roses from the Explorer (E) series are described below:

***Rosa* 'AC De Montarville'.** 'AC De Montarville' is a winter-hardy shrub rose which was introduced in 1997. The plant has an upright type growth habit and reaches 1.0 m in height and width at L'Assomption. The plant flowers repeatedly from June to September and is resistant to powdery mildew and tolerant to blackspot. This rose is superior in floral production to most hardy roses and is in a similar range to 'Champlain' and 'Frontenac' in total length of blooming season.

The dark red unopened bud of 'AC De Montarville' changes to a medium pink at the blossom stage and later fades to a medium mottled pink when fully opened. The flowers average 7 cm in diameter, have 26 petals, and are borne in clusters of 1 to

4. The plant propagates easily from softwood cuttings.

This selection has been tested at Ottawa for 2 years and an additional 3 years at L'Assomption. Little pruning is required in spring and it is hardy in Zone 3.

'AC De Montarville' originated from a cross between a breeding line derived from 'Queen Elizabeth' and 'Arthur Bell' and a line derived from *R. kordesii,* 'Masquerade', 'Red Pinocchio', 'Joanna Hill', and *R. spinosissima.*

***Rosa* 'AC Marie-Victorin'.** 'AC Marie-Victorin' is a hardy shrub rose launched in 1998 at the Montreal Botanical Garden. This is a small climbing roses that reaches a height of 1.5 m and 1.25 m in width at L'Assomption. It is winter-hardy, flowers abundantly and repeatedly, and is highly resistant to blackspot and powdery mildew.

The unopened bud which is a deep peach colour changes to a pale peach at the blossom stage and later fades to a pink in the fully opened flower. Its corymbs are made up of one to six flowers, each one averaging 9 cm in diameter, with 38 petals. The pink and peach buds can be used as boutonnieres. It has been released because of its unique peach colour rarely found in hardy roses, its excellent hardiness, and its disease resistance. The rose propagates easily from softwood stem cuttings.

The bright orange fruits in fall remain on the bush over the winter. The leaves, a dark shiny green in summer, turn yellow and red in the fall.

This selection has been tested at Ottawa for 2 years and 5 more years in various climatic Canadian Zones (2 to 5), in Quebec and Ontario. It is hardy in Zone 3 without special winter protection and adapts very well in Zone 2 with a natural snow cover. It may require pruning of deadwood in the spring.

'AC Marie Victorin' originated from a cross between the floribunda 'Arthur Bell' and breeding line L03, an open-pollinated seedling of a cross between *R. kordesii* and 'Applejack'.

***Rosa* 'AC William Booth'**. This cultivar will be introduced in 1999, is a winter-hardy shrub rose that has a spreading to trailing type growth and reaches a height of 1.5 m and a spread of 2 m at L'Assomption. The plant flowers repeatedly from June to September and has excellent resistance to blackspot and powdery mildew.

The deep red unopened bud of 'William Booth' changes to a medium red at the blossom stage and later fades to a light red in the fully opened flower. The flowers average 5 cm in diameter, have five petals and are borne in clusters of 8 to 10 blooms. Softwood stem cuttings root easily.

This selection has been tested at Ottawa for 2 years and an additional 3 years at L'Assomption. It requires little to no pruning in the spring and is hardy to Zone 3.

'AC William Booth' originated from a cross between L83, a line derived from *R. kordesii* and the breeding line A72, which originated from a cross between the floribunda 'Arthur Bell' and the shrub rose 'Applejack'.

These three cultivars were recently registered with Canadian Ornamental Plant Foundation (COPF), they have been protected with the Plant Breeders Right Office since 1997 and are available on the Canadian market to eight licensees and commercial American requests were assigned to Bailey Nurseries.

***Spiraea betulifolia* 'Tor'.** The pinnacle of adornment with a multitude of tightly packed, white flower clusters against a backdrop of iridescent green leaves. A compact, rounded habit, and exceptional purple autumn color add to this plants allure. Blooms in mid to late spring. It is a Scandinavian selection.

***Weigela florida* 'Alexandra', Wine & Roses™ weigela.** Weigela has never looked so good. Dark burgundy-purple foliage blows 'Java Red' weigela away; leaf color intensifies to near black in mid summer. Intense rosy-pink colored flowers jump against the dark glossy foliage. Developed by Herman Geers of the Netherlands.

POSTER SESSION PAPERS

A New Computer-Controlled Multifertilizer Injector for Recycling Nutrients and Water Run-Off in Nurseries

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INTRODUCTION

Nursery production practices can cause pollution if nitrate and other nutrients leach into the groundwater and surrounding environment.

NEW AUTOMATED TECHNOLOGY

A new computer-controlled multifertilizer injector has been developed to monitor, control, and recirculate nutrients and irrigation water. This patented system was designed in the late 1980s by Climate Control Systems, Inc., Leamington, Ontario, Canada, and subsequently tested by scientists at Agriculture and Agri-Food Canada in Harrow, Ontario (Papadopoulos and Liburdi, 1989). The system was initially developed for the greenhouse vegetable industry, but shows promise for use in outdoor container nurseries.

The system described herein (Fig. 1), was specifically designed for research and is smaller than a typical commercial unit. The cost was $25,000. The computer is an IBM compatible 486/66 MHz with 8 MB of RAM. A minimum of 100 MB of hard drive is required for data storage. The software is written in Quick Basic and contains 1.4 MB of code. The control panel uses plug-in Opto Modules, which facilitates ease of replacement.

Fertigation can be initiated manually or automatically by time or solar set point. A delay feature can postpone fertigation during rainfall. For each fertigation cycle, the computer stores and can graphically display all nutrients, electrical conductivity (EC), pH levels, and flow rates. The system is equipped with alarms to warn if nutrients, EC, and/or pH levels are too high or too low, or if there is a system malfunction.

A two-tiered (1.2 m long × 1.4 m high × 0.5 m wide) stainless steel frame contains 10 electrically driven, individually controlled, dosimetric pumps. Each pump is con-

***Weigela florida* 'Alexandra', Wine & Roses™ weigela.** Weigela has never looked so good. Dark burgundy-purple foliage blows 'Java Red' weigela away; leaf color intensifies to near black in mid summer. Intense rosy-pink colored flowers jump against the dark glossy foliage. Developed by Herman Geers of the Netherlands.

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A two-tiered (1.2 m long × 1.4 m high × 0.5 m wide) stainless steel frame contains 10 electrically driven, individually controlled, dosimetric pumps. Each pump is con-

nected to a separate fertilizer stock solution or an acid tank for pH control. Both the injection volume (0.1 to 1.0 ml) and stroke rate (up to 180 ml) of each pump can be adjusted. In-line EC, pH, and water flow sensors are housed within the central PVC manifold (2.5-cm diameter). An in-line blending tube thoroughly mixes the individual nutrients and acid. The system delivers up to 2000 liters of nutrient-charged irrigation water h^{-1}. Pumps in commercial units can deliver up to 5 liters of each stock solution per minute and have solution flow volumes up to 65,000 liters h^{-1}.

Fertigation and Recirculation. To fertilize a crop, the computer is programmed to deliver set levels of nutrients, EC, and acid. More than 50 different crops, grown at the same time, can each be given a different fertilizer formulation, without changing the stock solutions. Each formulation can be modified at any time to meet the crop's changing nutritional requirements.

If nutrients and water are recirculated, leachate run-off is collected from the containers and returned to the injector. The recirculated solution is then recharged to targeted nutrient levels, and returned to the crop.

Figure 1. The computer-controlled multifertilizer injector at the Horticultural Research Institute of Ontario showing the computer (far left), the control panels (on the wall), the injection pumps, and the solenoid valves and plumbing (far right). Each injection pump is connected to a separate fertilizer stock solution or an acid tank for pH control.

Research Trial. Results from preliminary experiments were promising (Purvis et al., 1997). Subsequently, we showed that containerized *Physocarpus opulifolius* 'Dart's Gold' grew best with nutrients recirculated by the multifertilizer injector, and least with nonrecirculated water soluble fertilizer (20N-8P-20K) delivered by a traditional dosimetric proportioner (Purvis et al., 1999). Growth was intermediate with incorporated controlled-release fertilizer (18N-6P-8K). The EC and pH of recirculated and nonrecirculated nutrient solutions supplied by the multifertilizer injector were accurate to within 6% of targeted levels. Recirculation reduced overall fertilizer use by 69% and run-off was completely eliminated.

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Growth and Adaptation Potential of Flowering Shrubs under Climatic Conditions of Quebec and North Eastern Ontario: REPLOQ

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INTRODUCTION

The Réseau d'essais des plantes Ligneuses Ornementales du Québec (REPLOQ) is a woody ornamental trial network. Its objective is to show the importance of qualifying the hardiness rating of ornamental plants when they're placed in different weather conditions to determine their real potential. This research permitted the compilation of data for more than 400 species of trees or shrubs over a 5-year period, through the eastern Canadian Zones covering the areas of Quebec and northeastern Ontario. For this poster, four species have been studied.

MATERIAL AND METHODS

Young plants of *Kerria japonica* and *Weigela* 'Bristol Ruby' were studied from 1984 to 1989, and young plants of *Hydrangea arborescens* 'Annabelle' and *Rosa multiflora* from 1986 to 1991. They were evaluated in eight different climatic zones, corresponding to Zones 2 to 5 of the Canadian Climatic Classification System defined by Ouellet and Sherk (1972).

Evaluation of the Adaptation and Growth Potential of the Species.
To evaluate the potential of those plants we measured winter damage and growth. The flowering period and peak flowering period were also recorded.

	Data studied	**When?**
Winter damage	Mortality (%)	Every spring
	Type of frost, evaluated on a qualitative scale (1 to 4).	Every spring
Growth	Height and width (cm)	Spring (after the annual pruning) fall (after the leaves had fallen)

RESULTS

Species and cultivars selected responded in three different ways to winter damage; three different potentials were defined.

Survival Potential. A plant's survival potential indicates where it can be expected to survive the winter.

Species	Mortality (%)	Rating zone (survival potential)
Rosa multiflora	No	2a
Weigela 'Bristol Ruby'	93% in Zone 2a	2b
Kerria japonica	Significant mortality in Zones 2a and 2b.	4
Hydrangea arborescens 'Annabelle'	Completely killed in Zone 2a 50% death in Zone 2b	4

Potential for Full Ornamental Expression. Potential for full ornamental expression will be fulfilled in zones where little or no winter damage occur, for example:

Weigela 'Bristol Ruby' — Slight damage in Zone 5b
More severe damage in the other zones
This species can reach its full ornamental expression in Zone 5b (Table 1)

In all other species evaluated, winter damage was observed even in Zone 5 (Table 1). Their potential for full ornamental expression, without risk of frost damage, can thus only be realized in zones warmer than Zone 5b.

Table 1. Characterization of the hàrdiness potential of four shrubs compared with the conventional hardiness rating.

Species	Canadian zone	U.S.D.A.	REPLOQ Survival	REPLOQ Full ornamental expression	REPLOQ Partial ornamental expression[z]
Hydrangea arborescens 'Annabelle'	3b	3	4	> 5b	2b, Flo
Kerria japonica	5	4	4	> 5b	5b, Flo-Fl
Rosa multiflora	5b	3	≥ 2a	> 5b	> 5a, Flo, Fl, Rt
Weigela 'Bristol Ruby'	5	5	2b	5b	4, Flo

[z]Flo = flowers, Fl = foliage, Rt = roots

Potential for Partial Expression of Ornamental Characteristics. A plant may partially fulfill its potential for expression even after winter damage is sustained, expressing a number of satisfying ornamental characteristics.

Species	Rating
Rosa multiflora	Blooms only in Zones above 5a Zone 2 for use as foliage plants
Weigela 'Bristol Ruby'	Zone 4 is warranted for this cultivar considering the abundance of the first flowering
Kerria japonica	Potential use for flowering is limited to Zone 5b and above; while it may be used for its foliage in Zone 4
Hydrangea arborescens 'Annabelle'	Stems were heavily damaged by frost at all sites; this cultivar may be used in Zones up to 2b

CONCLUSIONS

Results presented for these four species have led to a better understanding of the three potentials defined in this poster. At the limit of a plant's range, its potential is limited to survival. In the most favorable zone, the plant adapts to reach full ornamental expression. A plant's potential for partial expression of characteristics, which is often close to one of the first two potentials, provides a more specific indication of how it can be expected to perform in intermediate zones.

Propagation of *Amelanchier* by Softwood Cuttings

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INTRODUCTION

In the nursery market place, *Amelanchier* has become very popular, thus increasing its demand. For years seed propagated *Amelanchier* was available for lining-out stock. In recent years selections and cultivars with superior landscape characteristics have been made. This creates a need for clonal propagation. The two methods most widely used are micropropagation and softwood cuttings.

LaPorte County Nursery propagates the following *Amelanchier* taxa by softwood cuttings: *A.* ×lamarckii, *A.* ×*grandiflora* 'Cole's Select', *A.* ×*grandiflora* 'Princess Diana', and *A. laevis*.

MATERIALS AND METHODS

Plant Material. Softwood tip cuttings are taken from field or stockplants in the early part of June. The timing may vary due to the climatic conditions of that year. Cuttings are cut 4 to 8 inches in length. The bottom leaves are removed so there is 2 inches of stem to place in the rooting medium. A two-node cutting may also be used instead of tip cuttings. Cuttings are bundled with a rubber band to hold them together. Keeping the cuttings cool seems to be helpful in reducing stem burning.

Bundles of cuttings are completely dipped in a Green-Shield® solution. This soapy solution acts as a disinfectant for sanitation. Allow the cutting bundles to partly dry before dipping in a hormone solution. Cuttings are dipped for 10 sec in Woods rooting hormone at 2500 ppm IBA. Moisture is maintained on the cuttings at all times prior to sticking.

Medium. The medium consists of a peat and perlite mix (1 : 1, v/v). All parts are blended thoroughly and run through a shredder.

Propagation House. The polyhouses that the cuttings are placed in are covered with double-layer poly with the outer layer being white. Ventilation fans for cooling are in each house. The floor is fabric covered with 1 inch of pea gravel underneath. The house is sprayed with Green Shield® before the cuttings are stuck.

Cuttings are directly stuck into 2⅜-inch Anderson band pots. The pots are on the floor and placed pot to pot.

Mist is overhead using Eddie mist nozzles. A Phytotronics controller and a 24-h clock control misting. Mist goes on at 6:00 am and shuts off at 8:00 pm No bottom heat is provided.

Post Rooting. Root initials begin to appear in 3 to 4 weeks. On an average year a 75% to 85% rooting is obtained. Once rooting has occurred and mist is off, the tip will continue to grow. All cuttings are overwintered in polyhouses, provided with minimum heat.

I.P.M. at Zelenka Nursery

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Zelenka Nursery, Inc., a large wholesale operation located in Michigan and North Carolina, has developed unique strategies for implementing I.P.M. With a peak work force of 700 employees, comprised of local and migrant workers, there are many challenges to maintaining an awareness of I.P.M. and utilizing some of its methods. Toward this end, Zelenka promotes a broad base of direct employee involvement in I.P.M. issues, and has created ways to educate and encourage all employees in the practice of pest management.

Zelenka's I.P.M. program is characterized by how it is organized, and by the means used to encourage effective and accurate scouting, pest identification, and decision-making. Central to the organization is an I.P.M. core group, which manages interdepartmental I.P.M. issues. Led by the nursery's I.P.M. coordinator, members of the group represent each production department, staff horticulturist, and the shipping docks. The core group meets twice a month.

Because of Zelenka's large work force and production area of over 5000 acres, many employees have contact with plant material before it leaves the nursery. Workers are able to communicate pest findings on I.P.M. scouting reports. Efficient communication is also the driving force behind the nursery's annual I.P.M. workshop, pest alerts, and pest advisories sent via e-mail. The I.P.M. program includes a gypsy moth scouting incentive plan, a monthly I.P.M. calendar, and an I.P.M. notebook of resource material provided to each department. The I.P.M. notebook assists in pest identification along with in-house expertise, newsletters from Michigan State University, and outside consultants.

Pest management supervisors within the production departments use all available information to determine whether control measures are warranted. In considering whether action is necessary, supervisors consider (1) pest density and potential for damage, (2) proximity of harvest date, and (3) presence of natural enemies or other agents that could keep pests in check. Pesticide use through scouting and spot treatments occurs only when and where necessary.

Simple Acceleration

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Materials and Methods. Our softwood cuttings are taken starting in early July into August. This was the schedule for our softwoods, mostly being deciduous shrubs in 1997 at Riverbend Farms.

In March of 1998 we took our rooted softwood cuttings from the shallow K1020 flats filled with perlite or perlite and Pro-Mix and transplanted into Jiffy 220 plugs of Pro-Mix BX. We don't have enough room for direct sticking efficiently due to space limitations.

The plugs develop rapidly under clear double poly and minimum heat provided by propane heaters. Applications of 10N-52P-10K fertilizer, and a couple of prunings create a well branched 6- to 8-inch liner for May-June transplanting to the field or into containers.

In addition, in March 1998 we transplanted some of the rooted cuttings directly into 1-gal containers in Pro-Mix BX. We fertilized the 1-gal pots along with the regular Jiffy 220 plugs with 10N-52P-10K fertilizer approximately at 2-week intervals and with 20N-20P-20K a couple of times at regular recommended label rates for bi-weekly feedings.

Results. Some plugs that were never transplanted into containers or the field remained 6 to 8 inches.The accelerated 1-gal plants achieved an approximate range of 2 to 4 ft of growth.

Simple acceleration, utilizing plastic and minimum heat, with a good mix can rapidly finish cuttings to market size faster than that of conventional field or containers outside.

For another test we grafted a dwarf Korean lilac, *Syringa meyeri* var. *spontanea* 'Palibin', in January, flushed the scion, made a cutting in March which when rooted was forced into a 12-inch saleable 1-gal plant by July. The 1-gal plants were not pruned, but allowed to grow unchecked to measure growth (Table 1).

Table 1. Growth measurements for some of the 1-gal plants (measured from top of pot).

	Plant height (ft)	Spread (ft)
Cornus alba 'Elegantissima'	3½	1½
Forsythia 'Northern Gold'	2	2½
Prunus ×*cistena*	4	2
Spiraea japonica 'Little Princess'	1	1½
Weigela 'Red Prince'	4	1

We concluded that simple acceleration as outlined above produced saleable plants in a short time ready for market ahead of regular outside-grown field or container stock. This method could provide a shortcut when a product is required fast.

Increasing Flowers on Container-Grown Hybrid Rhododendrons with Uniconazole Sprays

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INTRODUCTION

Problem: Container-grown hybrid rhododendrons produced for garden center and spring landscape sales have their value enhanced by the presence of flowers or flower buds. However, certain cultivars are difficult to bud as young plants under commercial production conditions.

Possible Solution: Spray with the commercially available anti-gibberellin uniconazole-P (Sumagic) to limit late season vegetative growth, increase foliar pigmentation, and the number of flower buds per plant.

METHODS AND MATERIALS

The following test was conducted at different commercial container nurseries in the Piedmont (U.S.D.A. Hardiness Zone 7b) and mountains (Zone 6b) of North Carolina. All plants were sprayed with either 0, 50, or 100 ppm uniconazole-P (Sumagic). Plants in the Piedmont were larger and growing in 3-gal containers while those in the mountains were younger, smaller, and growing in 2-gal containers.

Previous research had demonstrated that mid to late July is the best time to spray. Spraying before July does not allow plants to conclude a growth flush. Spraying after July will stop the second growth flush plus no flower buds will develop. Plants were sprayed as the first growth flush had finished and just as the second growth flush was starting. Cultivars tested were 'Chionoides', 'English Roseum', 'Nova Zembla', 'Purpureum Elegans', and 'Roseum Elegans'. There were 10 individual plant replicates per treatment (30 plants per cultivar per nursery).

RESULTS AND DISCUSSION

There was no phytotoxicity from any of the treatments and no significant height increase for any of the plants following treatment. All flower buds opened normally with no deformity of flowers the following spring.

SIGNIFICANCE TO THE INDUSTRY

1) Similar results occurred at different nurseries under different growing conditions.
2) All five cultivars had a significantly increased number of flowers when sprayed with as low as 50 ppm Sumagic in mid July.

Table 1. Number of flower buds per plant at the end of the growing season for *Rhododendron* 'Nova Zembla.'

	Nursery locations	
Sumagic (ppm)	Mountains*	Piedmont*
0	0.5 a	4.0 a
50	4.6 b	10.8 b
100	5.2 b	12.1 b

*Rp05 Duncan's New Multiple Range Test.

Table 2. Number of flower buds per plant at the end of the growing season for *Rhododendron catawbiense* 'Purpureum Elegans' and *R.* 'Roseum Elegans.'

	Cultivar	
Sumagic (ppm)	'Purpureum Elegans'*	'Roseum Elegans'*
0	1.0 a	3.8 a
50	4.0 b	12.0 b
100	3.4 b	12.6 b

*Rp05 Duncan's New Multiple Range Test

Table 3. Number of flower buds per plant at the end of the growing season for *Rhododendron* 'Chionoides' and 'English Roseum.'

	Cultivar	
Sumagic (ppm)	'Chionoides'*	'English Roseum'*
0	0.7 a	0.0 a
50	4.1 b	1.4 b
100	6.2 c	2.6 c

*Rp05 Duncan's New Multiple Range Test

How and When Herbaceous Cuttings are Stuck Influences Winter Survival

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INTRODUCTION

Herbaceous perennials are frequently purchased as dormant, leafless rooted cuttings or liners for potting into larger containers for spring and summer sales. Occasionally these liners produce no new top growth yet roots appear to be healthy.

MATERIALS AND METHODS

The objective of this study was to investigate whether the time of propagation or the depth of cutting penetration into rooting medium has any effect on survival and subsequent growth of plants reported with this problem. Test plants were *Caryopteris divaricata*, *Monarda* 'Raspberry Wine', and *Phlox paniculata* 'Robert Poore'. Cuttings from container-grown stock plants at the Mountain Horticultural Crops Research Station (MHCREC), Fletcher, N.C., were stuck in mid June, mid August, and early September 1997 except for the phlox where only June and September cuttings were stuck due to a lack of sufficient propagation material in mid August.

Cuttings were treated with 1250 ppm IBA (C-Mone) quickdip and stuck into a sphagnum peat and perlite (1 : 1, v/v) rooting medium in 60-cell flats and placed under intermittent mist until rooted. Half of the cuttings were stuck so that a node was at least 0.5 inches beneath the surface of the rooting medium (+) while the others were stuck so that no buds were beneath the surface of the rooting medium (-). The number of cuttings stuck per treatment depended upon availability but no fewer than 18 cuttings per date and location (+,-) treatments were stuck in three replicates for any test plant. Once rooted, all cuttings were transplanted to quart pots in standard MHCREC potting medium (pine bark and sphagnurn peat [8 : 1, v/v]) to which 7 lb dolomitic limestone and 3 lb Esmigran was added per yd^3), and topdress fertilized with 0.25 tsp qt^{-1} Wilbro (Polyon) 12N-6P-6K Nursery Special for the June cuttings or with Peters 20N-20P-20K at 100 ppm N weekly until 1 Oct. for the summer rooted cuttings. Plants were placed under overhead irrigation at the MHCREC container research facility where they were exposed to ambient temperatures until late November when they were moved to an unheated white plastic covered overwintering structure. On 2 Feb 1998 all liners were moved to a heated greenhouse to encourage vegetative growth. Percent survival was determined on 13 Mar 1998. Those showing no vegetative growth were determined not to have survived.

RESULTS AND DISCUSSION

All cuttings rooted in high (over 90%) numbers and produced mostly vigorous liners. Cuttings with limited vigor were not kept as part of this study. All cuttings were exposed to 12 subfreezing (lowest temperature 18F) nights before being moved to the overwintering structure. Leaves had been killed and most had abscised. However,

stems were not cut back until after new growth appeared in the greenhouse. Percent survival for all plants is shown in Table 1.

Table 1. Percentage survival *Monarda* 'Raspberry Wine,' *Caryopteris divaricata*, and *Phlox* 'Robert Poore' following winter as affected by date and method of propagation.

	Monarda 'Raspberry Wine'		*Caryopteris divaricata*		*Phlox* 'Robert Poore'	
Date stuck[Y]	-	+	-	+	-	+
19 Jun	100	100	31	86	50	100
13 Aug	100	100	69	100		
2 Sep	67	100	27	43	50	100

[Y] "+" = Cuttings were stuck so that a node was at least 0.5 inches beneath the surface of the rooting medium; "-" = cuttings stuck so that no buds were beneath the surface of the rooting medium.

Survival of *M.* 'Raspberry Wine' was excellent. All treatments survived at 100% except the September cuttings without nodes beneath the propagating medium (-). Therefore, placement of cuttings for this cultivar only seems important for late stuck cuttings.

Caryopteris divaricata survived in commercially acceptable percentages only when cuttings were stuck 13 August or earlier and only when nodes were stuck below the surface of the rooting medium (+). Cuttings stuck in September did not survive in acceptable percentages regardless of node location.

Phlox paniculata 'Robert Poore' survived in commercially acceptable percentages only when nodes were below the surface of the rooting medium (+). Survival percentages were 100% on both propagation dates when nodes were beneath the propagating medium.

United States National Arboretum Plant Profiles

Susan E. Bentz and Ruth L. Dix
USDA, ARS, U.S. National Arboretum, 3501 New York Ave., NE, Washington, D.C. 20002 U.S.A.

How should the U.S. National Arboretum effectively publicize its plant releases and products to its customers? The Plant Profiles system evolved to meet this long-recognized need. A group of award-winning plant materials and a high level of administrative support gave impetus to the development process.

A review of marketing materials generated by other institutions and commercial companies led to the formulation of a plan adapted specifically to the USNA. The targeted audience was identified as the arboretum's primary customers: commercial growers and the gardening public. It was determined that the information should be brief but accurate and accompanied by visually pleasing photographs showing the desirable characteristics of the plant or product.

The format for the Plant Profiles is a single, easily read sheet printed on both sides. The front of the sheet contains eye-catching color photographs plus a short, enthusiastic paragraph on the product. The back of the sheet contains all the pertinent data: correct plant name and accession number; hardiness; history of development; significance to industry; description, culture, propagation, landscape use, and availability. References are kept for the information contained in each Plant Profile.

Development of such a project necessarily involved a team approach. USNA staff members contributed information which was not available in print. The Agricultural Research Service (ARS) Information Service played a key role in developing and refining the design for the Profiles and having them printed. Printed Profiles required 1 year from conception to end product and, once developed, could then be added immediately to the USNA web site. The Plant Profiles system thus serves a dual role both as printed material and as a USNA web site feature.

Single copies are available free upon request (U.S. National Arboretum, 3501 New York Ave., NE, Washington, DC 20002, or can be downloaded from the USNA web site (www.ars-grin.gov/na). Multiple copies can be obtained for a fee.

Screening Commercial Peat and Peat-based Products For the Presence of Ericoid Mycorrhizae

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Pieris floribunda, mountain andromeda, belongs to the family Ericaceae. This species, along with other members of this family, including *Rhododendron*, *Vaccinium*, *Kalmia*, and *Calluna*, are important plants in the landscape trade, especially in the northern regions. Many of these species are evergreen and, therefore, provide color in an otherwise stark winter landscape. Members of the Ericaceae lack root hairs. Instead, it is hypothesized, the roots form a unique association with ericoid mycorrhizal fungi. These fungi have been demonstrated to: aid in nitrogen and phosphorous availability and uptake, increase water uptake capability, increase lateral root branching, extend the overall root mass, and protect from certain toxic substances.

In this study, trials were conducted using seedlings of *P. floribunda,* as a model plant, to determine the presence or absence of these fungi in various commercial brands of peat and peat-based products. The geographical source and strata of harvest was identified for each product. An attempt was made to determine if the source and strata of harvest of the peat as well as any subsequent processing or handling effected the presence of ericoid mycorrhizal fungi.

Seed of *P. floribunda* was surface-sterilized and germinated aseptically in petri dishes containing water agar. Seedlings were transferred to Magenta boxes and

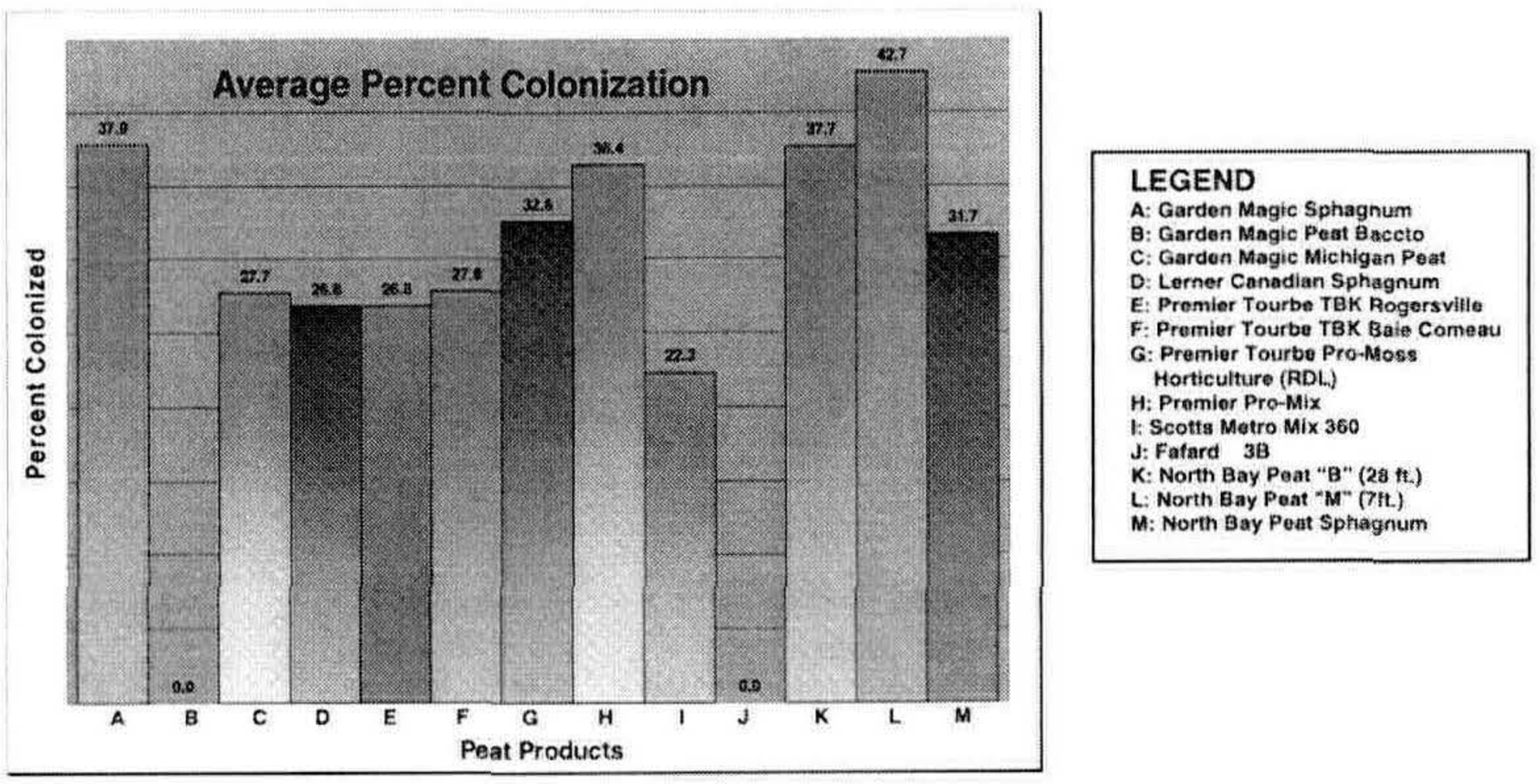

Figure 1. Average percent colonization of *Pieris floribunda* roots by ericoid mycorrhizal fungi in various commercial brands of peat and peat-based products.

grown in a growth chamber in select peat and peat-based products for 75 days. After 75 days, roots were harvested and evaluated for the presence of ericoid mycorrhizae. Roots were washed, cleared, and stained with chlorazole black E, a fungal-specific stain. The stain adhered to the fungus in colonized root cortical cells. Three sections of each root mass were randomly selected and colonized roots were counted. Average percent colonization of six replicates was determined for each root mass from every peat and peat-based product.

Preliminary results indicate that all commercial brands of media except Green Magic Peat Baccto® and Fafard® showed the presence of ericoid fungi (Fig. 1). None of the seedlings grown in Fafard® survived to harvest except the seedling grown in the sterilized (autoclaved) negative control. North Bay Peat harvested from the middle strata (approximately 7 ft) showed the highest percent root colonization.

Use of peat and peat-based media containing ericoid fungi for the propagation and growth of ericaceous species should benefit the production of these landscape plants. Further studies must be conducted to determine the cause of the differences in colonization relative to peat source and strata and whether increased colonization effects the growth of the host plant.

Some Ways to Acclimate Various Culture-Rooted Microcuttings

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INTRODUCTION

Culture-rooted microcuttings (CRM) are micropropagated plants that have been exposed to root initiation media in culture. Basically, these are just small softwood cuttings with the hormone already on them, ready to stick and root. They are different in that the plants have been grown in optimal environmental and nutritional conditions and have not developed the protection of a cuticle on the leaf surface. The key to success with these plants is to provide an environment that maintains cutting turgidity. The variables are humidity, light, and temperature.

CRMs can be an affordable and quick way to include a new (or old) plant into your production line without any more special equipment than most conventional propagation greenhouses already contain.

CRMs are also free from environmental pests, therefore they are generally easy to acquire from any micropropagation lab in the world.

ACCLIMATION OF CULTURE ROOTED MICROCUTTINGS

The following are some methods we have used at our nursery to acclimate various CRMs (Fig. 1).

Well Shaded Greenhouse.

- In an ideal climatic location, one may be able to acclimate cuttings with occasional hand misting.

Tent Within a Greenhouse.

- White overwintering poly works best for this, especially in the summer.
- Mist within the tent is necessary if the tent must be opened to exhaust heat during the day.
- Maintenance can be high to keep the tent covering adjusted just right to prevent heat buildup and expedite acclimation.

Automatic Mist or Fog System.

- When using mist, the mist head should produce a small enough droplet size to prevent the weight of the water from squashing the microcuttings.
- A fog system is best if an entire greenhouse can be devoted to acclimation. A small greenhouse or a sectioned-off bay also works well.

Humidity Domes.

- The domes are available from many greenhouse supply companies.
- Shade is usually necessary to prevent heat build-up.

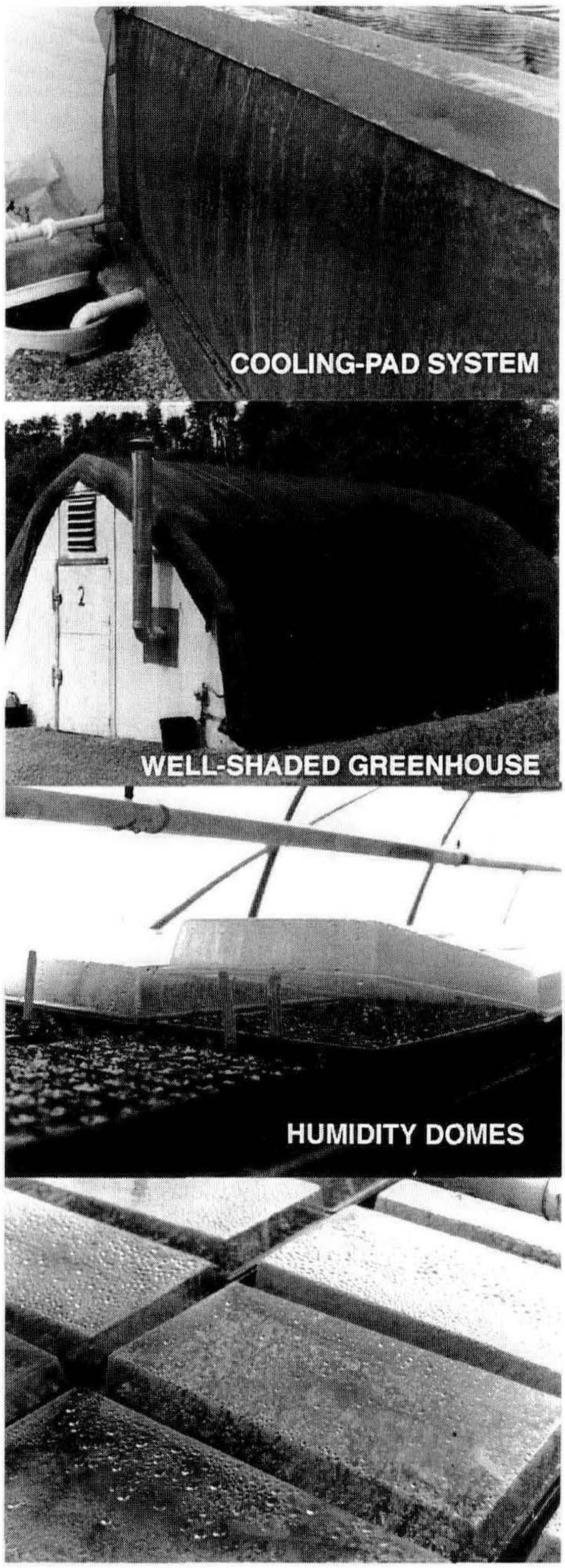
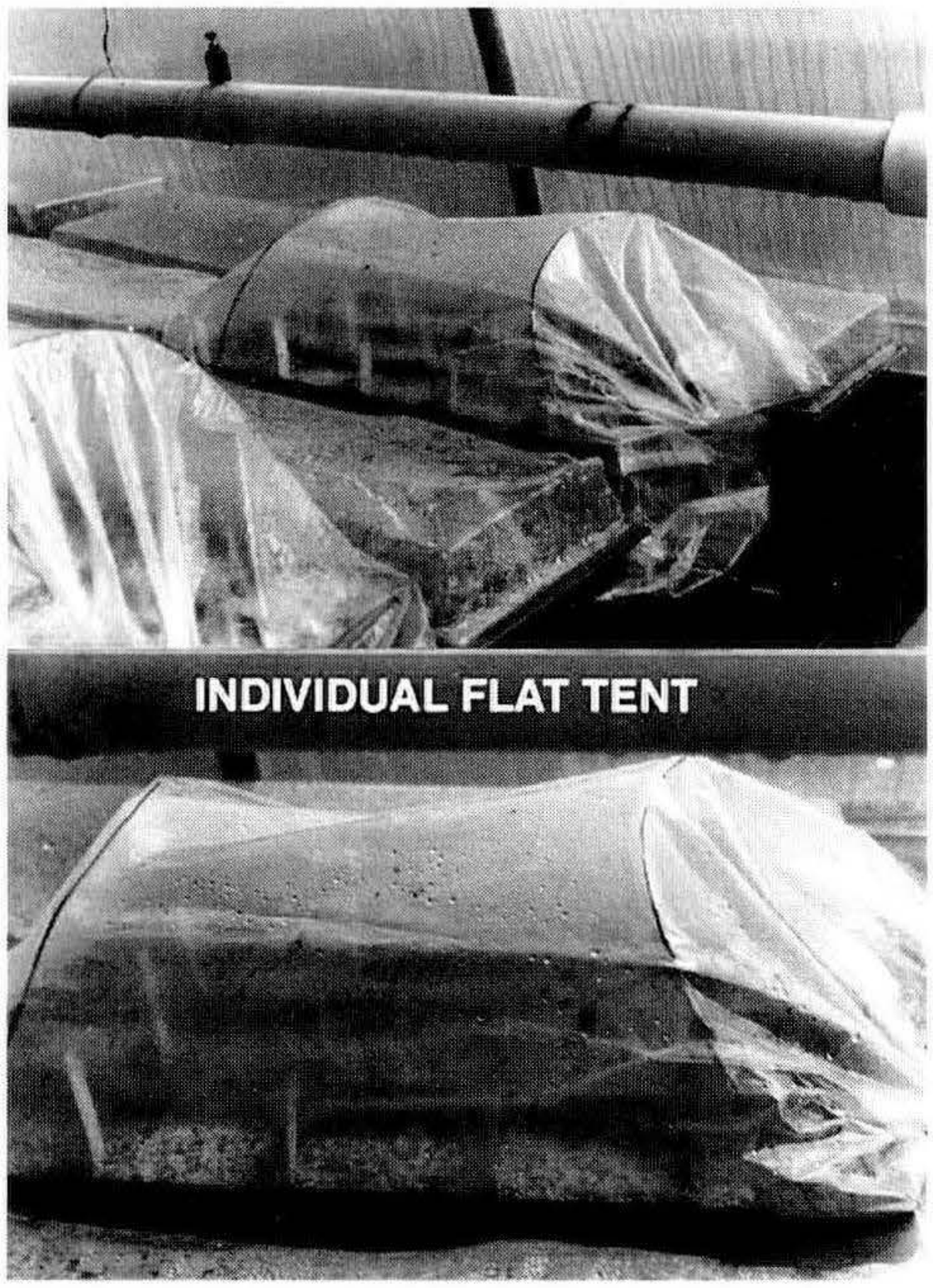


Figure 1. Methods used to acclimate various culture-rooted microcuttings.



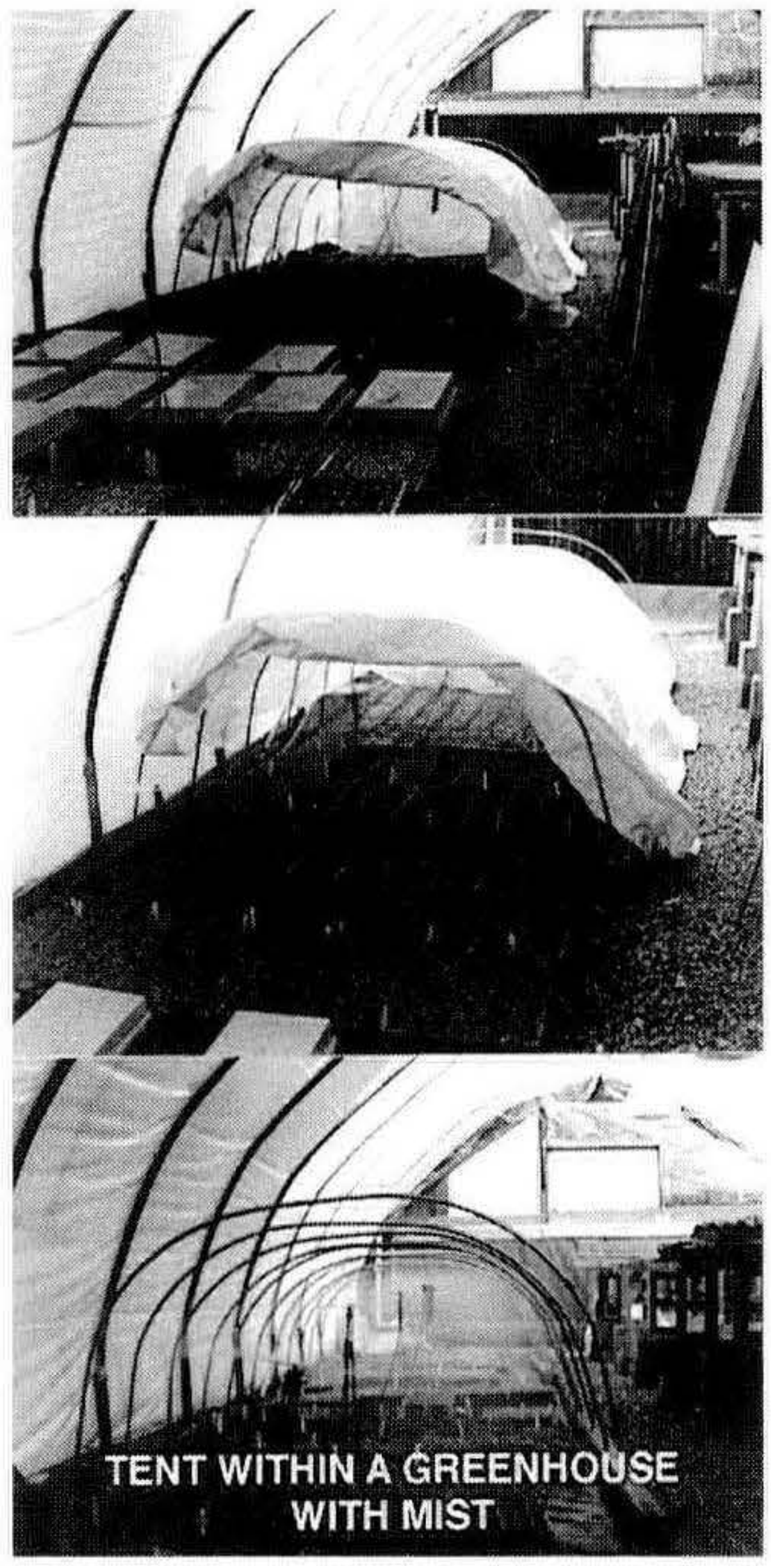


Figure 1. continued

- Gradually remove the domes after 1 or 2 weeks, or remove at night and replace later each day, weaning the plants onto the regular mist or fog.
- This method is ideal to prevent soggy media if a mist system is the alternative.

Tents for Individual Flats.

- These are easy to make with wire and plastic sheeting or bag.
- These are especially useful for flat sizes that do not have a commercially available humidity dome.

Cooling-Pad System.

- This system raises the humidity in the greenhouse, and is especially useful in low-humidity climates or seasons.
- Our system cools the greenhouse air 10F compared to outside temperatures on a low-humidity day. We are in a high-humidity climate and it cools to at least outside temperature on a sunny, humid day.

SUMMARY

Culture rooted microcuttings can be successfully handled in most existing conventional propagation systems with much of the same equipment and protocol one would use for rooting conventional cuttings. The use of a shaded greenhouse, tents, mist or fog, domes, cooling-pad, or a combination of these, can lead to the successful production of plants acquired from tissue culture laboratories.

Propagation Methods for the New Millennium

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To all concerned, the following summery and its findings are based on facts and data collect from production-grown plants. The help of several grower's on the East Coast and Mid West areas of the U.S.A. have my deepest "THANKS" for their belief in myself and my products. Along with those actual growers we are actively looking for university help in trials for two very important reasons. The first is to eliminate the stigma that biologically produced products can not replace chemical or synthetic products in actual production based on past results and costs. The second is to find out which products now on the market and which companies can produce results and are not just marketing masterpieces.

When I set out to find a more natural method other then traditional or conventional chemical means of propagating my thoughts were to list the goals I hoped to achieve. Those thoughts were of faster production from the viewpoint as a grower, and also as a backyard breeder. I also wanted it to work on as many plant taxa as possible. The list grew as my thoughts were also of worker and environmental safety. I set no priority on the list, but cost was something which had to be considered. On the following pages is the objective for the action taken, the methods of application used, and the results. As this is my first paper please read on.

We did a lot of work on perennials because they hold a spot close to my heart and they grow quickly. We know that the sooner cuttings are removed from the mist the losses due to excessive moisture decline. We wanted to increase or maintain an outside humidity level on the leaf surface and cut back on the amount of moisture needed to supply that level. The lignin polymers and surfactants found within the Grower Systems NGC accomplished those goals. But we also wanted to produce roots at the same time using natural plant hormones found in our kelp extract. The use of natural ingredients was a must for worker and environmental issues. Humic acid has an additional role in the rooting process by helping to buffer salts from soluble fertilizers which may be a detriment if the potting medium is allowed to become too dry. It also helps to chelate nutrients and make them readily available to the emerging tender roots.

We decided to use the NGC on Sunny Borders blue veronica, first of all because it was what the grower was sticking that day and had had a problem with damp-off due to excess water. The method of application selected was to use a hose-end bottle feeder set at a rate of 1 fluid oz NGC to 1 gal of water applied over the cutting and into the rooting medium in sufficient amount as to act as the first watering. This method was chosen because the grower was already applying KIBA in this manor and it was cost effective when time is considered. The treated cuttings were placed on the mist table and the mist was set on a 3-sec burst every 8 min. The nontreated cuttings were placed under mist set at 5-min intervals on a 6-sec burst. The treated cutting were taken off of mist in less then 2 weeks a full 8 days ahead of the nontreated and exhibited a larger flush of new growth. The plants were sold with no follow-up on how the plugs preformed.

The second method was to use the NGC as a 5-min soak. We used mini roses for our second trial. Cuttings were prepared for sticking and then immersed in a

solution of 1 fluid oz NGC and 1 gal of water for a period of 5 min and then stuck into 2¼-inch peat pots. The nontreated cuttings were individually dipped in a solution of Dip-N-Grow mixed at the suggested label rate. All cuttings were placed outside under mist and were checked about 8 weeks after sticking. There was very little difference exhibited in the root structure and only slightly in the amount of new growth. We were pleased with the results because we had generated roots in a method that we felt was safer to the workers and the environment, and was slightly less costly to use then their usual method. Again there was no follow-up to see how the rooted cutting transplanted for the next grower.

We completed a study that again used mini roses, this time the method of application was to make a 10% NGC solution mixed in a hand sprayer and applied over the top as a drench. The cuttings were rooted and transplanted before I had a chance to follow-up on the rooting. I was told that they rooted faster then normal and had a much more noticeable flush of new growth. The good part was that they were growing them on as part of their plant selection process and drenched them with a 1.5 fl oz per 10-gal water solution (NGC solution) at the time of transplanting. I was told that we had taken several months off the process.

We also wanted to finish container plants at a faster rate without forcing them with fertilizer, which in my mind is a quick fix. The desired effect were trialed for two reasons. First I wanted stockplants that would produce more cuttings to speed up my own selection process, the more plants produced the faster I could determine if they had the qualities I was looking for. The second motive was one with the grower in mind. If we could finish a plant faster with little extra cost it would open up a new approach to marketing a grower's plants. The plants consisted of a mix of perennials in 1-gal containers transplanted from 2-inch plugs. The potting soil was mixed in house using yard-waste compost, perlite, pea gravel, and silica sand. The treated plants received an over the top drench as a first watering using the rate of 1.5 fl oz (NGC) per 10 gal of water. All containers were topdressed with a granular fertilizer, no supplemental fertilizers were applied during the growing process. The treated plants received 2 oz of Grower Systems 5N-3P-4K plus, the nontreated plants 2 oz of a Scott's 20N-3P-11K 180 daytime-released fertilizer. The Grower Systems 5N-3P-4K plus treated plants were ready for market in 4 to 5 weeks, the others in 6 to 8 weeks.

Mission accomplished.

Evaluating Nursery Plant Performance in Biosolids Amended Soils

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INTRODUCTION

Soils in southern New Jersey have low native levels of organic matter, sometimes dropping below 1% and rarely exceeding 2%. This experiment examined the potential for use of biosolids materials as an organic matter source and the effect of amendment on growth. Sludge and co-compost were used in this study. Co-compost is the combination of municipal solid waste (the portion of garbage) and sludge that is composted.

Biosolids when added to native soils should increase the cation exchange capacity, reduce the leaching potential of fertilizers, enhance the water-holding capacity, and reduce heat and cold injury to the roots. One must, however, weigh the benefits against the cost. There have been restrictions on food crop procurement placed by processors on biosolids-amended land. This research project was designed to assist growers in making an educated decision regarding its use.

A loading rate study was initiated in 1993 that evaluated three rates of co-compost, three rates of sludge cake, and three rates of nitrogen fertilizer against non-amended plots. Results from that study indicated a significant negative growth impact with the addition of co-compost on *Viburnum dentatum* Chicago Lustre™ arrowwood. Unacceptably high levels of pH (7.8), soluble salts (2.98 mmhos), and carbon : nitrogen ratio (52) caused reductions in growth and plant death. Expected levels were a pH of 6.5 to 7.0, less than 1.25 mmhos of soluble salts, and a carbon to nitrogen ratio near 10. Sludge use resulted in significantly growth enhancement.

MATERIALS AND METHODS

A 2-year loading rate study was initiated in 1996 on the same plot as the 1993 study. In a randomized split-plot design with 6-ft-buffer strips containing 112 sub-plots containing 16 *V. dentatum* plants, including guard rows, were planted 36 inches on center. Co-compost plots received no additional amendment while sludge with an analysis of 25% total solids, 17% organic matter, 8.3% total nitrogen, and 4.25% available nitrogen was applied at three rates. Plots were fertilized with four equal applications each of 2 years. Individual treatment amendment combinations are listed in Table 1. Data was statistically analyzed using the Fisher's PLSD test. Separations were at the .05% level (95% probability).

RESULTS

Dry weight measurement indicated all cake treatments were significantly better than the untreated check (Fig. 1). No amendment level of co-compost was significantly better than the untreated check. There was no significant benefit from the use of different fertilizer rates.

The soil pH (Fig. 2) was significantly increased by co-compost and decreased by sludge treatments. Organic matter (Fig. 3) increased with increasing amendment

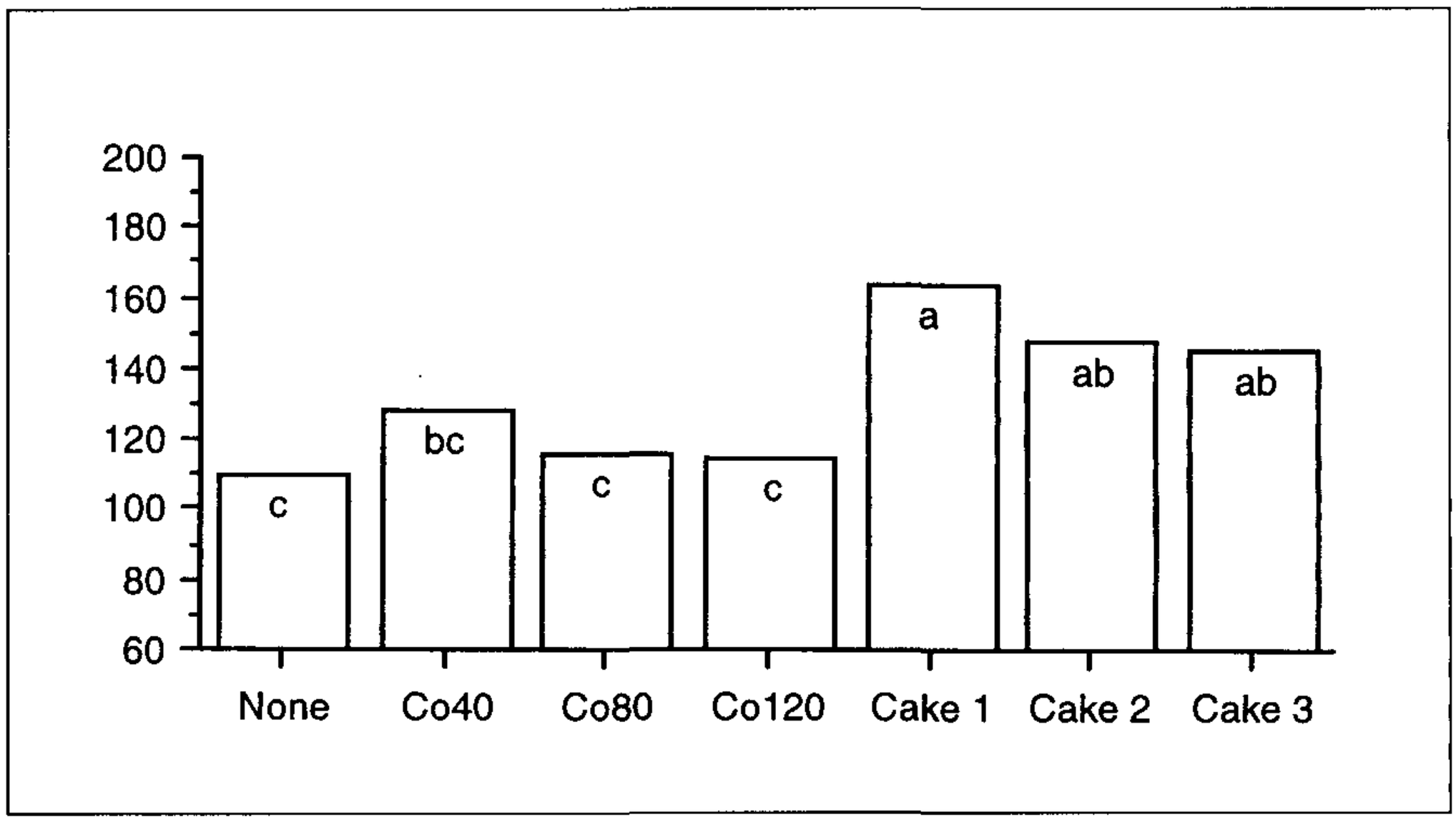

Figure 1. Effect of co-compost and sludge (cake) on the growth of *Viburnum dentatum*.

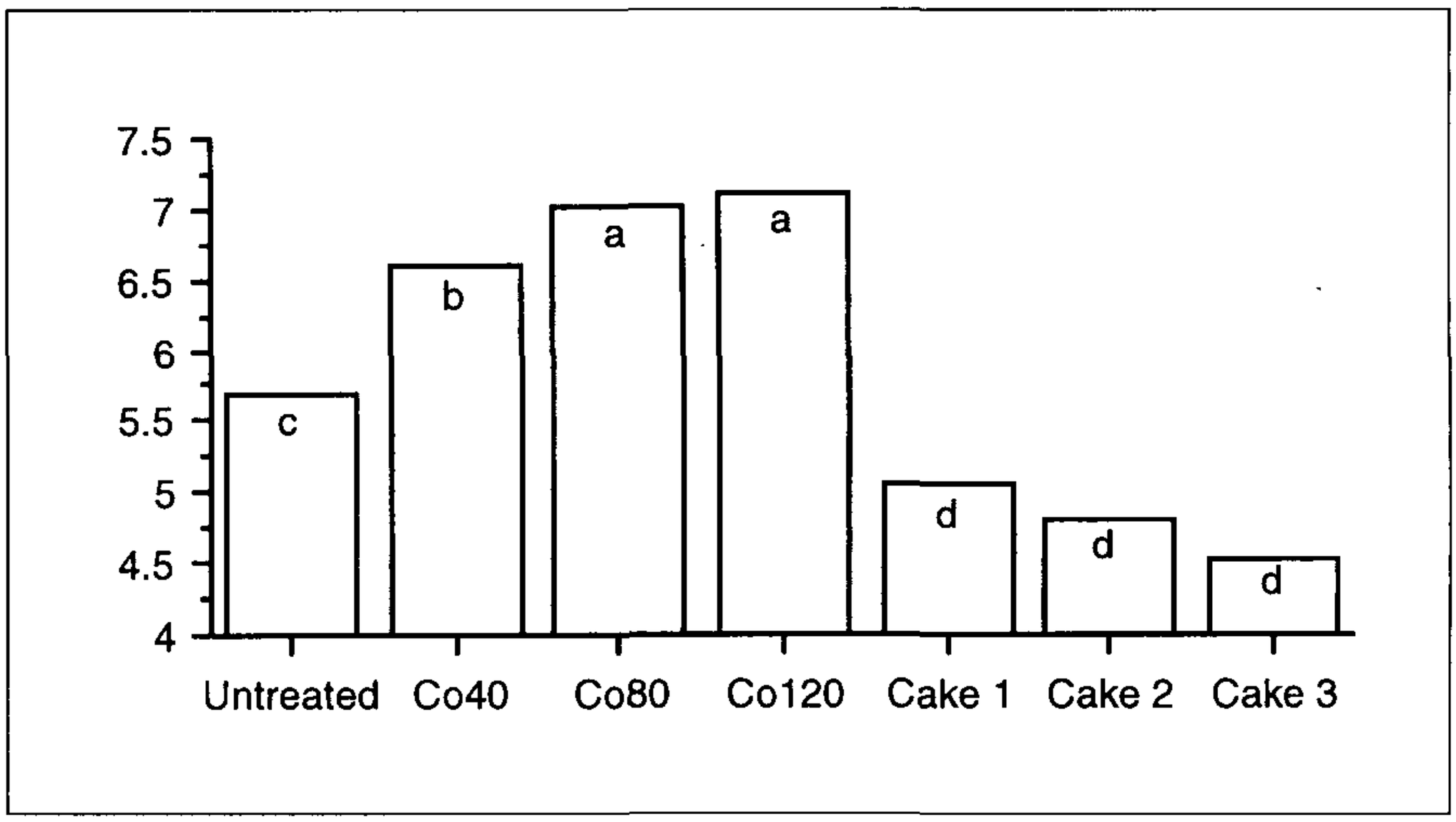

Figure 2. Effect of co-compost and sludge (cake) on soil pH.

in both the co-compost and cake treatments. All organic matter levels were significantly better than the untreated check. The trend for cation exchange capacity (Fig. 4) reflected that of organic matter content, with significant differences from the untreated check occurring in all but the lowest level of co-compost.

DISCUSSION

As with the earlier study, the cake source of biosolids again out-performed the co-compost treatments. Since the highest dry weight levels were recorded in the lowest cake treatment, additional information is required to determine if the pH reduction, while not significant, plays a part in that difference. Questions should be answered

Table 1. Individual treatment amendment combinations.

Amendment Rates	Treatments Fertilization (split appl.)
No Amendment	0# TN/A
	75 TN/A
	150 TN/A
	225 TN/A
93 Co-Compost	0# TN/A
@ 40 T/A = 1”	75 TN/A
	150 TN/A
	225 TN/A
93 Co-Compost	0# TN/A
@ 80 T/A = 2”	75 TN/A
	150 TN/A
	225 TN/A
93 Co-Compost	0# TN/A
@ 120 T/A = 3”	75 TN/A
	150 TN/A
	225 TN/A
Cake @ Load 1	0# TN/A
(3.04 bu/plot)	75 TN/A
	150 TN/A
	225 TN/A
Cake @ Load 2	0# TN/A
(6.08 bu/plot)	75 TN/A
	150 TN/A
	225 TN/A
Cake @ Load 3	0# TN/A
(9.13 bu/plot)	75 TN/A
	150 TN/A
	225 TN/A

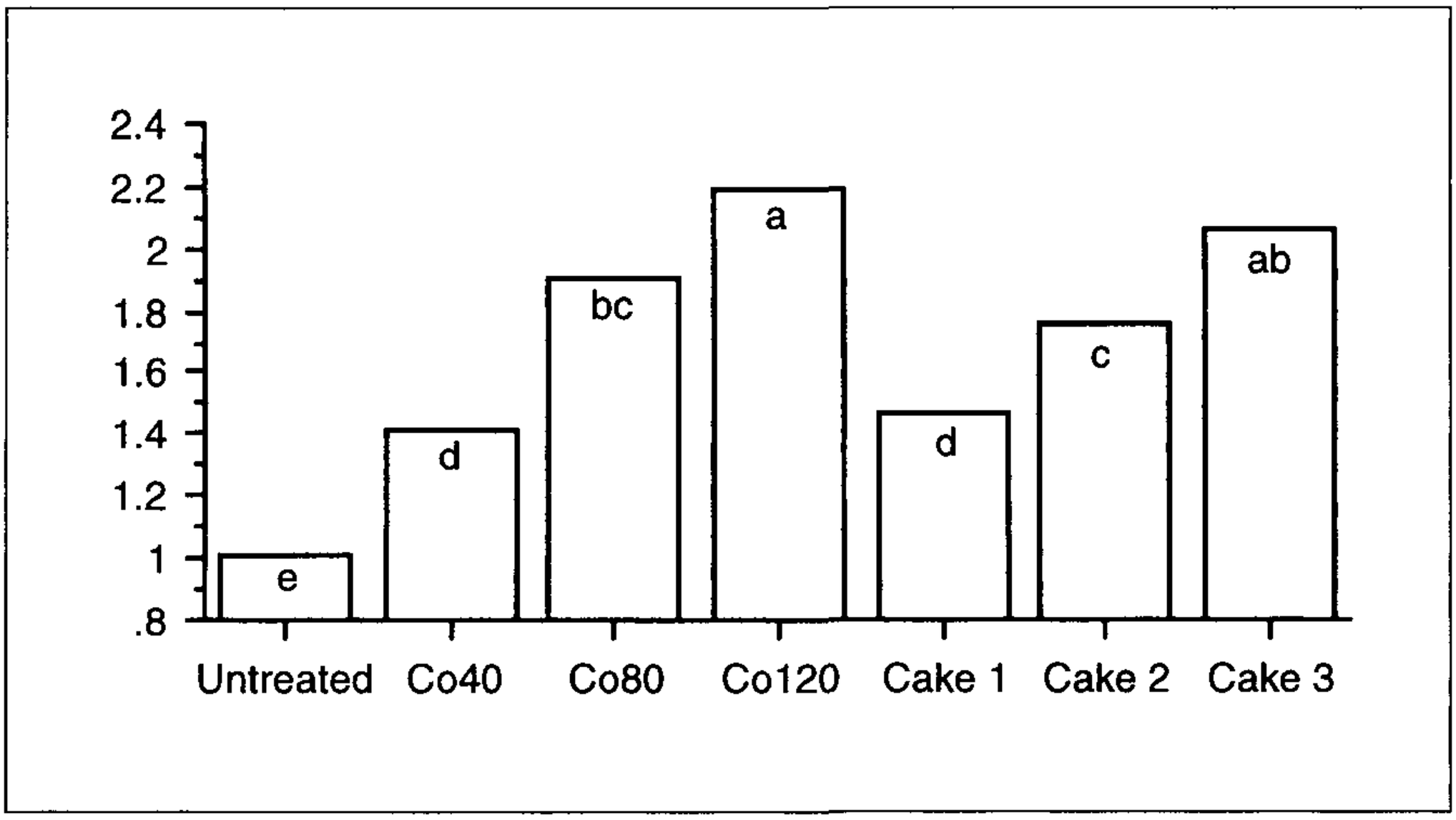

Figure 3. Effect of co-compost and sludge (cake) on soil organic matter content.

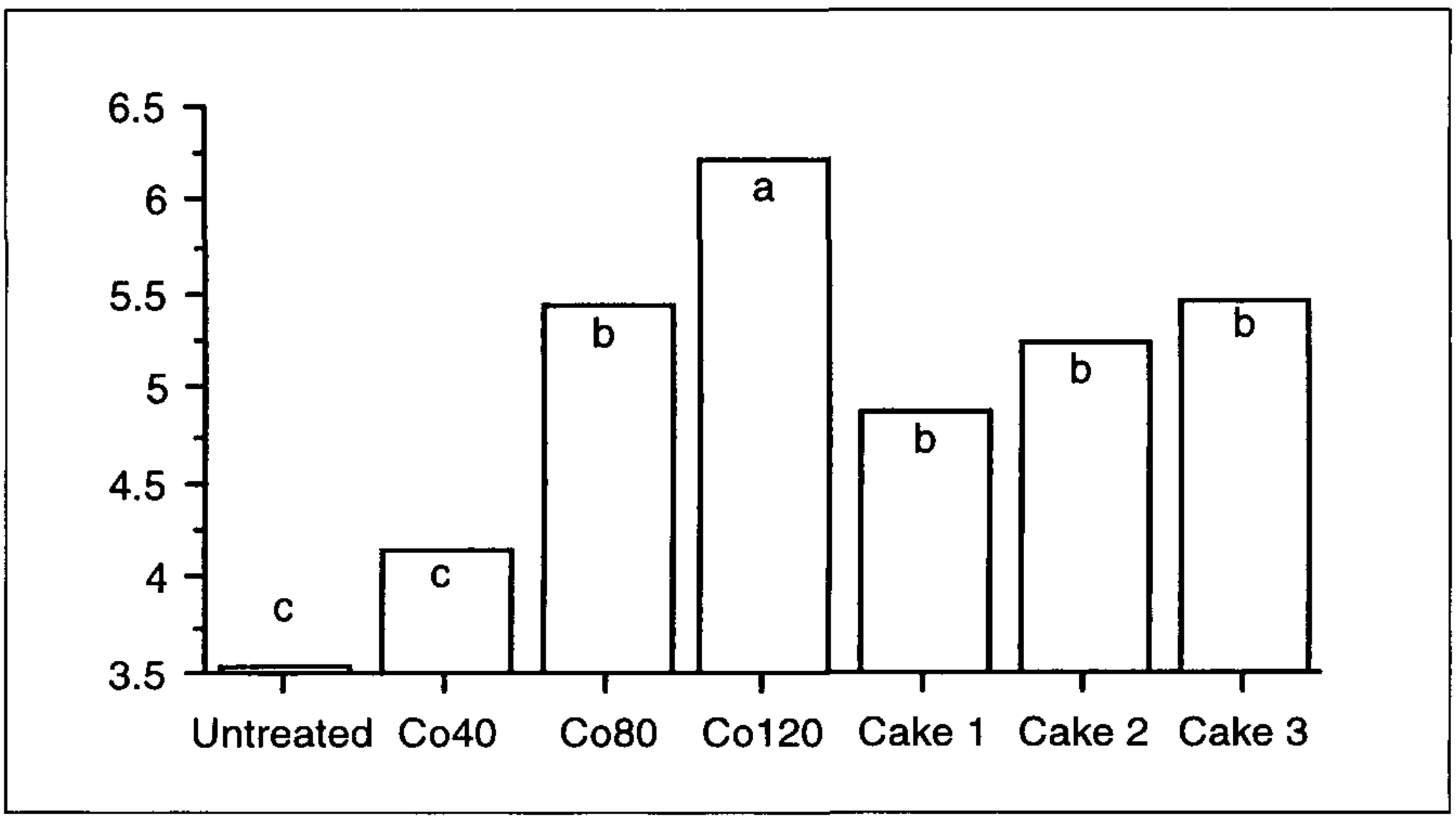

Figure 4. Effect of co-compost and sludge (cake) on soil cation exchange capacity.

why trends toward higher organic matter and cation exchange capacity levels resulted in reversed growth trends.

CONCLUSIONS

Results of this project demonstrated the greatest benefits and exposed the greatest concerns of using biosolids products in agricultural production. The lack of quality control resulted in no significant benefits from the use of co-compost through the two 2-year studies and actually caused significant problems in the first 2-year project. Even though soil organic matter and the cation exchange capacity were significantly increased through the co-compost biosolids there have been no growth benefits 5 years after application. Soil pH was also significantly increased.

The use of sludge biosolids resulted in significant growth enhancement during each of the two, 2-year studies. The soil organic matter and the cation exchange capacity were also significantly enhanced. The issue of soil pH depression with the use of cake must be addressed.

Acknowledgement. The author thanks Proctor & Gamble for taking the lead in a funding consortium that enabled the initiation of this project, to the Cumberland County Utilities Authority for financial and materials support, and to Cumberland Nurseries.

Low-budget Grafting of Japanese Maples

Ted Kiefer
Rivendell Nursery, P.O. Box 82, Stathern's Neck Rd., Greenwich, New Jersey 08323 U.S.A.

Rivendell Nursery is a 190 acre B&B nursery specializing in landscape-sized plant material. About 50% of our lined-out material is produced in-house. Japanese maples are one of the plants we produce by bench grafting.

I started grafting maples in January about 8-years ago. After a few years, I had two problems:

1) With only one heated house I was out of room with many grafts and many cuttings.
2) I needed more time in January and February for dormant pruning.

We switched to grafting maples at the end of August because:

1) It kept the help busy during a slow time
2) We created a grafting house with materials we had on hand using no heat.

OUR METHOD

Acer palmatum seed is collected in early September while still green. Seed is sown in flats and covered with sand. Young seedlings are transplanted into 4-inch pots in a pine bark, peat, and sand mix (3:2:1, by volume) with a 360-day time-release fertilizer. In late August, we collect scionwood early in the morning. Leaves are removed leaving a piece of petiole attached and stored in a refrigerator until ready to use. We only collect enough for 1 day's grafting. Scions are grafted onto the potted seedlings using a modified side veneer graft. Once grafted, the union is wrapped with an 8-inch budding strip and the top sealed with Tree Kote.

Finished grafts are placed in a 14-ft-wide polyhouse covered with plastic saved from the spring. Mist is applied every 20 min for about 2 weeks at which time the plastic is removed and replaced with a shade cloth. Grafts are then overwintered in an unheated cold frame and headed back in mid-February with a 3-inch snag left. In May, the snag is removed and plants are potted into 2-gal pots anytime from June until August (time permitting). Plants are staked and grown on for 2 years and lined out in September-October.

This method has produced 80% to 95% depending on the cultivar. Although I use a Tina grafting knife, my help uses a 98¢ razor knife purchased at local hardware stores.

After 5 years of this low-budget method, we have upgraded to a high-budget house with vents and a fog system. My initial results show the "low-budget" method works just as well on maples.

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Acer palmatum seed is collected in early September while still green. Seed is sown in flats and covered with sand. Young seedlings are transplanted into 4-inch pots in a pine bark, peat, and sand mix (3:2:1, by volume) with a 360-day time-release fertilizer. In late August, we collect scionwood early in the morning. Leaves are removed leaving a piece of petiole attached and stored in a refrigerator until ready to use. We only collect enough for 1 day's grafting. Scions are grafted onto the potted seedlings using a modified side veneer graft. Once grafted, the union is wrapped with an 8-inch budding strip and the top sealed with Tree Kote.

Finished grafts are placed in a 14-ft-wide polyhouse covered with plastic saved from the spring. Mist is applied every 20 min for about 2 weeks at which time the plastic is removed and replaced with a shade cloth. Grafts are then overwintered in an unheated cold frame and headed back in mid-February with a 3-inch snag left. In May, the snag is removed and plants are potted into 2-gal pots anytime from June until August (time permitting). Plants are staked and grown on for 2 years and lined out in September-October.

This method has produced 80% to 95% depending on the cultivar. Although I use a Tina grafting knife, my help uses a 98¢ razor knife purchased at local hardware stores.

After 5 years of this low-budget method, we have upgraded to a high-budget house with vents and a fog system. My initial results show the "low-budget" method works just as well on maples.

Propagating Native Cool Season Grasses for Conservation Use

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PROJECT BACKGROUND

Part of the USDA's Natural Resources Conservation Service, the National Plant Materials Center (NPMC), is concerned with developing plant species and technology for conservation applications. Erosion control, water quality improvement, upland and wetland wildlife habitat enhancement, and grazing land improvement are focus areas for the NPMC as well as the other 25 plant materials centers which make up the NRCS Plant Materials Program. The goal of the Program is to make improved plants and information available to land owners and managers.

The NPMC and the Plant Materials Centers in Big Flats, New York; Cape May, New Jersey; and Rose Lake, Michigan, have initiated a project to investigate propagation and seed production of selected native cool-season grasses for the Northeast United States. Very few native cool-season grasses are available for widespread use in the region, and the Plant Materials Program is trying to develop both untapped species and technology (i.e., propagation, seed production, processing requirements, and field establishment). The techniques developed by this project will make nursery production of regional grass ecotypes possible.

The NPMC is working with many groups, including the University of Maryland, NRCS field offices, several National Parks, and citizen volunteers to make the initial regional collections of seven native cool-season grass species.

SPECIES UNDER INVESTIGATION

The primary species of interest at the NPMC are Virginia wildrye (*Elymus virginicus*), hairy wildrye (*E. villosus*), and bottlebrush grass (*Hystrix patula*). These species are available on an extremely limited basis from seed vendors, most seed is from outside the region, and each has potential conservation applications. Secondary species of interest include little foxtail (*Alopecurus carolinianus*), Canada brome (*Bromus purgans*), stout woodreed (*Cinna arundinacea*), and little barley (*Hordeum pusillum*). These species are not commercially grown in production fields (or in some cases, not even available), and more research is needed regarding the potential for seed production as well as conservation uses.

PROJECT SCOPE AND CURRENT STATUS

The NPMC is focusing on collections of these native grasses from the coastal plain, piedmont, and mountain regions of the mid-Atlantic states. The collection area extends from the Maryland-Pennsylvania border in the north, south to North Carolina, and west to West Virginia.

Initial seed collections were made for all species in summer and fall 1998, seed from each site was assigned an accession number, and three 100-seed replicates of each collection were tested for percent germination in the greenhouse. Grass plugs will

be lined out in evaluation blocks in late fall 1998 and in spring 1999.

Information generated by previous work at the NPMC with Virginia wildrye, hairy wildrye, and bottlebrush grass will be used to maintain weed-free evaluation blocks, as well as harvest and clean seed. The NPMC has been growing these three species for roadside revegetation projects. Production fields have been established by planting plugs in rows with a modified tobacco planter. Weed maintenance between rows has been accomplished through planting a cover crop or through cultivation. Seeds are harvested using a combine, and seeds are cleaned using a two-screen clipper.

Horticultural Research at The Holden Arboretum

Robert D. Marquard and Charlotte R. Chan
The Holden Arboretum, 9500 Sperry Road, Kirtland, Ohio 44094-5172 U.S.A.

Formal research at the Holden Arboretum began in 1991 with the hiring of staff with scientific training. Currently, the centerpiece of research is breeding woody ornamental plants to support our mission to develop improved plants for the landscape through breeding or selection and to make significant contributions to the plant sciences. Complementary research includes: studies of plant reproductive biology, measuring genetic diversity, estimating the heritability of important traits, utilization of biochemical markers, and developing alternative propagation methods. The current focus includes work within several genera (*Aesculus, Cercis, Hamamelis, Magnolia,* and *Rhododendron*).

Acquisition of germplasm has been an organizational and early research objective. In 1993, we began assembling a collection of *Hamamelis* cultivars and seed was collected from throughout the range of our native *H. virginiana.* By formal agreement, the Holden Arboretum acquired the property and germplasm accumulated by David G. Leach who was a prodigious breeder of *Rhododendron* for over 50 years. Acquired in 1986, this plant collection is one of the best for cold-hardy *Rhododendron* germplasm. Three full-time employees maintain this satellite research station of nearly 20 acres located within 30 miles of The Holden Arboretum.

At the Arboretum proper, research is conducted from the Horticulture Science Center (HSC) which was completed in early 1994. Currently, over 4000 ft^2 provides ample office, herbarium, darkroom, and laboratory space for research. The HSC also has a 3000 ft^2 headhouse and about 4500 ft^2 of greenhouse space to support the expanding needs of the organization.

The Corning Institute for Education and Research was designed, in part, to promote research by young scientists. This program may support graduate students who conduct research at Holden and complete class work at an appropriate college or university. Alternatively, the Corning Institute may support individuals at the post-graduate level to work with the Research staff on specific projects. A second opportunity is the R. Henry Norweb, Jr. Fellowship that typically supports individual research at the Arboretum typically during the summer. Staff selected for this program may work on a specific project of interest, bring an existing program to The Holden Arboretum, or be supported while on sabbatical leave.

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Isozyme and RAPID Analyses of Witch Hazel Cultivars

Robert D. Marquard, Charlotte R Chan, Eric P. Davis, and Emily L. Stowe
The Holden Arboretum, 9500 Sperry Road, Kirtland, Ohio 44094 U.S.A.

Numerous isozyme systems were found to be polymorphic in witch hazel *(Hamamelis* spp.). However, aconitase (ACO), malate dehydrogenase, phosphoglucose isomerase (PGI), and phosphoglucomutase were most useful for identification of cultivars. From these enzyme systems, three genes were identified that control

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patterns of ACO (2) and PGI (1). Isozymes can be used to help verify cultivars and their simple inheritance could be useful to validate hybrids and gene flow between plants. DNA was readily extracted from young leaf tissue after grinding in liquid nitrogen and extraction in warm CTAB. DNA was amenable to amplification using polymerase chain-reaction technology. Primers (400) were screened to identify polymorphic RAPID bands. Ultimately, 19 primers were used to generate 68 RAPD markers that were reproducible. Cultivars were scored for presence or absence of the 68 markers. Genetic similarities were calculated using a Nei coefficient and clustering was conducted for more than 40 cultivars using a UPGMA program. Arbitrarily, the cultivars were assigned to seven groupings after cluster analysis. The seven classes gave one group each of *H. japonica* and *H. mollis,* two groups of *H. vernalis,* and three groups of H. ×*intermedia.* Clustering allowed some interpretation about relatedness among cultivars and genetic similarity data helped assign some cultivars to a particular taxa that were previously in question.

Rhododendron Root Rot Resistance

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Root rot caused by the soil-borne pathogen *Phytophthora cinnamomi* is one of the deadliest and most costly diseases in rhododendron culture. Unfortunately, the majority of cultivars appear to be susceptible to this fungus. Host resistance does occur, but it represents a tolerance of rather than immunity from the disease. A breeding program has been initiated to develop a broader array of root-rot-resistant cultivars and to determine the genetic basis for resistance. Greenhouse inoculations and screenings of 48 contemporary cultivars yielded seven clones with moderate to high levels of resistance to *P. cinnamomi.* Protocols for evaluation at the seedling stage were developed in order to screen large breeding populations of about 200 seedlings per cross. Root-rot tolerance appears to have low to moderate heritability in these rhododendron populations. Groups of progeny with one resistant parent had a slower mortality rate and higher survivorship (avg. 10%) after 2 months of disease pressure than crosses in which both parents were susceptible (0 survivorship). A recurrent selection strategy is planned to increase the frequency of alleles for resistance in breeding populations of rhododendrons.

Rapid Micropropagation of ×*Chitalpa tashkentensis*

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×*Chitalpa tashkentensis* (*Chilopsis linearis* × *Catalpa bignonoides)* is an attractive small tree producing lavender to white orchid-like flowers. Micropropagation would allow for the rapid clonal propagation of new hybrids for testing cold hardiness and landscape performance. The rapid growth response of *Chitalpa* shoot cultures also

makes it an excellent subject for the study of in vitro growth parameters of woody plants. Shoot cultures were initiated from shoot tips on Anderson's rhododendron medium with MS vitamins, 3% sucrose, 1 μM BA, pH 5.6, and solidified with 0.6% Phytagar. Shoot cultures stabilized rapidly. Two-node microcuttings were placed on modified MS medium (200.1 μM Na2 EDTA and 200.5 μM $FeSO_4$ $7H_2O$), MS vitamins, 3% sucrose, pH 5.6, 0.6% Phytagar and supplemented with NAA (0, 0.5, 1.5, or 3 μM) in combination with BA (0, 1, 5. 10, 15, 20, 30, or 40 μM). Cultures grown on media supplemented with 1 mM BA produced the longest shoots and the most nodes per shoot. Cultures grown on media supplemented with 10 ppm BA produced the most shoots. Microshoots readily rooted on plant-growth-regulator-free MS medium and were easily acclimated.

Use of Chlorophyll Fluorescence in Propagation

Sarah E. Bruce and Bradley Rowe
Department of Horticulture, Michigan State University, East Lansing, Michigan 48824 U.S.A.

INTRODUCTION

Chlorophyll fluorescence is the small portion of light that is re-emitted from chlorophyll during the processes of photosynthesis. It is an estimation of photosynthetic efficiency and in turn provides an indirect measure of plant stress which is important because stress levels detrimental to the plant are usually present before they are visible to the naked eye. Current applications include the detection/evaluation of environmental stresses such as: cold tolerance (Westin et al, 1995), heat stress (Ranney and Peet, 1994), water stress (Eastman and Camm, 1995), nutrient deficiencies (Strand and Lundmark, 1995), irradiance levels (Layne and Flore, 1993), and air pollution (ozone) (Patterson and Rundel, 1995). It has been used in micropropagation of transvaal daisy (van Huylenbroeck and Debergh, 1992) but until now there have been no experiments involving conventional propagation by stem cuttings.

If a quick, reliable method of determining potential rooting of cuttings based on the condition of a specific stock plant was available for propagators, then rooting success could be predicted prior to an investment in time, labor, and resources. Thus, a reduction in production costs could be realized. Therefore, the objective of this study was to examine chlorophyll fluorescence readings of ten cultivars of *Taxus* over the course of propagation and compare initial fluorescence measurements with subsequent rooting percentages.

MATERIALS AND METHODS

Ten cultivars of *Taxus* were selected for the study: Bobbink, Brownii, Dark Green Pyramidal, Dark Green Spreader, Densiformis, Densiformis Gem, Hicksii, Runyanii, Tauntonii, and Wardii. Cuttings were taken in mid October from field grown plants at Zelenka Nursery, Grand Haven, Michigan, and were placed in cold storage at 2.5C (36F) for 5 weeks. At this time they were recut to a uniform length of 4.5 inches, treated with Woods Rooting Hormone (IAA 1.03%; NAA 0.66%) at 2800 ppm (5 : 1 ratio), and placed into a medium of 100% perlite. The experiment followed a

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Table 1. Rooting percentage of ten cultivars of *Taxus* ×*media*.

Cultivar	Rooting %
Densiformis	96.7 abc*
Wardii	88.3 abcd
Densiformis Gem	85 abcde
Dark Green Pyramidalis	76.3 bcdef
Runyan	70 cdef
Hicksii	65 def
Dark Green Spreader	61.7 defg
Taunton	56.7 efg
Brownii	46.7 fg
Bobbink	31.7 g

* Means with the same letter are not significantly different. Mean separation among cultivars by LSD, P 0.05.

Table 2. Initial chlorophyll fluorescence measurements of ten cultivars of *Taxus* ×*media*.

Cultivar	Fv / Fm*
Dark Green Pyramidalis	0.8728 a**
Taunton	0.8511 ab
Densiformis	0.8261 bc
Hicksii	0.8194 bc
Runyan	0.8173 bc
Dark Green Spreader	0.815 bc
Densiformis Gem	0.7909 cd
Brownii	0.772 d
Bobbink	0.7601 de
Wardii	0.7305 e

* Ratio of variable fluorescence to maximum fluorescence

** Means with the same letter are not significantly different. Mean separation among cultivars by LSD, P 0.05.

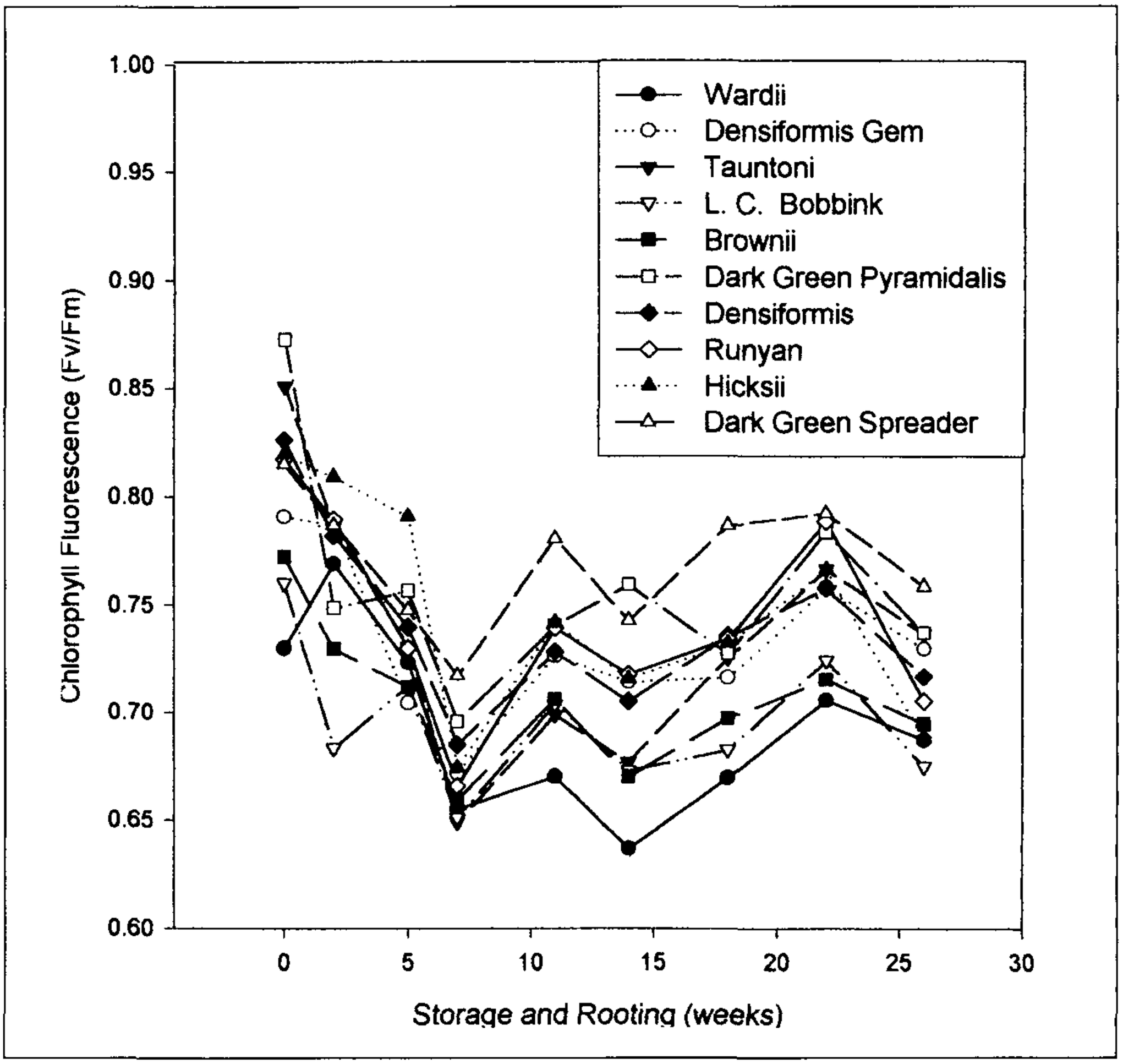

Figure 1. Chlorphyll fluorescence of Taxus during propagation.

randomized complete block design consisting of six blocks and 10 cultivars. There were 10 cuttings within each block/cultivar combination for a total of 600 cuttings. Periodic chlorophyll fluorescence measurements were taken with a Morgan CF-1000 Chlorophyll Fluorescence Measurement System throughout storage and rooting. Readings consisted of the ratio of variable fluorescence to maximum fluorescence (F_v/F_m). Following 20 weeks in the rooting beds, cuttings were evaluated and rooting percentages were determined. Means for each group of ten cuttings were subjected to analysis of variance (ANOVA) procedures to determine significant effects and means were separated by an LSD test.

RESULTS AND DISCUSSION

Fluorescence measurements exhibited a sharp decrease following severance from the stock plant which continued through storage and into the first 2 weeks in the propagation bed (Fig. 1). This decline in fluorescence measurements quantifies the increase in stress that the cuttings are enduring during the propagation period. Differences in the way chlorophyll fluorescence changes over time were found to exist among cultivars.

Differences among cultivars were also found in initial field chlorophyll fluorescence levels and final rooting percentages (Tables 1 and 2). An overall correlation between the two was not found, indicating that chlorophyll fluorescence values need to be examined at the individual cultivar level.

Acknowledgment. This experiment was one of three in a Michigan State University study funded by: Zelenka Nursery in Grand Haven, Michigan, International Plant Propagator's Society, Michigan Nursery and Landscape Association, and Michigan Agricultural Experiment Station.

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Softwood Propagation of *Platanus* x*hispanica* 'Columbia'

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INTRODUCTION

Platanus ×*hispanica* (syn. *P.* ×*acerifolia*) is a hybrid cross between *P. orientalis* and *P. occidentalis*. It is a large, widely branched fast-growing tree known for its beautiful exfoliating bark. It thrives in a rich moist soil but this plant will also tolerate polluted city conditions. It was so widely planted in London, England, because of its adaptability that it became known as the London planetree.

A combination of disease problems coupled with overplanting have tempered the use of *P.* ×*hispanica*. Superior cultivars such as 'Columbia' and 'Liberty' which are resistant to anthracnose and powdery mildew are now grown.

Goals. In 1986 the Royal Botanical Gardens in Hamilton received a few plants of *P.* ×*hispanica* 'Columbia' and 'Liberty' which we lined out in our nursery to size up. As so often happens in many nurseries some plants for various reasons are forgotten or left behind. Before we knew it 'Columbia' had grown too large too move. Our goal was to secure propagules which would eventually go to our collection.

A review of past proceedings of the I.P.P.S. reveal that *P.* ×*hispanica* can be successfully propagated by seed, but leaf-bud cuttings as well as hardwood cuttings have had limited success. As for softwood cuttings, Dirr mentions that if taken in June they would root successfully. No information could be found on rooting any of the cultivars. It was our hope that they would root as well as *P.* ×*hispanica*.

MATERIALS AND METHODS

Cuttings (120 each) with a minimum of three nodes were collected on 12 June 1998. Every cutting was given a ½-inch wound just above the bottom node and the leaves were trimmed by half to help reduce transpiration. They were then given a 5-sec quick dip into Stim–Root 5000 (0.5% indole-3-butyric acid) and stuck into trays of sand and peat moss (4 : 1, v/v). The cuttings were set under intermittent mist and checked daily.

RESULTS AND DISCUSSION

On 24 July 1998 the cuttings were inspected for roots. Of the 120 cuttings 111 had well branched roots which were then potted into 4-inch pots and set under the mist for another week to acclimatize.

A total of 92.5 % of the cuttings rooted. The potted plants were then placed into our lathouse and by 1 Sept. many had started to break bud and to set some new growth. The plants will be protected in a cool greenhouse for the winter for the hardiness of the roots is not known at this time.

Not only were we able to successfully propagate 'Columbia' for our collection but the results also indicate that softwood propagation of this cultivar may be profitable for the nursery trade.

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IBA-K Induced Rooting in Perennials

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The effects of IBA-K treatment on the adventitious root rate and root number of cuttings of three herbaceous perennial species were determined. Cuttings were submerged in 500, 1000, or 2000 ppm IBA-K for 2 min or were quick-dipped in 1000, 3500, or 7000 ppm IBA-K for 20 sec. After 2 weeks rooting success was determined by root rate and root number. Root rate was evaluated by assigning cuttings numbers 0 to 3 (0-dead, 1-no callus, 2-callus, and 3-roots longer than 1 mm). Rooting success depended on season, method of IBA-K application, cutting technique, and concentration of IBA-K. However, response to these four factors was mostly inconsistent within and between species. Phytotoxicity was observed at high concentrations of IBA-K. Therefore, no recommendations for optimal treatment can be given without quantitatively measuring phytotoxicity as well as root rate and root number.

Veronica **'Noah Williams'.**

Root rate was not clearly affected by IBA-K. Cuttings that were submerged showed little difference among the control, 500 ppm, and 1000 ppm IBA-K treatments. At 2000 ppm, submerged cuttings showed a decrease in root rate. Cuttings that were basally dipped followed a similar pattern. The control, 1000 ppm, and 2000 ppm all rooted at the same rate. In addition, the control and 1000 ppm in the basal dip application had the same root rate as cuttings submerged at those treatments. At the highest basally dipped treatment (7000 ppm), root rate decreased and rooted at the same rate as the highest submerged treatment (3500 ppm) (Fig.1).

Results describing the effect of IBA-K on root number were unclear as well. In the submerged application, root number decreased at 500 ppm and then continued to increase at 1000 and 2000 ppm IBA-K. In the basal dip application, root number slightly increased as concentration of IBA-K increased up to 3500 ppm. At this point, there was a large increase from 3500 to 7000 ppm IBA-K. In both submerged and basal dip applications, the highest concentration of IBA-K had the smallest root rate but the largest number of roots (Fig.2).

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IBA-K Induced Rooting in Perennials

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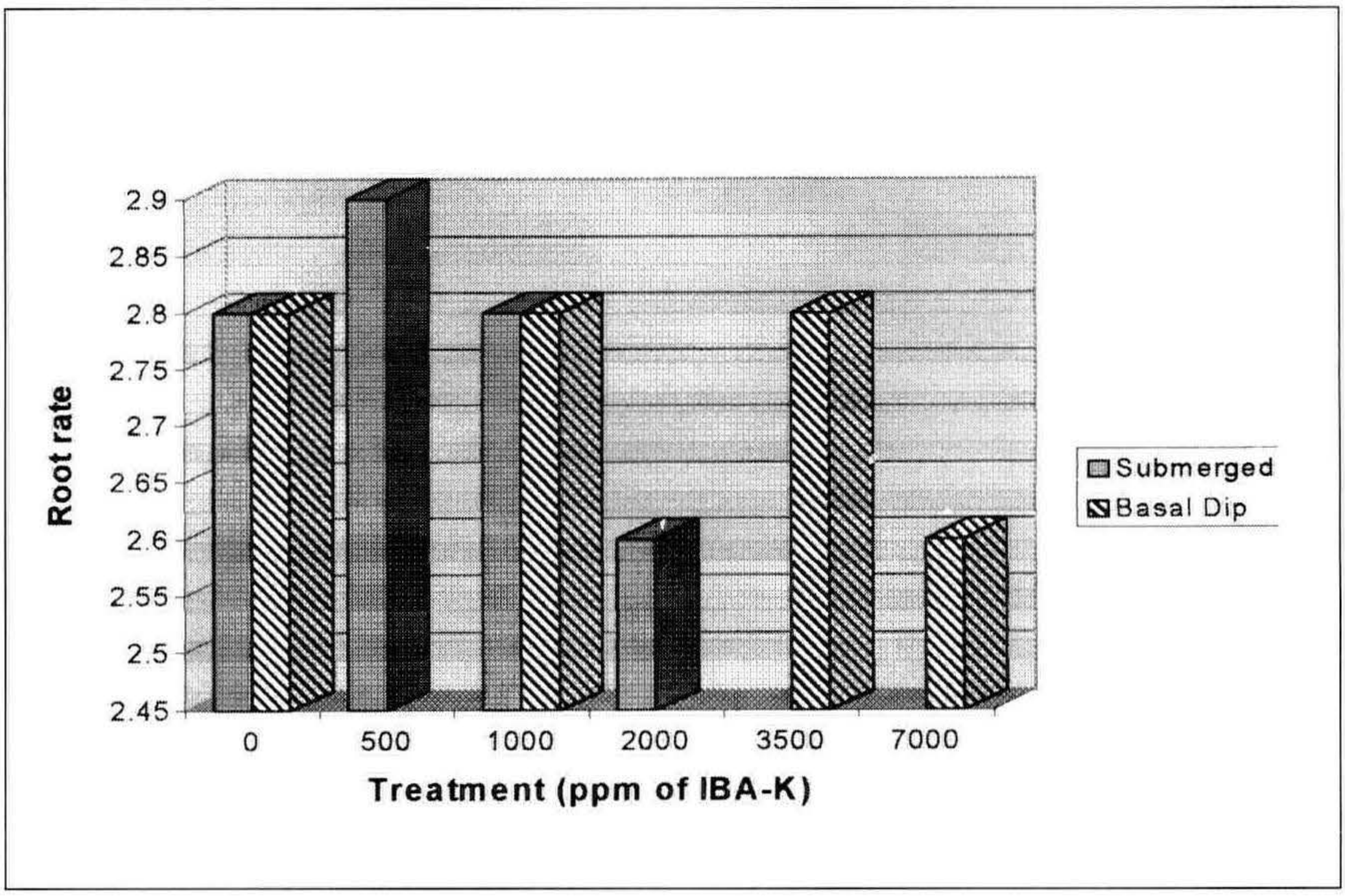

Figure 1. The effects of IBA-K on root rate in submerged and basally dipped cuttings of *Veronica* 'Noah Williams.'

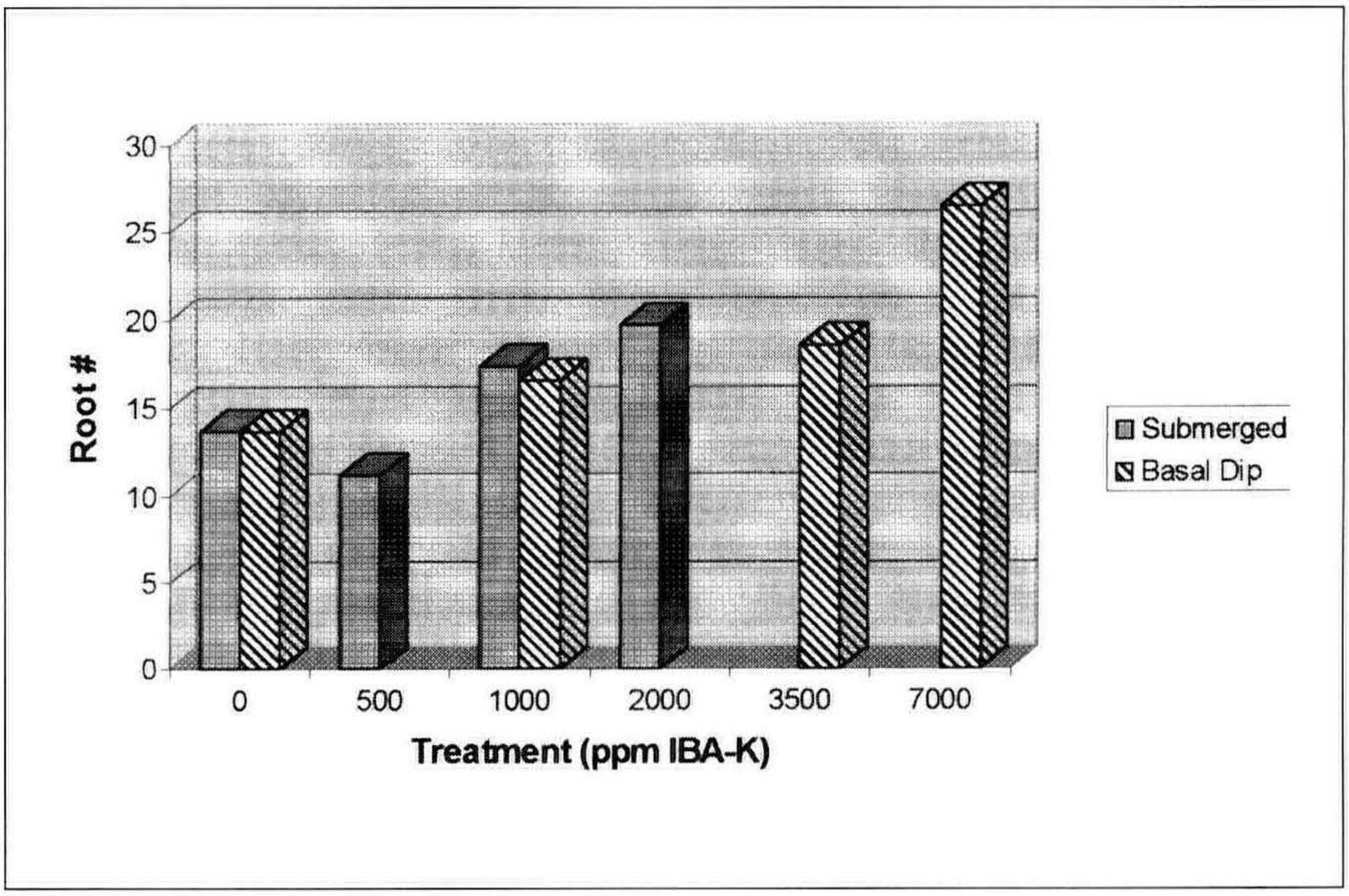

Figure 2. The effects of IBA-K on root number in submerged and basally dipped cuttings in *Veronica* 'Noah Williams.'

Severe phytotoxicity above the soil was observed. As IBA-K concentration increased, leaf burn increased, especially in cuttings submerged in rooting hormone. This may explain the lower root rate at high concentrations of IBA-K in submerged and basal dip applications. In addition, replication of this experiment during fall and spring did not affect the rooting success.

Achillea 'Moonshine'

Root rate was affected by IBA-K in both submerged and basal dip applications. Cuttings that were submurged with 500 ppm IBA-K had the same root rate as in the control. However, from 500 to 1000 ppm, there was a dramatic increase in root rate and then a leveling off at 2000 ppm. In the basal dip application, root rate increased as concentration of IBA-K increased up to 3500 ppm where root rate leveled off (Fig. 3).

As IBA-K concentration increased, root number increased in both submerged and basal dip applications. Cuttings that were submerged increased root number linearly up to 1000 ppm at which time, root number leveled off. However, cuttings that were basally dipped increased root number exponentially as concentration of IBA-K increased (Fig. 4).

At high concentrations of IBA-K, cuttings in both applications experienced phytotoxicity in the form of chlorosis. This could explain why root rate leveled off in both the basal dip and submerged applications. The leveling off at 1000 and 2000 ppm may have been a result of phytotoxicity in the submersion treatment. Phytotoxicity in the form of chlorosis did not affect root number in basally dipped cuttings as shown in Fig. 4.

Cuttings that were vegetative (no flower stalk) appeared to have better overall rooting success. Replication of this experiment showed that cuttings taken in the spring and fall did better than in the summer. This may be true because *A.* 'Moonshine' is a long-day obligate plant and cuttings taken during the summer were likely to contain flower stalks.

Baptisia pendula

Indole-3-butyric acid-potassium salt affected root rate in both submerged and basal dip applications. As IBA-K concentration increased, root rate in submerged cuttings increased up to 1000 ppm. From 1000 to 2000 ppm IBA-K root rate dramatically decreased. A similar trend occurred in the basal dip application. Root rate increased from the control to 1000 ppm, leveled off at 3500 ppm, and then a decreased from 3500 ppm to 7000 ppm (Fig. 5).

Increased IBA-K concentration did not clearly show an effect on root number in cuttings that were submerged. Root number went from approximately 4.5 in the control, to 7 at 500 ppm, back down to approximately 5 at 1000 ppm, and then finally back up at 2000 ppm. The basal dip cuttings followed a more consistent pattern. Root number increased with concentration up to 3500 ppm and then decreased (Fig. 6).

In the submerged application, root rate of treated cuttings was the smallest at the highest concentration (2000 ppm IBA-K) but had the largest root number. As expected, cuttings basally treated had the smallest root rate and root number at the highest concentration (7000 ppm IBA-K).

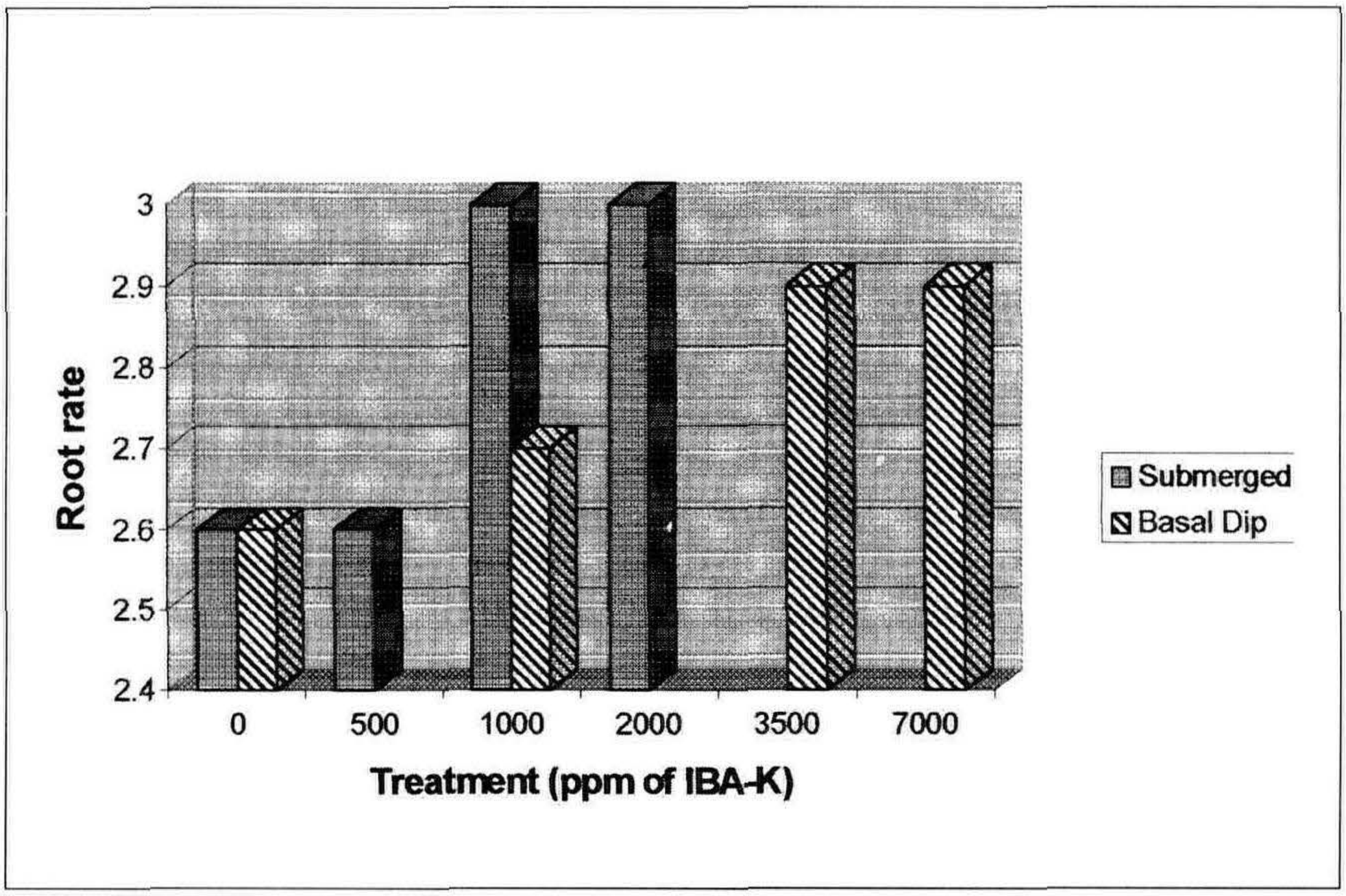

Figure 3. The effects of IBA-K on root rate in submerged and basally dipped cuttings of *Achillea* 'Moonshine.'

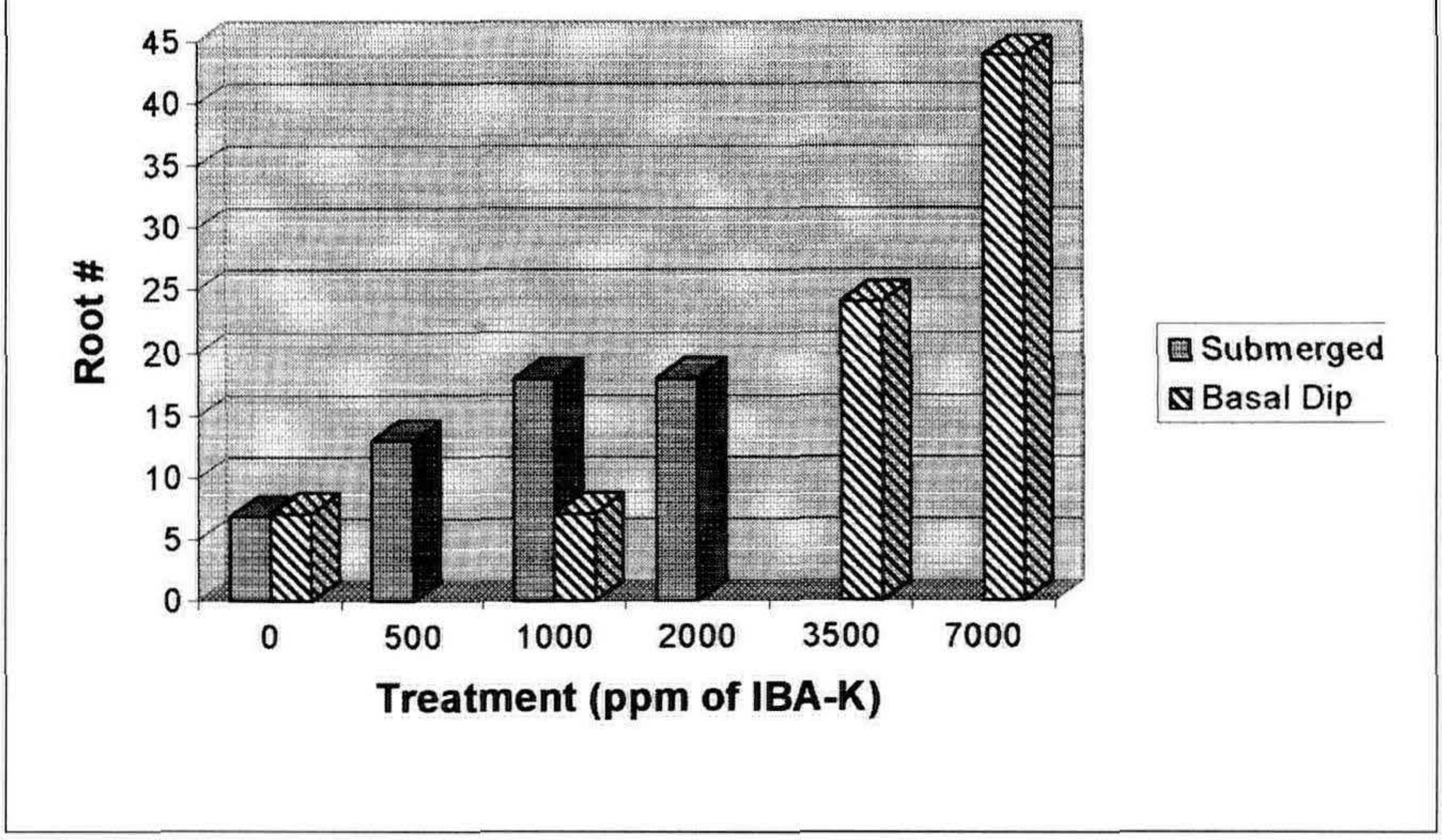

Figure 4. The effects of IBA-K on root number on submerged and basally dipped cuttings in *Achillea* 'Moonshine.'

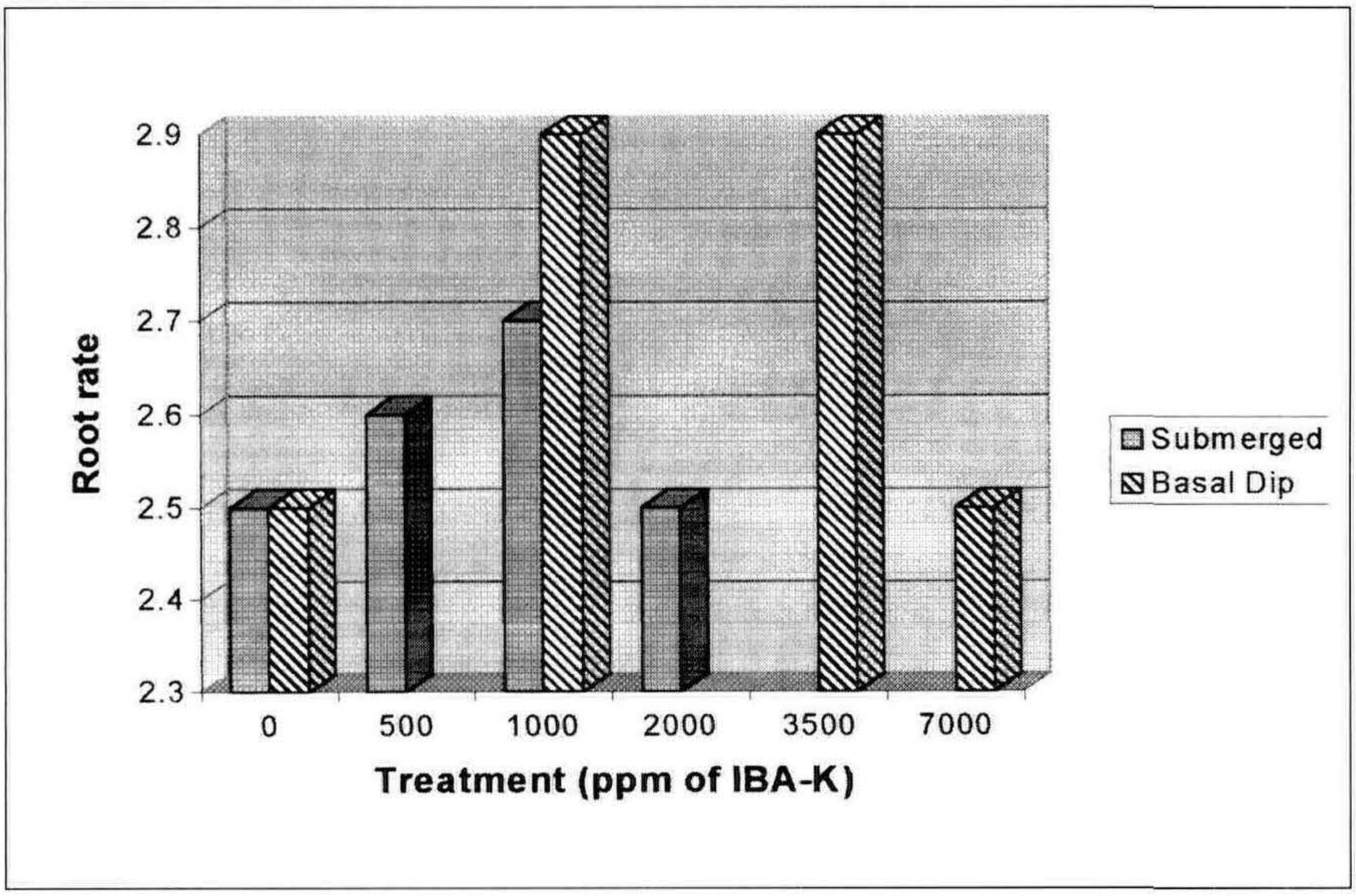

Figure 5. The effects of IBA-K on submerged and basally dipped cuttings of *Baptisia pendula*.

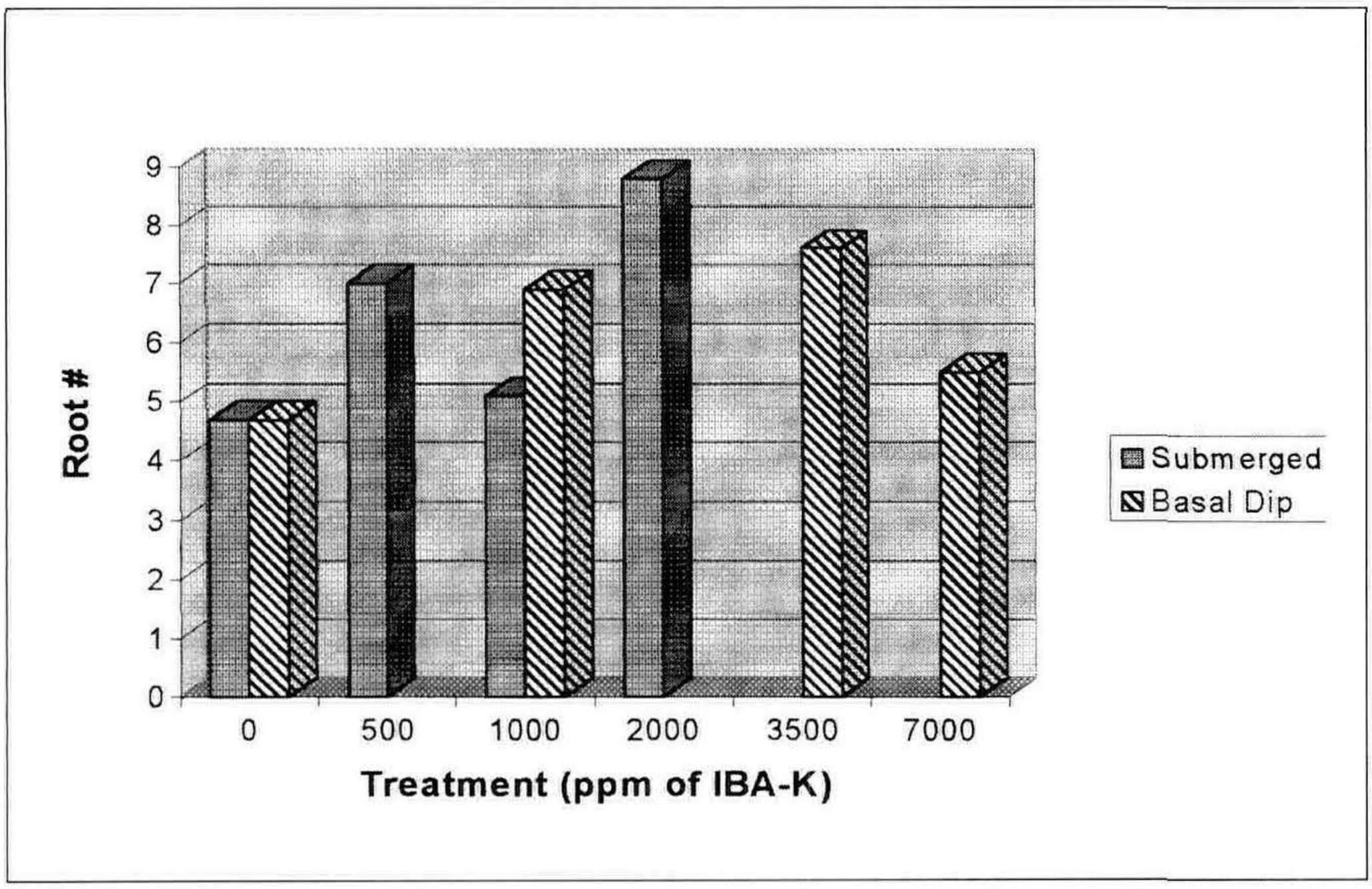

Figure 6. The effects of IBA-K on root number in submerged and basally dipped cuttings of *Baptisia pendula*.

Several factors may explain the inconsistencies in these results. Firstly, two different types of cuttings were taken for the experiment, tip and butt cuttings. Because tip cuttings contain younger, more tender tissue, these plants could have been more vulnerable at high concentrations of IBA-K, especially when applied by submersion. Phytotoxicity was observed above the soil at higher concentrations of IBA-K (leaf curl), almost exclusively with tip and submerged cuttings. Very little phytotoxicity above the soil was observed in cuttings that were basally dipped. Also, some cuttings contained one node and others contained two (one above and one below the soil). Two-noded cuttings had overall better rooting success.

Lastly, after replication of this experiment, time of season presented a noticeable difference in rooting success. Cuttings done in early spring performed much better than those taken during other seasons.

The Effect of Temperature on *Trillium grandiflorum* and *Trillium erectum*

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INTRODUCTION

In the early 1940s, Lela V. Barton (1944) did research investigating the dormancy of *Trillium grandiflorum* and *T. erectum* and concluded that both species exhibited double dormancy. Two periods of cold interrupted by a warm period were needed for complete germination — the first period for root emergence and the second for cotyledon emergence. The first period in Barton's experiments was expressed in "months" (3 months for *T. grandiflorum* and 6 months for *T. erectum*). It was the goal of these experiments to more precisely define the first period in days.

MATERIALS AND METHODS

Seeds of *T. grandiflorum* were collected from three sites in Chittendon County in Vermont, cleaned, mixed, and surface sterilized. They were first divided into 12 lots of 160 and then into eight replicates of 20 seeds each. Each replicate was placed in a petri dish lined with filter paper and then half of the petri dishes were wrapped in aluminum foil to exclude light. The wrapped and nonwrapped petri dishes were randomly placed in plastic boxes lined with moistened paper towels and treated at 5C for 62, 69, 76, 83, 91, or 98 days. They were then brought into 20C and germination started 35 to 42 days later (Solt, 1996).

Seeds of *T. erectum* were collected from Leddy Park, Burlington in Chittendon County, Vermont, and cleaned. They were first divided into five lots of 200, then into 10 replicates of 20 seeds each and placed on a moist paper towel. No surface sterilization was done because it was thought that the small amount of sodium hypochlorite in the paper toweling would discourage fungal growth. Each set of 10 replicates was placed in a small heavy-duty freezer bag and put in my refrigerator at 9 to 11C (39 to 42F). The lots were treated for 87, 123, 147, 216, or 240 days. They were then brought into 20 to 23C (68 to 72F) in my basement and germination started approximately 65 days later. Light was not controlled in this experiment.

RESULTS

In the experiment using *T. grandiflorum*, a cold period of 83 days or longer resulted in maximum germination: 79% in the presence of light (Fig. 1) and 73% in the absence of light (Fig. 2) (Solt, 1996). In the experiment using *T. erectum*, a cold period of 216 days resulted in 90% germination (Fig. 3).

DISCUSSION

The length of cold required to break dormancy in *T. grandiflorum* is approximately 83 days while *T. erectum* required approximately 216 days. This suggests that the dormancy of species of trillium varies. Anecdotal information obtained through personal communications with fellow trillium enthusiasts (Denton, 1998; McClements, 1998) suggests that not only does the length of cold period vary but

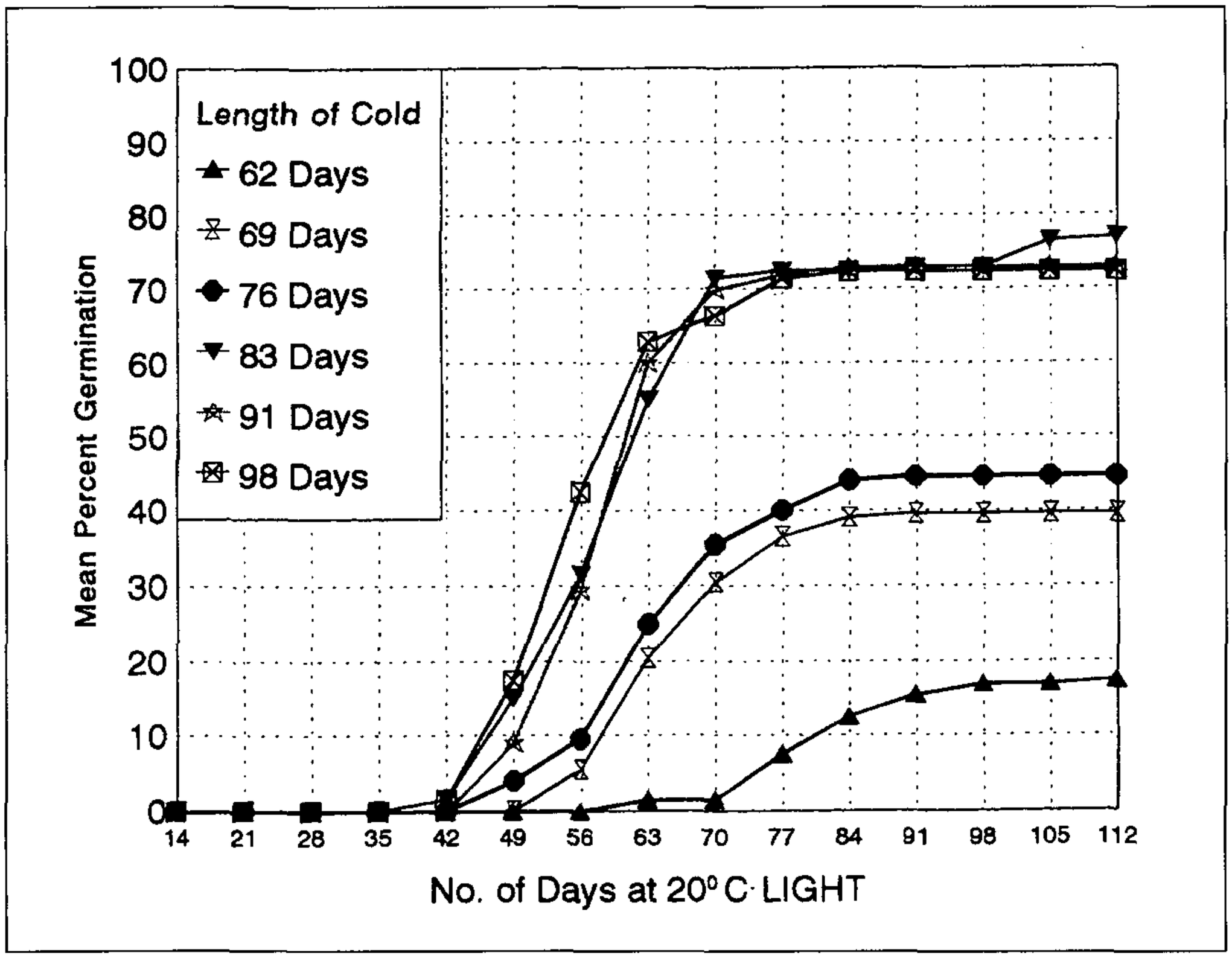

Figure 1. The effect of cold period length at 5C on the germination of *Trillium grandiflorum* in the light.

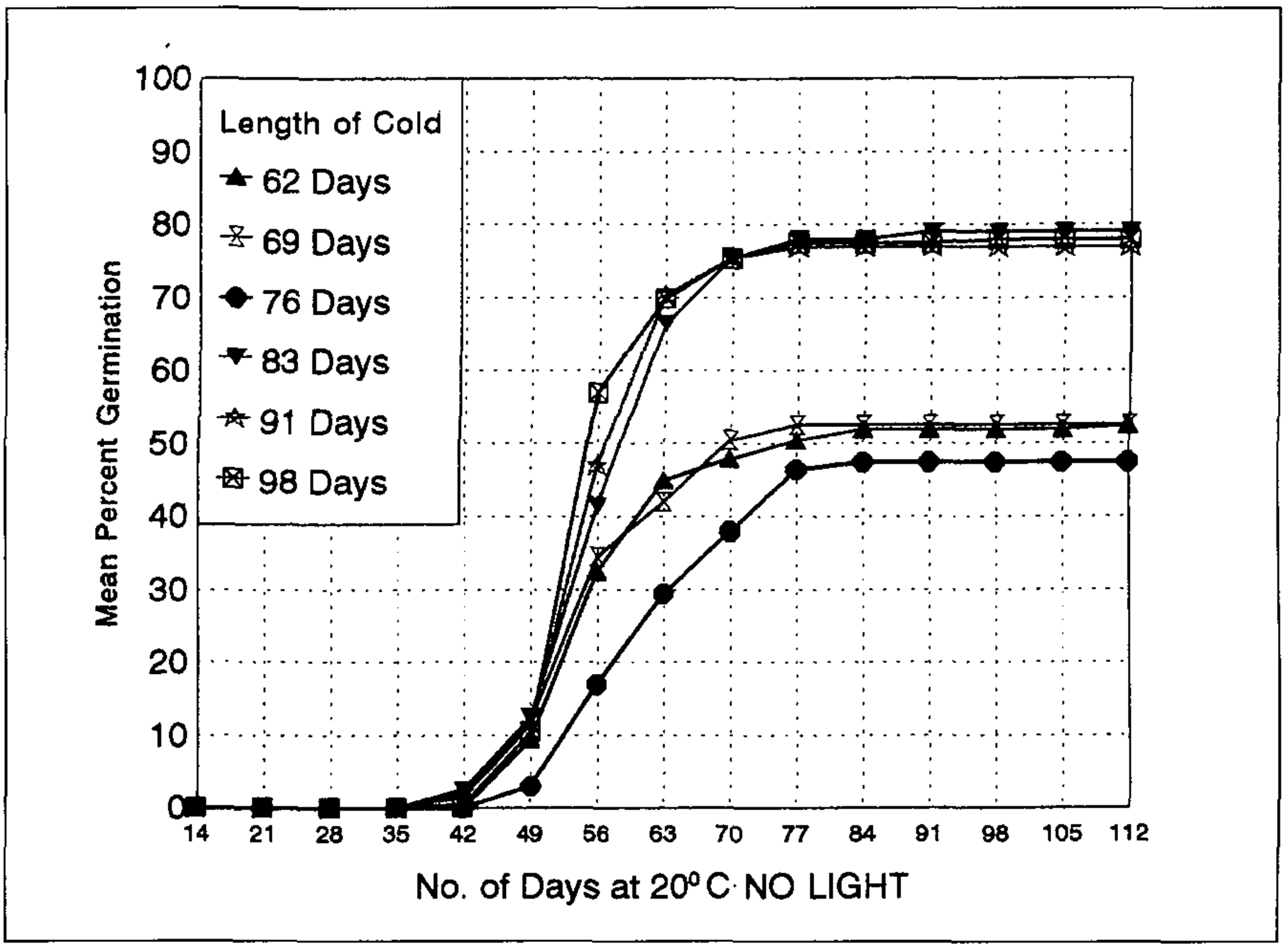

Figure 2. The effect of cold period length at 5C on the germination of *Trillium grandiflorum* in the dark.

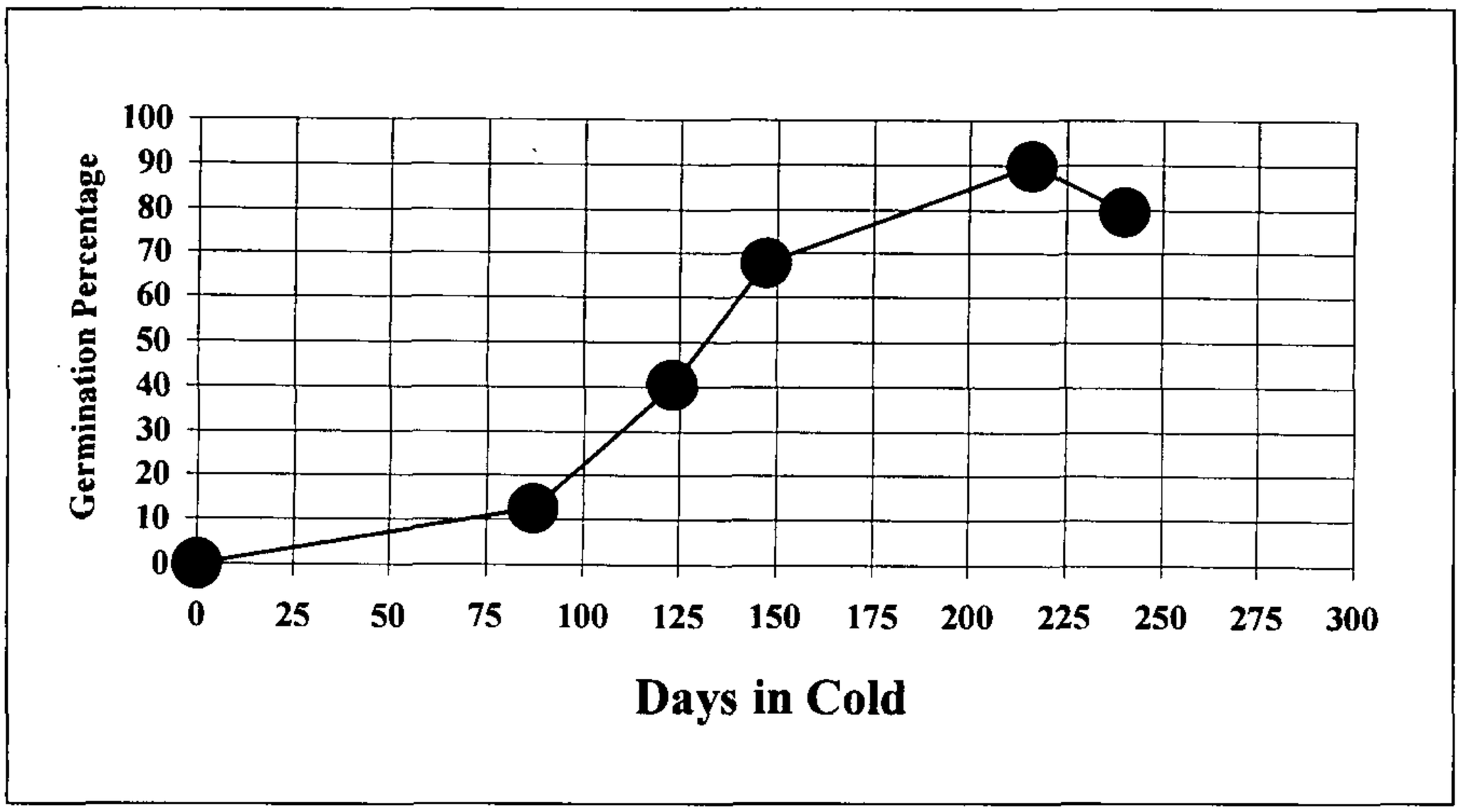

Figure 3. The effect of cold period length at 9 to 11C on the germination of *Trillium erectum*.

that some species do not require cold. It is also to be noted that under these experimental conditions, germination was completed after the first cold period. This suggests that *T. grandiflorum* and *T. erectum* exhibit an embryo dormancy, one period of cold needed for embryo maturation with germination being completed during the following warm period (Solt, 1996). Light did not appear to be a factor in either experiment.

A current experiment is attempting to further define the length of cold required for the first period for *T. erectum*. Treatments are 150, 172, 194, and 216 days.

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Propagation and Field Production of *Daphne* x*burkwoodii* 'Somerset' and 'Carol Mackie'

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Daphne ×*burkwoodii* is a cross of *D. caucasica* × *D. cneorum.* The place of origin was the nurseries of Burkwood and Skipwith, Kingston-on-Thames, England, about 1935.

A versatile shrub, the extremely fragrant flowers are creamy white flushed with pink, ½ inches in diameter, and forming dense terminal clusters about 2 inches in diameter. The foliage is semievergreen, I have observed mature plants, depending on the severity of the winter months, retain their leaves for the duration of the winter in northeast Ohio.

'Somerset' was patented in the U.S.A. on 28 Feb 1939, by Wayside Gardens, which at that time was located in Mentor, Ohio.

A beautiful clone of *Daphne* 'Somerset' is 'Carol Mackie' which has cream-edged leaf margins. Both plants can reach 4 ft tall and 6 ft across with a very round and dense growing habit. Plants respond well to pruning.

Although *Daphne* taxa are exquisite and very hardy (-30F, University of Maine's display garden) they are sometimes overlooked in the nursery industry due to degree of difficulty in propagation, and sensitivity to overwatering and heavy soil conditions.

Unlike many other deciduous species, 'Somerset' and 'Carol Mackie' root most successfully from semihardwood cuttings. Terminal shoots from mature wood taken during the months of August and September are prepared with a wound to promote callus tissue, and dipped in Hormodin #3, a talcum-powder-based indolebutyric acid product of 0.8% active ingredients. Caution must be taken in stripping the cuttings. Due to the stringy nature of the stem, leaves should be individually plucked upwards to insure a clean, sturdy stem.

Cuttings are stuck in 38-plug trays measuring 5 inches in depth. Space to allow for air movement is critical to prevent *Botrytis*, gray mold, and stem rot. A well drained mix of Canadian peat, perlite, and concrete silica sand (5 : 5 : 2, by volume) provides adequate aeration and drainage.

Once placed in the greenhouse, water is closely monitored during the rooting process. Like poor air movement, excess water will also contribute to a host of disease problems. Periodic applications of fungicide and removal of diseased leaves make for a clean environment. During sunny days, mist is regulated on 30-min intervals for 15 sec. Similar to evergreens, moisture retention is high and water requirements are minimal. Rooting occurs in approximately 6 weeks.

Cuttings are then weaned from mist. The newly rooted cuttings are overwintered in heated polyhouses at 38 to 40F.

The following spring, the cuttings are potted in tree bands measuring 2¾ inches × 5½ inches. *Daphne* taxa are generally deep-rooted plants that require a larger pot to accommodate their habit of growth. A well drained soil mix with plenty of sand and perlite is imperative to insure a good stand. This interim step helps to establish the plant both in size and caliper. During the growing season, liquid fertilizer is applied every 14 days along with occasional pruning to establish lateral branching.

Pots are overwintered in minimum heat polyhouses.

If *Daphne* could have their way, they would rather be in a field of sandy-loam or gravel. Good drainage is a must which makes container production difficult but not impossible. The 2-year potted cuttings are hand planted in 4-ft field rows to be grown to finished plants. An application of 20N-6P-12K fertilizer, cultivating, and hand hoeing is done during the growing season. No herbicides have been used to date although we are experimenting with some preemergents. No damage has been detected thus far. Each plant is staked and tied for the duration of the winter to prevent breakage due to snow loads.

During the 2nd year of field production, established *Daphne* explode with growth. After judicious pruning, the plants begin to take on a round and dense growth habit. By the end of the growing season the majority of the plants will be full bodied and 24 to 30 inches in height. Plants are once again tied to prevent snow breakage. We are ready to harvest!

A balled and burlapped *Daphne* 'Carol Mackie' is ready for sale. Plants can be successfully harvested in spring after leaf buds have swelled, or in fall after growth has hardened off.

Daphne 'Somerset' and 'Carol Mackie' make wonderful landscape plants either as specimens or planted in mass as shown here. Placed near an entrance of high traffic area, the sweet aromatic fragrance, rich evergreen foliage, and dense growth habit will enhance any landscape. Truly a conversation piece!

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Use of Digital Analysis of Radicle Extension of Marigold Seedlings as an Early Indicator of Seed Vigor

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INTRODUCTION

Radicle extension has been shown to be an accurate, early predictor of vigor in several horticultural crops (Bingham et al., 1994). Digital imaging of the radicle has potential to meet the criteria for an ideal vigor indicator. Several seed producers and seed testing laboratories are presently using or exploring this technology. In this study, MacRhizo® software was used to analyze digital images of the radicle captured on a flatbed scanner. This study attempts to correlate the computer-generated marigold vigor data with results from commonly used vigor tests.

In order to examine the correlation between radicle length and the standard tests that predict seed vigor, seed from a single, high-vigor lot was mildly (24 h AA) and moderately (72 h AA) deteriorated by accelerated aging (AA) in a high temperature and relative humidity environment (McDonald, 1977). Once significant differences in vigor between groups of seed was achieved, several measurements commonly used as vigor indicators were taken.

If a positive correlation exists between computer-generated radicle length analysis and the Association of Official Seed Analysts vigor test results, the use of digital images of radicles may be a reliable predictor of seed vigor.

MATERIALS AND METHODS

1) Aging. From a single *Tagetes* 'Little Devil Flame' seed lot, seeds were deteriorated by AA method for 0, 24, or 72 h. Seed moisture content was measured for each treatment.

2) Germination Test. Seeds were incubated for 7 days in petri dishes at 30C with fluorescent light for 16 h day^{-1} and at 20C for 8 h of darkness. One-half of the petri dishes were laid flat in the incubator and one-half were placed at an upright angle. Normal germination counts and seedling biomass were obtained.

3) Plug Emergence Test. Seeds were incubated under the above-described environment using six-pack cells and greenhouse propagation media.

4) Computer Imaging. Entire dish, individual seedlings and excised radicles were imaged and analyzed using MacRhizo® software.

RESULTS AND DISCUSSION

Seed moisture content of the control seed was 15.23%, 40.77% for mildly-aged seed, and 52.85% for moderately-aged seed and showed significant differences (at $P<0.05$) between levels of deterioration in all but one case. Standard germination results also had significant differences between levels of deterioration (at $P<0$ .05) with 84.5% germination for controls, and 49.5% germination for mildly, and 9.7% for moder-

ately aged seeds.

Digitally analyzed radicles also revealed significant differences (at P<0 .05) in length between each vigor level. Average radicle length for control seed was 2.1 cm, 1.9 cm for mildly-aged seed, and 1.3 cm for moderately-aged seed.

Using radicle length, seedling emergence test, or AA vigor test results as predictors of seed vigor, radicle length was regressed against percent standard germination (R^2=0.797) and percent seedling emergence (R^2=0.995) and a positive correlation was found in each case (Table 1). Correlation coefficients (r) based on the prediction variable means also showed a positive correlation of prediction accuracy. The r value for radicle length and seedling emergence (r=0.997) suggests radicle length may be a better predictor of future performance in the plug tray than the AA-standard germination test (r=0.893).

Table 1. Correlation coefficients (r) for *Tagetes patula* 'Little Devil Flame' using means of variables that indicate seed vigor level.

	Radicle length (mm)	Standard germination (%)	Emergence (%)
Radicle length	1.000	0.893	0.997
Germination*	0.893	1.000	0.924
Emergence**	0.997	0.924	1.000

* R^2 = 0.797 where y = 1.02 + 0.01× when radicle length is regressed against germination.

** R^2 = 0.995 where y=1.17 + 0.01× when radicle length is regressed against seedling emergence.

It has been established that radicle length can be used for marigold as an accurate, economical, reproducible seed vigor indicator. When the petri dish assay protocol is established, using digital analysis as a indicator of seed vigor will meet all the criteria for a reliable and efficient test and the potential for this technology in the seed industry can be fully realized.

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Production of Wetland Plants in Constructed Wetland Cells Designed to Treat Nursery Runoff

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INTRODUCTION

Containerized nurseries and greenhouses produce nutrient-laden runoff which may contribute to the nutrient loading of surface waters (HWQA, 1992; Alexander, 1993). This occurs when liquid fertilizer is applied through irrigation systems, or when nutrients are leached from fertilized fields or containers. In some operations it is estimated that up to 78% of applied irrigation water ends up as runoff (Furuta, 1978).

Constructed wetlands have emerged as effective, low-cost methods of water treatment which have the potential to reduce agricultural nonpoint source pollution. The role of wetlands in pollution and flood control has been recognized since the 1960s (Young, 1996). Beginning in the 1970s Congress adopted a wetland policy of "no net loss" and mitigation, which required that new wetlands be created or restored as natural wetlands were lost to development (Young, 1996). However, the costs of implementing treatment wetlands are relatively high, with little opportunity for cost recovery.

With few wetland plant nurseries operating in the Northeast, demand often greatly exceeds supply. Given the demand and increasing popularity of the commodity, wetland plant production could represent a profitable niche. At one time wetland plants had been collected from the wild for mitigation projects, but public policy has moved toward reducing or prohibiting such practices (Harbaugh et al., 1992). At the same time, water gardening has become one of the fastest growing specialties in landscape design and home gardening (Altekruse, 1997). Ornamental emergent and floating aquatic plants represent some of the greatest demand and commercial value in the gardening industry today.

Our objectives are: (1) to demonstrate an economical solution to treating nursery runoff by growing, harvesting, and selling wetland plants produced in a constructed wetland, and (2) to research nutrient removal potentials of several different plant species.

METHODS

Four vegetative propagules (75 to 100 g FW) of *Iris pseudacorus* (yellow flag), *Sagittaria latifolia* (arrowhead), *Phalaris arundinacea* 'Picta' (variegated ribbongrass), *Colocasia esculenta* (taro), and *Canna flaccida* hybrid were planted individually in 120-liter cylindrical wetland cells (0.3 m^2 × 0.4 m). Each cell was equipped with a drain plug and filled with 4- to 6-mm gravel. The water level was maintained at the gravel surface. A gravel medium was chosen to prevent ponding and establish good contact between water and plant roots. Unplanted wetland cells served as controls.

Experiments were carried out at the Rhode Island Agricultural Experimental Station (Lat. 42° 29' N). Wetland cells were established outdoors from 15 July 98 to

21 Sept 98 with N-P-K fertilizer solution, then moved into a greenhouse (mean temp. 23±7C) to protect plants from rain during the nutrient removal experiment.

Wetland cells were drained and filled with 100 ppm N 20N-20P-20K Peters fertilizer on 23 Sept 98. During the week tap water was added to the cells to replace water lost by evapotranspiration. On 29 Sept 98 the cells were drained and the effluent water was analyzed (Eaton, et al.,1995) for nitrogen (ammonia and nitrate) and phosphate reduction (Table 1). The number of divisions in each of the wetland cells were determined and expressed as divisions per m^2.

Table 1. Nutrient removal[1] and plant increase[2] of several species of ornamental and native wetland plants.

	Nutrient removal (%)		Average division estimates	
Plant species	N	P	No. m^{-2}	Wse. Value
Canna flaccida	81	59	100	$1.00-$3.00
Colocasia esculenta	72	35	70	$0.75-$2.50
Iris pseudoacorus	69	48	66	$0.50-$0.75
Phalaris arundinacea 'Picta'	51	34	60	$1.00-$2.00
Sagittaria latifolia	80	52	126	$0.50-$1.00
Typha latifolia	79	40	74	$0.50-$0.75
Control (no plant)	24	28	-	-

[1] Wetlands cells were fertilized with 100 ppm N 20N-20P-20K Peters fertilizer with a retention time of 7 days.

[2] Each treatment cell was established with four propagules of 75 to 100 g FW on 15 July 1998. Cells were harvested on 29 Sept. 1998.

RESULTS AND DISCUSSION

Results of this experiment show that all the wetland plants in this study were able to remove nutrients from fertilizer better than the no plant control, with canna > arrowhead > cattail > taro > iris > ribbon grass > no plant control in N removal and canna > arrowhead > iris > cattail > taro > ribbon grass > no plant control in P removal. The different plants species produced between 66 to 120 divisions m^{-2}, representing an earnings potential of up to $300 per m^2. Our experience growing different plant species in constructed wetland filters shows a trend towards the plants with the greatest biomass removing the most nutrients. For example, canna removed more nutrients than ribbon grass primarily because of biomass. In our wetland cells canna grew up to 2 m and had stems up to 2.5 cm in diameter, while ribbon grass grew to only 0.5 m and had stem diameters of only a few millimeters. Most wetland plants have plant tissue nutrient contents of approximately 2% N and 0.5% P (Debusk et al., 1995).

This study serves as an example of how constructed wetlands can be designed to remove nutrients from fertilizer runoff while producing a marketable crop. If these wetland cells had been established in the spring as opposed to mid July there would most likely have been a larger number of divisions per square meter. It might also have been possible to achieve multiple harvests in a single season if the wetland was established early. Wetland plant production cycles can be started with the propagation of plants from existing stock and growth of the propagules for appropriate lengths of time ranging from 3 months to 1 year before sale. Appropriately sized stock can then be harvested bareroot and sold to wetland construction and landscaping firms, or established for a short time in containers for sale to garden centers. Some plants are replanted to initiate a new production cycle. Partial harvests help maintain the nutrient removal efficiency of the treatment system. This self perpetuating system derives nutrition from the treated effluent and requires only the labor of harvesting and replanting.

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Advances in the Cultivation and Popularity of Chrysanthemums in the Edo Era

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INTRODUCTION

From the Nara era to the early part of the Hiean era (700 to 750), the chrysanthemum (*Dendranthema*) was introduced from China to Japan and became acclimated. Chrysanthemum had been cultivated as a medicinal plant, but subsequently became an ornamental one. It is mentioned in innumerable literary works, especially Japanese poems, and also used in other works of art as a symbol of the fall season.

The importation of chrysanthemums from China did not occur just once, but many times during this period when Japan was on friendly terms with China. From horticultural literature written in the early part of the Edo era (1603-1868), there is limited evidence that some cultivars, for example 'Kinsangindai', retained the same name as used in China.

From the Muromachi era to the Adzuchi-Momoyama era (1400 to1600), the growing popularity of ikebana (Japanese flower arranging) promoted the horticulture industry, so that more and more beautiful flower material was required. But there are no specific horticultural writings from the period and all the knowledge we have comes from the traditions of ikebana, from Buddhist priests, and the diaries of court nobles.

During the Edo era there were two popular periods in the cultivation of chrysanthemums — during both the breeding and evaluation of chrysanthemums developed in a truly Japanese style.

THE FIRST PERIOD — CHANGES IN THE COLORS AND FORMS OF CHRYSANTHEMUMS

The first period was from the Enpo to Kyoho eras (1680-1730). This boom period started from Kyoto and spread to Osaka and Edo (the ancient name of Tokyo). At first, the collecting of different cultivars was the most important interest. Before long exhibitions called Kikuawases were held in urban areas. In the first year of the Kyoho period (1716), Kikuawase were held 14 times in Kyoto the most times ever recorded for 1 year. There were at least 70 to 80 exhibitors in each exhibition, the largest exhibition had 160 exhibitors and 280 exhibits.

During this boom time, according to a common price list from two shops in Temna Osaka Shingikunaawari daizukecho, the highest sale price for a new cultivar of chrysanthemum was about 525,000 yen and the lowest about 12,500 yen. This shows that the breeding of new cultivars was very lucrative.

There were many flower forms produced in this period, but the size of flower was only 15 to 17 cm in diameter until 1700. By 1720, chrysanthemums over 30 cm in diameter had been bred and the models for the flower forms known today were set in this era.

Most chrysanthemum cultivation took place in gardens, from where cut flowers were sent to the exhibitions, using bamboo containers for flower vases. Containers for cartage, especially over long distances, were devised which enabled the cut flowers to remain in top condition even over 20-day journeys.

THE SECOND PERIOD — THE BEGINNING OF CHUGIKU COMPETITION AND KIKUNINGYO

After the Kyoho period (1716-1735), the cultivation of chrysanthemums continued sporadically, however, from the Bunka to the Kouka period (1802-1852) it became popular again. This later boom has two distinctive features. The type chugiku, a regular-sized chrysanthemum, was the most commonly grown and it did not gain the same level of interest as the previous boom period. Chugiku is a medium-sized chrysanthemum (15 to 18 cm in diameter) with various types of petals. When it reaches full bloom, some petals turn inside out, others twist and turn, or stand up, and finally they revert to the original form. Not only flowers but also the mode of flowering were the subject of competition. Exhibitors included samurais, rich merchants, and others. It was most popular during the Bunsei period, when two or three exhibitions were held in Edo each year. The printed ranking lists, chugiku hana kuraizuke, as a competition record remained. Chugiku (called edogiku today) was brought to other regions and improved in types like Isegiku, Sagagiku, Higogiku, and so on. These chrysanthemums belong to the spray type, and are without doubt the main cultivars used for cut flowers in the world today.

The second main area of interest was kikuningyo (chrysanthemum figures). Many horticulturists and gardeners lived in Sugamo, Somei, Koishikawa, Mejiro, and Shirogane, which are suburbs of Edo, and they constituted huge gardening centers. In these areas, making figures using chrysanthemums modeled on forms such as animals (topiary) became very popular. During the fall season it was a popular entertainment to visit these areas to enjoy these chrysanthemum figures, after that the figures became the subject of a story and drama. These were arranged within haiku or kyogen and published in booklets or kawaraban (local newspapers) like *Sugamo Meisangiku no shiori* and *Kikushiorichikamichi*.

In the Ansei period (1854 to 1859), atsumono (which means thick petals) types were bred and tairingiku (which means big chrysanthemum) became popular. But when subsequent political changes took place, interest in chrysanthemum culture waned.

SUMMARY

When the chrysanthemum was introduced from China, its flower size was at most 10 cm in diameter. But during the next 200 to 250 years, we made many forms of chrysanthemum such as tairin (over 30 cm in diameter), chugurui (changing form in bloom), and it was also used in topiary and as food. It is easy to see that the prosperity of the Edo region and its culture are closely associated with the chrysanthemum.

Wild Flowers In Brazil

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THE GEOGRAPHY OF BRAZIL

Brazil is located in the eastern part of South America and in area covers nearly half of that continent (85,110,000 km^2). Brazil is the fifth largest country in the world and second largest in the Americas. Its area is about 23 times that of Japan and the population is about 160 million, the sixth largest in the world following Indonesia. The country lies from 5'16N to 33'45S across the equator. The northern region of Brazil, the Amazon, has a tropical climate, while the southern part is temperate and it snows there every year. Apart from the highest mountain, Mt. Neburina located on the border with Venezuela, the other mountains are below 3,000 m high and are concentrated around the southeast coastal region.

The largest area in vegetation is the tropical rain forest along the Amazon river and it covers 54% of northern Brazil. The central part of the country is savanna, called Cerade, which is covered with weeds and low scrub and comprises 22% of the country. The northeast is drier, called Kantiga, and covers 10% of Brazil. The plants in this region are mainly cactus and thorny shrubs, hence the English name Thorn Bush. The east coast area along the Atlantic ocean was a subtropical forest region, but because of land development only 5% remains. In the south 4% is steppe and is used as grazing land. There is also the Parana pine area and a unique feature of the center-west, upstream of the Paraguay river, is a big wetland called Pantanal, as large as the Japanese mainland and a treasure house of flora and fauna. Also, there are palm forests in the central northern region and wet lands called Resutinga in the low coastal area.

Brazil is divided into five administrative parts and is a federal republic consisting of 26 states and one direct control area. Because of its size, only several southern states are developed and there is a tremendous gap between the rich and the poor. At present, ecological destruction is a serious problem in the world and from 60 years personal experience, particularly so in Brazil. Seventy percent of the land in Brazil has the capacity to be developed because there are few mountains and it is easy to create farms. Recently, the speed of development has increased rapidly and the extinction of biological species is immeasurable, including many useful species now lost forever.

THE HISTORY OF THE CULTIVATION OF FLOWERING PLANTS

Before World War II in South America the cultivation of flowers was popular in Argentina. It employed introduced European technology and this resulted in increased consumption. In Brazil, however, only in Rio-de-Janeiro were flowers produced and sold using the techniques introduced from Argentina, orchid production was especially popular. After the war, as economic conditions improved, the consumption of flowers increased with a resultant increase in cultivation. Particularly in the 1980s, many growers started operations around Sao-Paulo. A flower market was held twice a week in Sao-Paulo central market and the distribution of

flowers improved rapidly. Dutch growers introduced good cultivars from the Netherlands, under a big cooperative association and improved cultivation techniques. Japanese growers also increased around Sao-Paulo, improving culture techniques, and the number of visitors from Argentina is on the rise.

Cymbidium, Dendrobium, Phalaenopsis, Cattleya, and *Oncidium* species are the mainstays of orchid production. Large-scale production also occurs with roses, chrysanthemums, limoniums, dianthus, cyclamen, and Cactaceae. In the Brazilian spring, flower exhibitions and competitions are held in various places.

WILD FLOWERING PLANTS

The number of native higher plants in Brazil is about 30,000 species, comparable to that of China. Many useful plants are included, I summarized and published 2168 species of known Brazilian medicinal plants in 1966. It is difficult to give a total of useful plants because the number is increasing daily. It is also difficult to count the number of flowering plants of horticultural merit, but I will record here some wild species and related species which are cultivated at present or show horticultural potential.

In the south of Brazil, there are many plants that could grow well in Japan because the climate is similar. Wild species of petunia and verbena bloom and decorate the moors there nowadays. Cacti also show a rich variation. *Schlumbergera russelliana* and *Zygocactus* (syn. *Schlumbergera*) grow on trees in the mountains in Rio state, in the northeast dry areas many *Melocactus* species grow in conjunction with tree cactus and *Rhipsalis* grows hanging down from the trees in the forest. Orchids are present in great variety, beautifully flowered species are found growing on trees and rocks. *Cattleya* and *Oncidium* species are plentiful as well as many other interesting and rare orchid species.

Green Plants to Improve the Quality of Indoor Environments

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It has been found that in urbanized society, people spend about 90% of their time indoors, separated from the air, soils, water, and natural surroundings of our ancestors. The quality of the indoor environment has, therefore, become a major issue in determining the health and well being of building occupants. Some connection with the "real" environment needs to be maintained or restored. It has been found, for example, that patients recover from surgery more rapidly when their hospital windows look onto planted landscapes. It is also well-known that buildings surrounded by beautiful gardens or scenery are more highly priced (i.e., valued by buyers and users) than those with no pleasant vistas.

Indoor plants can also make a substantial contribution to improving the indoor environment, which has yet to be fully realized by building designers, owners, and managers. They greatly assist in the aesthetics of the internal surroundings, provide *more satisfactory surroundings for occupants, and can complement engineering* approaches to office design and maintenance. They also appear to help stabilize humidity levels and clear dust from the air. These attributes will be considered in some detail. In addition, interior foliage plants can contribute significantly to improved air quality of the indoor environment. Outdoor air pollution is increasing annually, along with industrialization and vehicle use. However, indoor air pollution may be increasing even faster, with incoming air bringing in outdoor pollutants and the indoor environment producing its own as well. Trace amounts of over 300 volatile organic compounds (VOCS) can be found in indoor air, most of which are derived from furnishings, office chemicals, cleaning fluids, and the clothing and perfumes (deodorants, after-shave, etc.) of occupants. Where the ventilation rates from outside are minimized to save costs of temperature regulation, these pollutants become more concentrated. "Sick building syndrome" is more related to chemical exposure than to microorganisms in the air conditioning system (although they also play a role). The aim of our continuing project is to investigate the capacity of commonly used indoor plants to absorb VOCS and so improve indoor air quality. We are also interested to discover the mechanisms involved, so that breeding programs for improved plants can be undertaken. To date we have employed three species used commonly around the world in interior plantscaping, *Spathiphyllum* (peace lily), *Howea forsteriana* (Kentia palm,) and *Dracaena* (Compacta Group) 'Janet Craig'. We have found that each species is capable of removing from 2 to 5 times the Worksafe Australia Time-Weighted Occupational Maximum concentrations of benzene and n-hexane, over a 24-h period. The primary agents of removal appear to be the microorganisms of the growth medium. The plant and soil thus form a microcosm for air pollution absorption. We are now investigating the soil flora for each species, using scanning electron microscopy and extending the range of VOCS and plant species used, working towards being able to recommend best species and best densities of plantings for indoor air pollution reduction.

Hybridization, Selection, Propagation, and Introduction of Multi-Season Flowering Evergreen Encore Azaleas™

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Evergreen azaleas have been admired and enjoyed for many centuries. The first reported plants grew wild on the islands of Japan. In the late 16th century, the beauty of the azalea's flowers captivated early traders from the Western World (the English and Dutch). This quickly led to the exportation and spread of early azalea cultivars from Japan to Europe and then eventually to North America. Today, azaleas are still admired for their spectacular blooms and are popular in the Southeastern, Pacific West Coast, Ohio Valley, and East Coast regions of the United States.

Southern Indian hybrids are adapted to and popular in the warmer Deep South and Southern California. The Kurume hybrids were imported from Japan mostly in the early 1900s and they were most popular because of their cold tolerance and intense flowering. American horticulturists were most productive in creating many new hybrid groups, many of which have become commercially successful. Some of the most popular American hybrids are, Gartrell, Pericat, Glenn Dale, Girard, Pennington, and Back Acres. Recently the Satsuki group of evergreen azaleas have become more popular because of their May and June flowering characteristic.

The only slight drawback to an otherwise exceptional plant group is their brief blooming period. In pursuit of a longer blooming azalea, Robert E. Lee of Independence, Louisiana, U.S.A., initiated a breeding program in 1982. Intensely interested in plants since childhood, Mr. Lee discovered *Rhododendron oldhamii* flowering in midsummer at a friend's nursery. This *R. oldhamii* clone was particularly heavy flowering on July 1st. His friend, Dr. John Thornton, had obtained the clone from Hohn Patrik of California.

Obtaining a few plants from Dr. Thornton, Mr. Lee began to dream of hybridizing *R. oldhamii* with existing hybrids which have a tendency to flower in the fall. Pollinations were made in the fall while both *R. oldhamii* and the selected hybrids were flowering. Pollen was also collected that fall, dry stored under refrigeration, and used the following spring for pollinations. Thirty-six hybrid evergreen spring-flowering cultivars (Table 1) were selected to hybridize with *R. oldhamii*. Upon seed maturity, the seed pods were collected and the seeds were sown.

Germination yielded 25,000 seedlings, which were carefully transplanted into individual containers when they were large enough. The seedlings were given normal care with no winter protection. Five years later, 10,000 survivors were large enough to transplant into 6-inch containers.

All 10,000 unique hybrids were growing in Mr. Lee's back yard, being cared for by his wife, two children, and himself. As they grew and began flowering, he realized that his efforts had been very successful. Mid-summer brought a vast array of flower colors and forms. Many individuals were similar; some individuals as expected were less than beautiful. However, he was exhilarated with what he saw. Heavy flowering began and continued through the summer into the fall and again in the spring.

Realizing that much more work was needed he sought a relationship with Flowerwood Nursery, Mobile, Alabama, U.S.A. to select, produce, and introduce

superior individual plants. Flowerwood Nursery, Inc. is a very large wholesale nursery with the assets, integrity, and interest to further the development of hybrid evergreen azaleas that flower in spring, summer, and fall.

In 1992 and 1993, 7000 6-inch azaleas were transferred to Flowerwood Nursery, Loxley, Alabama and they were transplanted into 11-inch containers. Each plant was dormant-trimmed, fertilized, and otherwise treated as though they were in normal production.

Evaluation began in the mid-summer of 1993 as the seedlings began to flower. Each week many hours were spent observing each plant closely. Superior traits were noted. Foliage quality, growth rate, growth habit, flower color, flowering period, flower quality, and pest resistance were evaluated. In 1993, 100 individual clones were selected for propagation. Many were planted for long-term observation, under tall pine trees to provide filtered shade, while a few inferior plants were destroyed.

The original 100 selections were narrowed to 50 by 1995. Flowerwood Nursery, Inc. then had large quantities in 6-inch and 11-inch containers and they were trying to narrow the choices to 12 selections based on overall horticultural merit. During the winter of 1995 temperatures dropped quickly to 13F. Two of the chosen 50 were killed while others had severe cold damage, mild cold damage, or were unaffected.

That cold stress was very helpful in assessing cold tolerance of each clone. Clones with superior horticultural traits, yet lacking significant cold tolerances, were transferred to Flowerwood Nursery, Bushnell, Florida for further evaluation. Bushnell, Florida is situated in USDA Zone 9.

The University of Georgia stress laboratory tested samples of plant tissue from selected clones to determine cold hardiness. In 1995, 12 clones were selected for testing. Samples were collected and analyzed to determine late fall, early winter, mid-winter, and early spring leaf and stem acclimatization to cold temperatures. The 1995-96 evaluation was similar to field observation in the nursery. The same test was repeated in 1996-97 on fewer more promising clones.

During 1997 12 clones were designated as cultivars. Two additional clones are being introduced in 1998 as cultivars. Eight cultivars of Encore Azaleas™ are cold hardy to USDA Zone 7B and each cultivar is part of the Autumn Series. The selected clones are:

AUTUMN SERIES

Autumn Rouge™ PP#10438 azalea ('Conlea'). Autumn Rouge™ azalea is very prolific, flowering from early July through the fall. Peak flowering periods are July-September and mid spring. The blooms are semi-double and are strong pink almost red in color. This azalea tends to grow upright.

Autumn Royalty™ PPAF azalea ('Conlec'). This cultivar is robust. The shrub is upright and globose. The foliage is large and dark green. The flowering period is from August to frost. Autumn Royalty™ azalea again flowers in mid-spring. The blooms are large, single, and rich purple in color.

Autumn Coral™ PPAF azalea ('Conled'). This plant's growth habit is mounding. It blooms abundantly from July through the fall. Flowers are salmon pink with prominent fuchsia flecking and are medium in size. It flowers again in mid-spring.

Autumn Embers™ PPAF azalea ('Coneleb'). The growth habit is low, spreading, and dense. Foliage is dark green. Flowering is from early August through the fall

and very intense. Blooms are single and semi-double and are deep orange-red in color, producing unbelievable quantities in the fall. Autumn Embers™ azalea flowers again in mid-spring.

Autumn Amethyst™ PPAF azalea ('Conlee'). The foliage on this azalea is elongated, pointed and rough in texture. Leaves in the winter take a beautiful dark cast. Flowers are soft purple. The growth habit is moderately dense and spreading. Flowering begins in late July, heavy in late fall, and recurs in early spring.

Autumn Cheer™ PPAF azalea ('Conlef'). Foliage, growth habit, and flowers look like a Kurume-type azalea. Flowers are slightly larger than Kurume flowers and are deep pink. This cultivar is the most compact of the Autumn Series cultivars. Flowering is from September through the fall and repeats in early spring.

ENCORE AZALEAS™ FOR 1998 INTRODUCTION

Autumn Monarch™ PPIP azalea ('Conleo'). Autumn Monarch™ PPIP azalea flowers heavily in July, September, and mid-spring. The flowers are rich salmon and double. The growth habit is upright, similar to Autumn Rouge™ azalea, but taller. The foliage is light green.

Autumn Bravo™ PPIP azalea ('Conlen'). The growth habit of Autumn Bravo™ azalea is upright and spreading. The shrub is full and displays tremendous quantities of single, medium-sized deep orange-red flowers from September through fall and again in mid-spring.

The autumn Encore Azaleas™ were donated to many public gardens and public research facilities in 1997. We received quarterly reports from those institutions giving us more data covering landscape performance and areas of adaptation information.

The Encore Azaleas™ were introduced in 1997 into the Atlanta, Georgia market. In 1998, they are generally available in the Southeastern U.S. and in 1999, they will be introduced into the California market. We anticipate that the Encore Azaleas™ will become a major production item for our nursery because of the multi-season flowering.

PROPAGATION

Encore Azaleas™ propagate like all evergreen azaleas — easily. Cuttings can be taken year round. In the late spring through early fall, 3-inch cuttings treated with 1875 pp IBA or 5000 ppm KIBA and put under intermittent mist, will root in 4 weeks. Cuttings are directly stuck into 3-inch containers filled with a pine bark, peat moss, and perlite rooting medium (????, by volume). The medium contains a slow release N-P-K fertilizer, minor elements, and dolomitic lime.

The ease of propagation was very important in determining which clones would be named and marketed. Several clones still under evaluation are very beautiful yet very difficult to propagate. Flowerwood Nursery is exploring tissue culture as a variable method of propagation for those of a difficult nature.

Through the evaluation of the *R. oldhamii* hybrid seedlings, Flowerwood propagated over 100,000 plants, produced over 50,000 6-inch plants and over 30,000 11-inch plants. Most of these nursery-grown plants were never sold and the process cost considerably in supplies, time, and labor. The research is continuing since many outstanding azaleas remaining, deserve designation as a cultivar. It is projected that as many as 20 more cultivars will be designated over the next 10 years.

Encore Azaleas™ are currently being produced for the southeastern United States where azaleas are traditionally used in the landscape. The Encore Azaleas™ are suited to much of the Western U.S. coast from Southern California to Oregon and will be introduced into that market in 1999.

The Encore Azaleas™ are being managed by Plant Development Services, Inc. (PDSI) of Loxley, Alabama. PDSI will be investigating the opportunities to license, produce, and market these exciting multiple-season-flowering hybrids in traditional azalea markets in South Africa, Japan, Australia, and Europe.

Table 1. Taxa selected for hybridization with *Rhododendron oldhamii.*

Blaauw's Pink	Kromo Skikibu
Brian Harris	Mae Blaine
California Sunset	Mount Bold
Carita	Mrs. Henry Schroder
Carro	Mrs. Nancy Dippel
Copperman	Patrick
Daphne Salmon	Peter Pooker
Double Beauty	Pink Cascade
Elaine	Pink Cheer
Encore	Pink Cloud
Fisher's Pink	Pink Macrantha
Flame	Polypedlum
Fortunei Group Purple	Purple Macrantha
Georgia Giant	Red Slipper
Glirard's Rose	Schroder's Pink Perfection
Gumpo	Sherbrook
Hoosier's Sunrise	Shunrei
Ivan Anderson	Vespers
Jessie Cruz	White Jade
Karen	

I.P.P.S. in New Zealand "Seek and Share"

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Firstly what is "Seek and Share". I would like to take a few moments to go into the meaning behind this phrase. The success of the I.P.P.S. and it's well being and future involves all members taking to full heart the Society's motto "Seek and Share".

In English the word "Seek" has a number of meanings:

- to search or inquire.
- try or want to find or get.
- endeavor or try.
- hunt or attempt.

Seek will have slightly different meanings for academics and craftsmen. The academic researcher is after facts, proving ideas right or wrong, and wants answers to questions. The craftsman is more concerned with finding a better way to carry out a task and is not so much concerned with the reasons - but is still very interested. His role is to constantly improve.

The word seek, therefore, means we are constantly striving to find out more information.

In English the word "Share" means:

- to give and receive.
- to contribute so others can benefit.

We must be first to share as through sharing we discover something new. It's a form of what we English call swapping or exchanging, it happens willingly without remuneration of any form and with no strings attached.

Seeking and sharing requires people to put aside any status, prejudices, or barriers. Discovering the joy of helping, in this case plant propagation and cultivation, is what has made people so enthusiastic about the I.P.P.S.

The International Plant Propagators' Society provides the platform for members to seek and share. They do this in large forums such as this conference where people can present papers or discuss their experiences openly and frankly and share their knowledge across a cup of coffee at the tea breaks, or dinners, or in the bar in groups, or in a one-to-one situation.

The success of I.P.P.S. has been the respect members have had for its motto "Seek and Share".

In the time available to me I will present to you an overview of I.P.P.S. in New Zealand.

- The I.P.P.S. is an international society of people of all ages from nurseries, parks, universities, and research organizations willing to "seek and share" information. In addition, fostering international relationships and networks is an important aim of the I.P.P.S. and a feature of many gatherings.

- New Zealand conferences always hold a rare and unusual plant auction which raises money to offset conference costs and help fund projects. Plants are donated — prices often keen.

- Subjects and technology discussed at I.P.P.S. conferences and field days are often extended into Polytechnic courses. For example, Spin Out™ root control (copper treatment) trials were organized by students. This trial extended their knowledge and data available on the material throughout New Zealand and added to the students' education.

- Field days and visits to nurseries and research stations are held during the year throughout the country and at conferences. At such an event in Nelson results of a comparison trial between Swedish, Japanese, and New Zealand cell trays for forestry species occurred. The speakers, such as N.Z. International Director Robert Appleton, are active I.P.P.S. members. Sweden's Stellan Karlson gave a paper at the Nelson conference on the theme "forestry container production".

- Industrial relations are fostered through the I.P.P.S. For example, at Top Trees, a mail order retail nursery at Hastings, the owner, not an I.P.P.S. member, spoke about his nursery and crops and showed members through the operation.

- Botanic gardens managers and curators are active participators in I.P.P.S. At a past conference Jack Hobbs, manager/curator Auckland Botanic Gardens, discussed the performance of New Zealand native plants in the scree garden.

- I.P.P.S. members are always interested in the latest machinery and exhibits such as mobile potting machines always attract large interest during nursery visits. Although I.P.P.S. members are plant oriented they are also keenly interested in new and modified machinery that, while they may not use it themselves, gives them a greater understanding of the industry.

- I.P.P.S. field trips often include retail garden centers. Spontaneous two-way discussions involving plants and their performance often develop between retailers and growers and also amongst growers. This is an important part of I.P.P.S. knowledge dissemination. Grasses and sedges are currently popular in New Zealand as we saw on a field trip at the last I.P.P.S. conference shows.

- Jim Rumbal, propagator at New Zealand's largest nursery, Duncan & Davies (New Plymouth) is a long standing I.P.P.S. member and his contributions often add a sparkle to conferences and field days. His hobby is collecting Japanese enoki cypress (*Chamaecyparis obtusa*) cultivars.

- The I.P.P.S. offers young people the opportunity to develop speaking skills and prepare papers for seminars and conferences, and help is always at hand. At a recent conference a young propagator who

had never spoken in public before made an olive propagation presentation to I.P.P.S. members and was helped by her boss Doug Simpson one of New Zealand's top fruit tree producers.

- New Zealand nurseries are quite varied in the plants grown. For example, Deane Keir has an exciting program growing New Zealand species for coal and limestone mine revegetation.

- Australian I.P.P.S. member, Clive Larkman, a regular visitor to New Zealand has developed a network of propagator contacts and is growing and promoting New Zealand raised hybrids in Australia.

- Plant breeders, such as Dr. Keith Hammett who is recognized world wide as a sweet pea, dahlia, and dianthus breeder, are also I.P.P.S. members. He is developing a strain of perennial *Nemesia* and the first progeny will be released on the N.Z. market this spring.

- New Zealand I.P.P.S. region presents an award annually recognizing service to horticulture and the I.P.P.S.. The 1998 recipient was cyclamen and polyanthus breeder Noel McMillan who owns a garden center and nursery in the North Island and has never missed an I.P.P.S. conference since he joined in about 1971.

- I.P.P.S. is not all serious business and learning. Members also enjoy social get togethers at their conferences.

Picloram-Induced Plantlet Regeneration of *Cypripedium calceolus* Through Root Tip Culture In Vitro

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Picloram has auxin action similar in effect to 2,4-D. It can serve as the auxin source in tissue culture with a number of species, but its primary value has been that it is effective at lower concentrations than 2,4-D and thus less likely to cause genetic changes.

Cypripedium calceolus is an endangered species and one that is difficult to propagate vegetatively via in vitro culture. Techniques were investigated to achieve a rapid propagation system for this species and we were successful in regenerating plantlets from root tips exposed to Picloram.

Seedlings of *C. calceolus* raised from immature seed were used. These had been removed from aseptic culture and kept in sealed vinyl bags in the dark at 5C for about 3 months. After surface sterilization with CaOCl for 20 min, root tips (ca 5 to 10 mm long) were cultured on half-strength MS medium supplemented with different concentrations of Picloram or 2,4-D (0,10, and 50 mg liter^{-1}) combined with BAP (1 or 10 mg liter^{-1}). All media were supplemented with 20 g liter^{-1} sucrose, solidified with agar (7 g liter^{-1}) or Gellan gum (3 g liter^{-1}), with pH adjusted to 5.5 before autoclaving. All cultures were kept in the dark at 20C.

Initial callus proliferation was observed on the media with Picloram or 2,4-D combined with BAP, solidified with Gellan gum after 4 weeks of culture. Almost all calli on the medium with 2,4-D turned brown and died after 8 weeks of culture. Calli survived on the media supplemented with Picloram and BAP. Where BAP was kept constant and Picloram increased, an increase in the rate of callus formation was noted. On the surface of growing calli, shoot proliferation was observed after 16 weeks.

After 22 weeks of culture, root differentiation was observed on the base of some shoots. These plantlets and shoots were separated from root-tip explants and transferred onto half-strength MS medium (plant growth regulator free) with Gellan gum (3 g liter^{-1}). Roots differentiated and plantlets were established after a further 4 weeks of culture.

These results demonstrate a novel method with potential for vegetative propagation of *C. calceolus* via in vitro culture.

Effects of Basal Medium and Concentration of Sugar and Banana Flesh on the Growth of *Oncidium* Protocorm-like Bodies Cultured in Vitro

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INTRODUCTION

We have reported previously that the growth of in vitro plantlets of *Cymbidium* and *Cattleya* was promoted remarkably when organic supplements were added to the basal medium (Kusumoto, 1969; Kusumoto and Furukawa, 1977; Kusumoto, 1979a; Kusumoto, 1979b; Kusumoto, 1980). In our last report we described the effects of basal medium and the concentration of added sugar or banana flesh on the growth of *Oncidium* plantlets cultured in vitro (Kusumoto and Takeda 1997). In the present experiment, the effects of the same factors as the last experiment were investigated on the growth of separated *Oncidium* protocorm-like bodies (PLB) which were not cut up.

MATERIALS AND METHODS

The PLB were used as the experimental material and were obtained by in vitro culture of peduncles of axillary buds of *Oncidium* 'Aloha Iwanaga'. Each small PLB, 2.5 mm in diameter, without differentiated buds and roots was selected by separation, and 40 pieces (1 g in total weight) of selected PLB were planted on each 50 ml of medium which was contained in a 200-ml flask. Murashige and Skoog's (MS) nutrient medium was used as the standard basal medium, with 0.1 mg liter^{-1} of NAA and BA, 3 g liter^{-1} of Gellan gum, and 20 g liter^{-1} of sucrose added to the basal medium. The PLBs were cultured under 16-h day length at 2500 lx and 24±2C. PLB growth was checked at 60 days after planting.

Experiment 1. Four different media, MS, White(W), Knudson's C (KC), and Hyponex (H), were used as basal media in this experiment. In addition to these basal media, MS medium at ¾ and ½ normal concentration was investigated.

Experiment 2. Banana flesh (100 g liter^{-1}) was added in each basal medium to check its effects on the growth of the PLB.

Experiment 3. Sugar and banana flesh concentrations were varied to check effects on growth and differentiation. In this experiment the PLB, with buds over 1 cm in height and roots were defined as differentiated PLB, smaller were classified as undifferentiated.

RESULTS AND DISCUSSION

The results are shown in Tables 1, 2 and 3. The results from Experiment 1 showed that the most suitable basal medium for the growth of the PLB was MS as in the earlier experiment. At the lower MS medium concentrations (¾ MS and ½ MS)

Table 1. Effects of basal medium and concentration of Murashige and Skoog medium.

Medium	Growth index	Fresh weight of dif. (g)	Fresh weight of undif. (g)**	No. of dif.**	Aver. height of shoot (cm)	Aver. no. of roots	Aver. length of roots (cm)
MS	33.7	5.3	28.4	22	2.4	2.1	1.4
¾MS	30.6	3.2	27.4	16	2.4	2.1	1.9
½MS	28.9	3.0	25.9	12	2.2	2.3	2.3
W	10.5	0.0	10.5	0	0	0	0
KC	15.0	0.0	15.0	0	0	0	0
H	24.1	0.6	23.5	3	2.0	2.7	2.3

* Growth index = growing total fresh weight/planting total fresh weight.
** Fresh weight of dif. = total fresh weight of differentiated PLB.
Fresh weight of undif. = total fresh weight of undifferentiated PLB.
No. dif. = number of differentiated PLB.
***PLB = protocorm-like bodies, MS = Murashige and Skoog, W = Whites

Table 2. Effects of basal medium, Murashige and Skoog medium concentration and addition of banana flesh on the growth of *Oncidium* PLB cultured in vitro.

Medium***	Growth index	Fresh weight of dif. (g)	Fresh weight of undif. (g)**	No. of dif.**	Aver. height of shoot (cm)	Aver. no. of roots	Aver. length of roots (cm)
MS	33.7	5.3	28.4	22	2.4	2.1	1.4
MSB-100	43.5	15.0	28.5	40	3.5	2.9	2.2
¾MSB-100	34.7	11.4	23.3	34	3.6	2.7	3.1
½MSB-100	29.1	9.5	19.6	28	2.6	3.2	3.1
WB-100	13.9	1.9	12.0	5	1.7	2.1	3.4
KCB-100	26.9	9.6	17.3	29	2.2	2.8	2.6
HB-100	25.9	11.3	14.6	32	2.1	2.3	3.3

* Growth index = growing total fresh weight/planting total fresh weight.

** Fresh weight of dif. = total fresh weight of differentiated PLB.
Fresh weight of undif. = total fresh weight of undifferentiated PLB.
No. dif. = number of differentiated PLB.

***PLB = protocorm-like bodies, MS = Murashige and Skoog, B = banana, W = Whites medium, K = Knudson's, and H = Hyponex.

Table 3. Effects of Murashige and Skoog medium containing various concentrations of sugar or banana flesh on the growth of *Oncidium* PLB cultured in vitro.

Medium***	Growth index	Fresh weight of dif. (g)	Fresh weight of undif. (g)**	No. of dif.**	Aver. height of shoot (cm)	Aver. no. of roots	Aver. length of roots (cm)
MS(S-20)	33.7	5.3	28.4	22	2.4	2.1	1.4
MSS-30	37.1	7.1	30.0	40	2.5	2.5	1.3
MSS-40	40.8	12.9	27.9	40	3.2	4.0	2.0
MSB-100	43.5	15.0	28.5	40	3.5	2.9	2.2
MSB-150	36.4	11.0	25.4	32	2.9	2.3	3.1
MSB-200	29.1	9.5	19.6	14	2.2	2.9	3.3

* Growth index = growing total fresh weight/planting total fresh weight.
** Fresh weight of dif. = total fresh weight of differentiated PLB.
Fresh weight of undif. = total fresh weight of undifferentiated PLB.
No. dif. = number of differentiated PLB.
***PLB = protocorm-like bodies, MS = Murashige and Skoog, S = sucrose, and B = banana.

growth index, weight, and number of differentiated PLB decreased, but differentiation and elongation of roots was promoted. Medium H was slightly inferior in growth index, markedly inferior in the number of differentiated PLB to those on ½ MS, but the same as ½ MS in root development of differentiated PLB. When medium W was used, the green color of the PLBs changed to yellow and growth and height decreased. No differentiated PLBs occurred in media W and KC. We believe that the salt concentrations of the W and KC media were too low and insufficient when compared with the MS medium, i.e., the high salt level in the MS medium was better suited to the growth of *Oncidium* PLB. These results were the same as with the growth of *Oncidium* plantlets in the previous experiment.

The results from Experiments 1 and 2 showed that the addition of 100 g liter^{-1} of banana flesh to each medium considerably promoted the growth of PLB. In Experiment 3, the addition of sucrose at 1.5 times (30 g liter^{-1}) and 2 times (40 g liter^{-1}) that of the standard MS medium promoted the growth of PLBs as did the addition of 100 g liter^{-1} of banana flesh. Increasing the quantity of banana flesh above 100 g liter^{-1}in the medium retarded the growth of PLB after planting, and decreased the growth index, number and weight of differentiated PLB, but promoted root elongation. Our conclusion is that *Oncidium* PLB in vitro exhibited the best growth with the addition of 40 g liter^{-1} of sucrose and 100 g liter^{-1} of banana flesh to the MS medium. These results are similar to those noted with *Oncidium* plantlets (previous report), but it differs in the amounts of sugar or banana flesh required. With PLB the range of sugar content is wider and that of banana flesh is narrower in *Oncidium* in comparison to plantlets cultured in vitro. The optimum content of sugar or banana flesh differs between PLB and plantlets as was found previously with *Cattleya* and *Cymbidium*.

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Studies on Micropropagation of *Odontoglossum* Alliance

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***Odontoglossum* alliances are south American native, epiphytic, cool-temperature-growing, tropical orchids consisting of more than 200 species. There are many nice hybrids with beautiful flowers, but it is difficult to cultivate them in Japan because of the hot summers. Recently, however, heat-tolerant hybrids have been bred and production of these has started in Japan. Mericlonal plants are available and on sale now, but there is only limited information on the micropropagation of these orchids. In the present experiments, sterilization methods, culture media, and culture conditions were investigated.**

MATERIALS AND METHODS

Sterilization Methods. Shoot tips were excised from young immature unrooted shoots. These shoots were cut from stock plants, washed in tap water, dirty parts cut away with a scalpel, and any leaves surrounding the stems were removed. These stems with exposed buds were sterilized in sodium hypochlorite solution with moderate shaking, washed three times with sterilized water, 2 or 3 scale leaves removed, and the shoot tips excised. The isolated shoot tips were rinsed with 0.5% sodium hypochlorite solution, soaked in sterilized water, placed on new phalaenopsis medium (NP; Table 1) supplemented with coconut water (150 ml liter^{-1}), and cultured at 25C with a constant illumination of about 650 lux provided by Plantlux (Toshiba) fluorescent lamps.

Times of sterilization, concentration of sodium hypochlorite, ultrasonic treatment during sterilization, and the effects of pH adjustment of the sodium hypochlorite solution were investigated.

Culture Media. Sucrose concentrations and organic supplements were investigated using protocorm-like bodies (PLB) of *Odontoglossum* 'Lovely Morning' and *O.* 'Spring Dress'.

Culture Temperature. Protocorm-like bodies of the above two cultivars were cultured on NP medium at 20, 22.5, and 25C.

RESULTS AND DISCUSSION

Sterilization. The contamination rate decreased with the increase in sterilization time in 0.5% sodium hypochlorite solution, but the rate of dead shoot tips also increased. The maximum survival rate without contamination was obtained with 20 min sterilization. In 1.0% sodium hypochlorite solution, the sterilization rate was also the best (90%) when sterilized for 20 min.

No beneficial effects from ultrasonic treatment and pH adjustment were observed.

Culture Conditions. The addition of sucrose, sorbitol, and coconut water (CW) was effective for PLB growth. The effect of sorbitol was inferior to that of sucrose and CW.

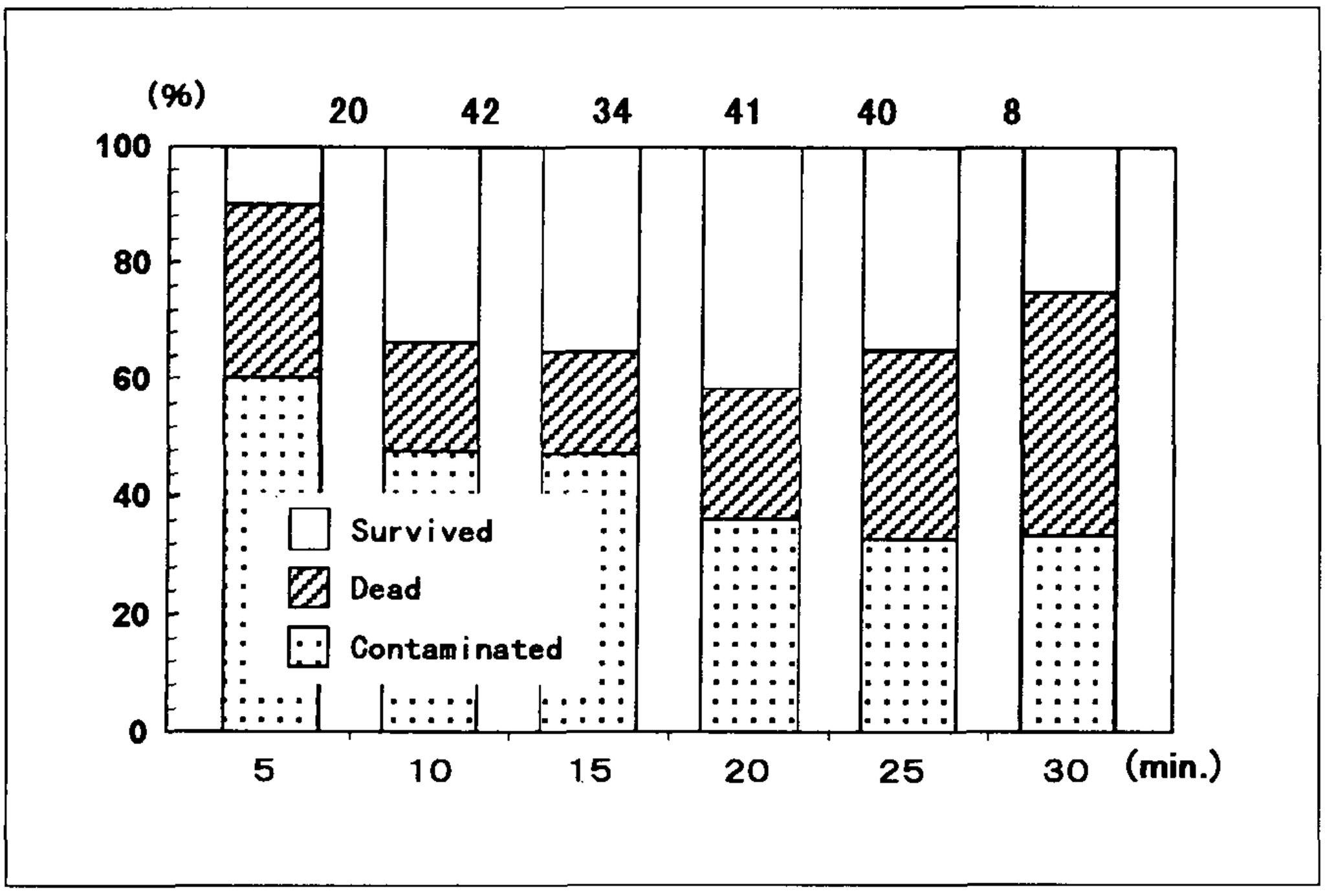

Figure 1. Effects of sterilization times with 0.5% sodium hypochlorite. Numbers on the top indicate number of shoot tips used.

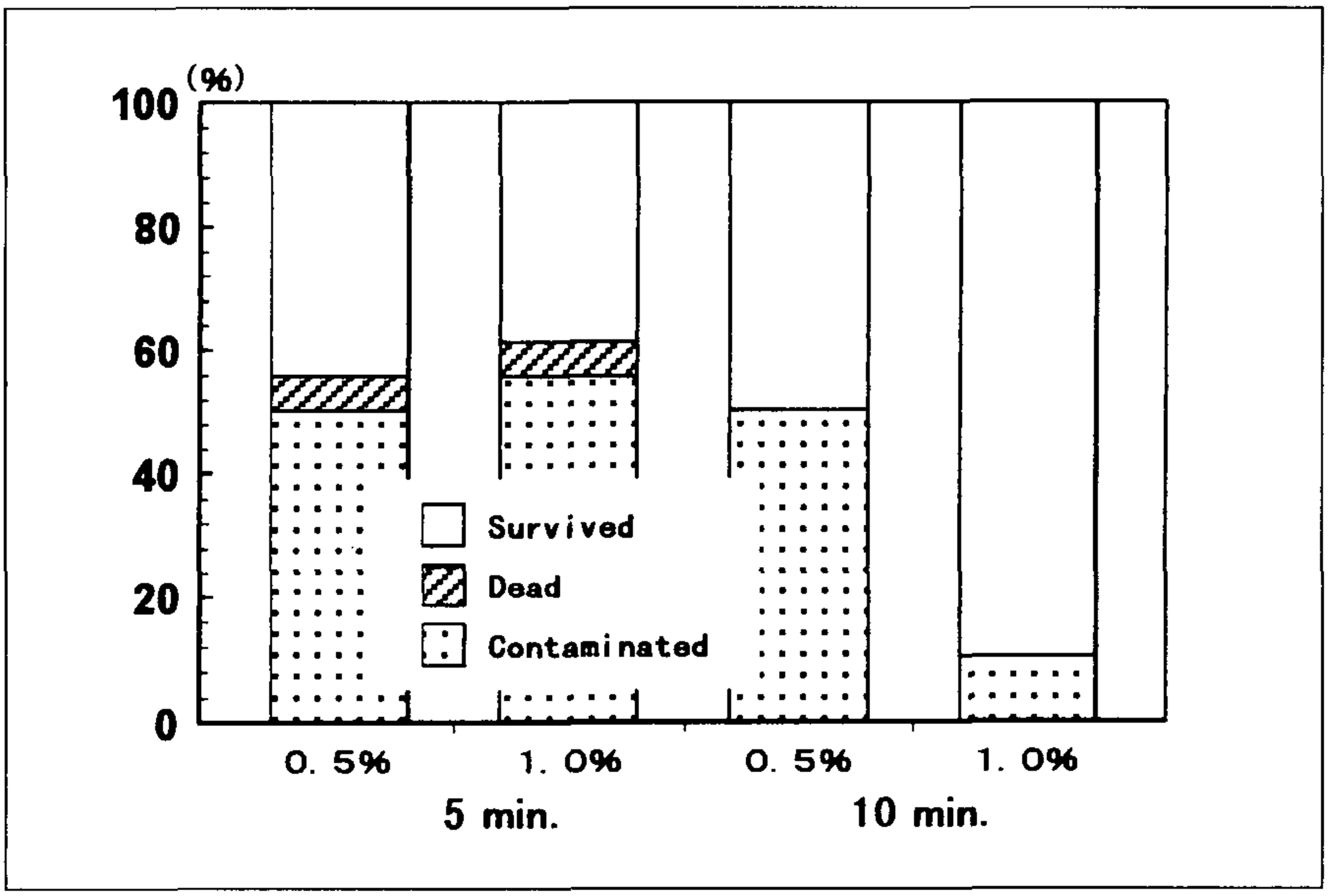

Figure 2. Effects of sterilization times and concentration of sodium hypochlorite. Ten shoot tips used for each treatment.

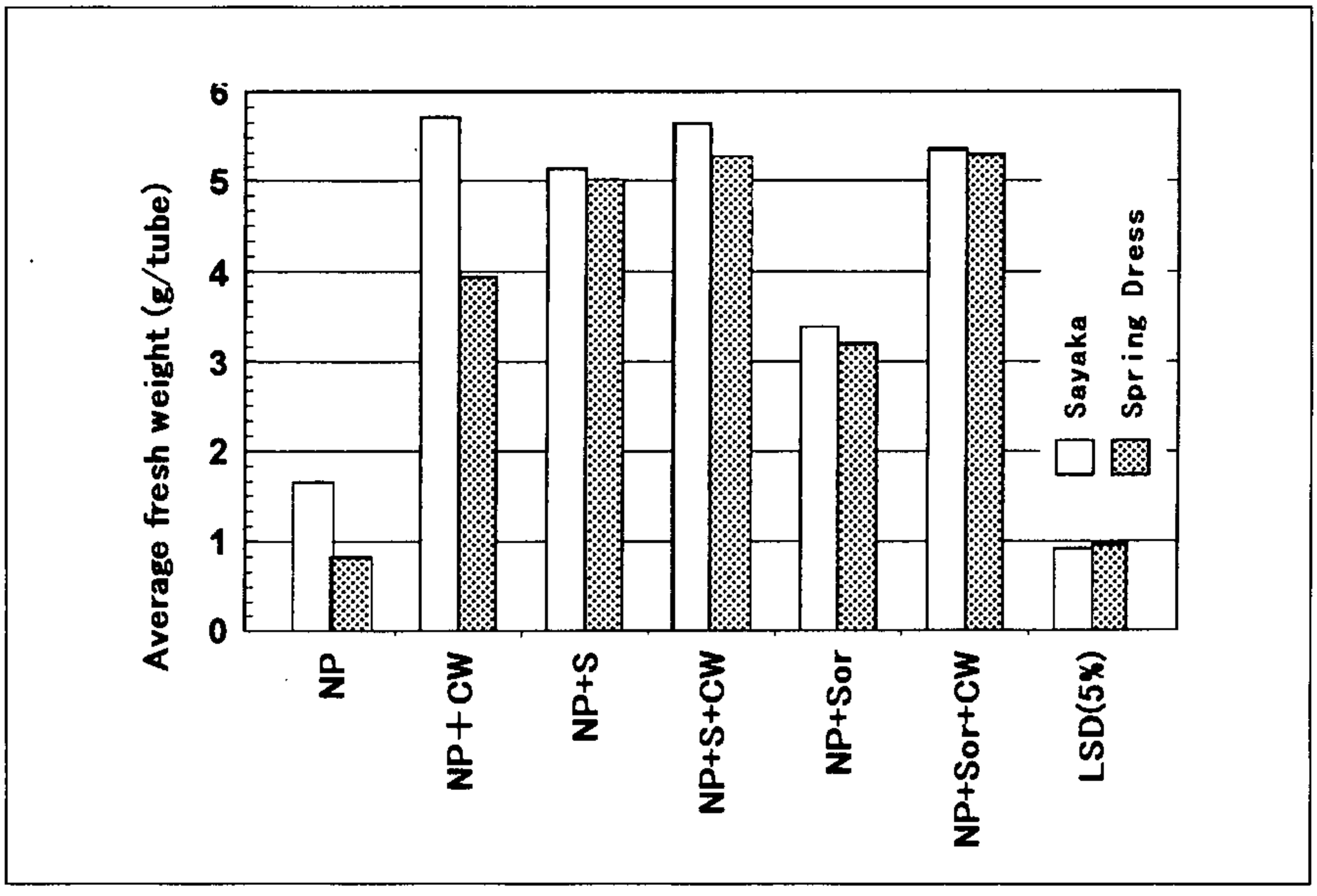

Figure 3. Effects of sucrose (S) and sorbitol (Sor) with and without coconut water (CW) on the growth of protocorm-like bodies (PLB).

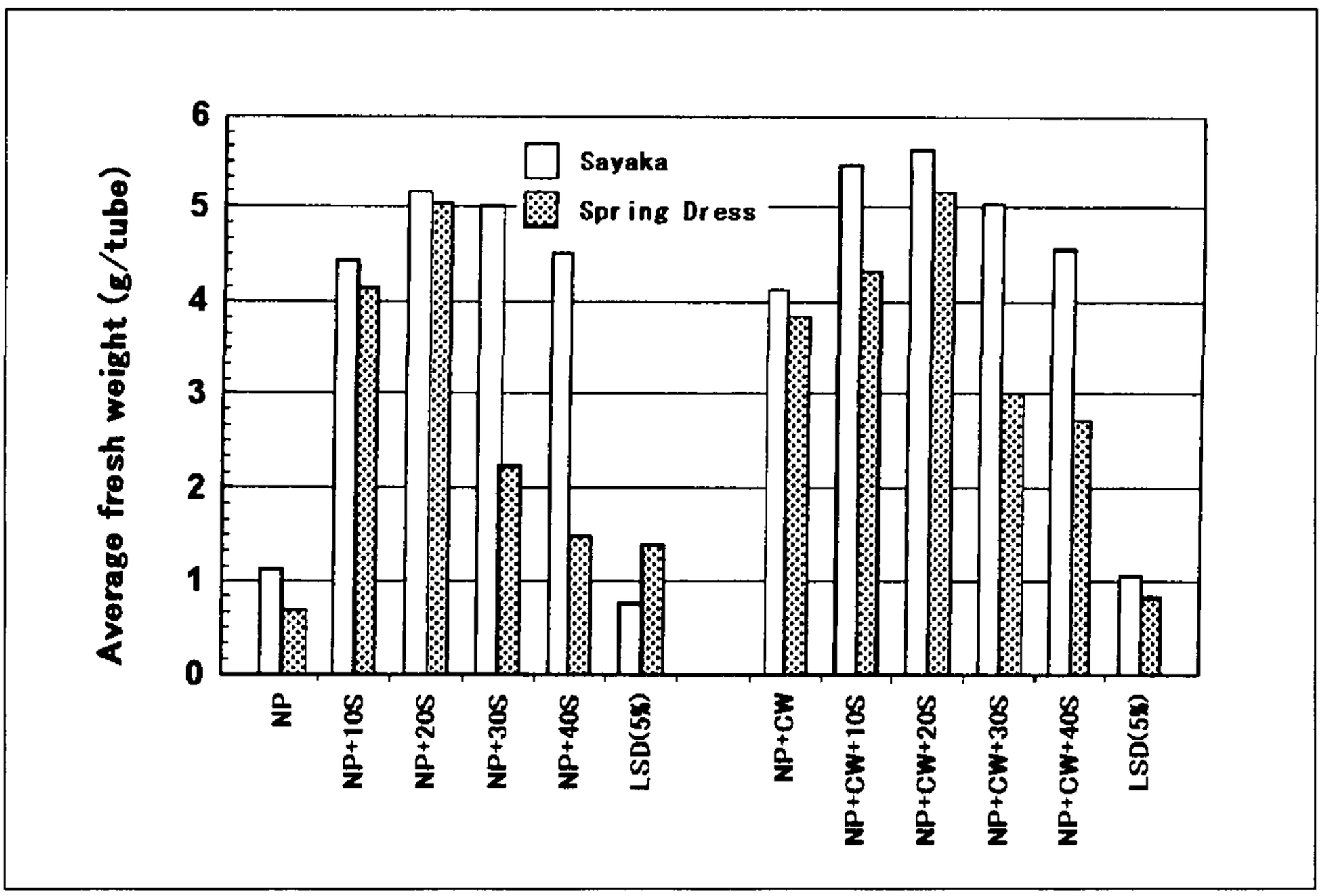

Figure 4. Effects of sucrose concentration with and without coconut water (CW) on the growth of protocorm-like bodies (PLB).

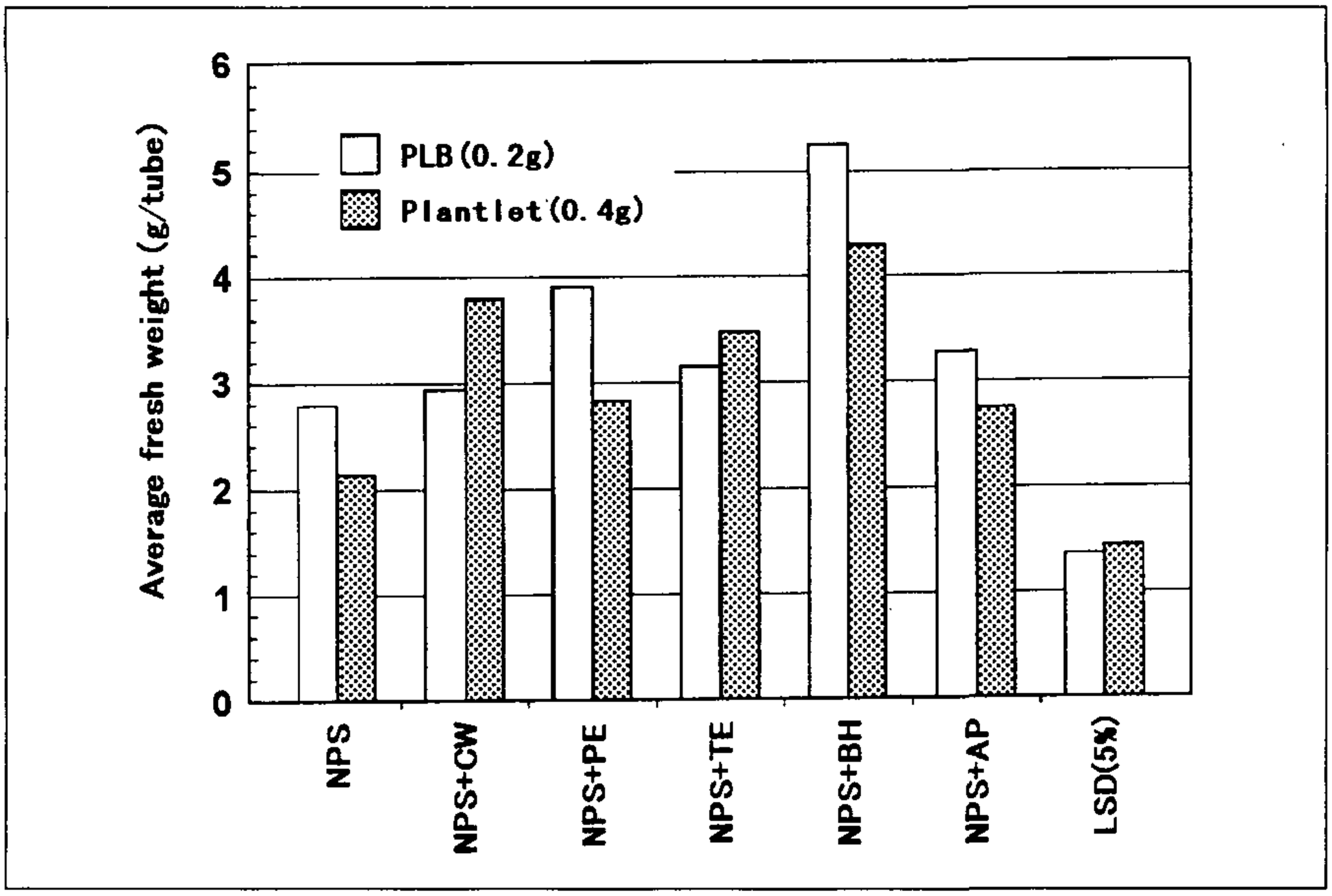

Figure 5. Effects of organic additives on growth of *Odontoglossum* 'Lovely Morning'. Coconut water (CW) 150 mg liter^{-1}, potato extract (PE) 150 g liter^{-1}, taro extract (TE) 150 g liter^{-1}, banana homogenate (BH) 75 g liter^{-1}, and apple extract 150 g liter^{-1}.

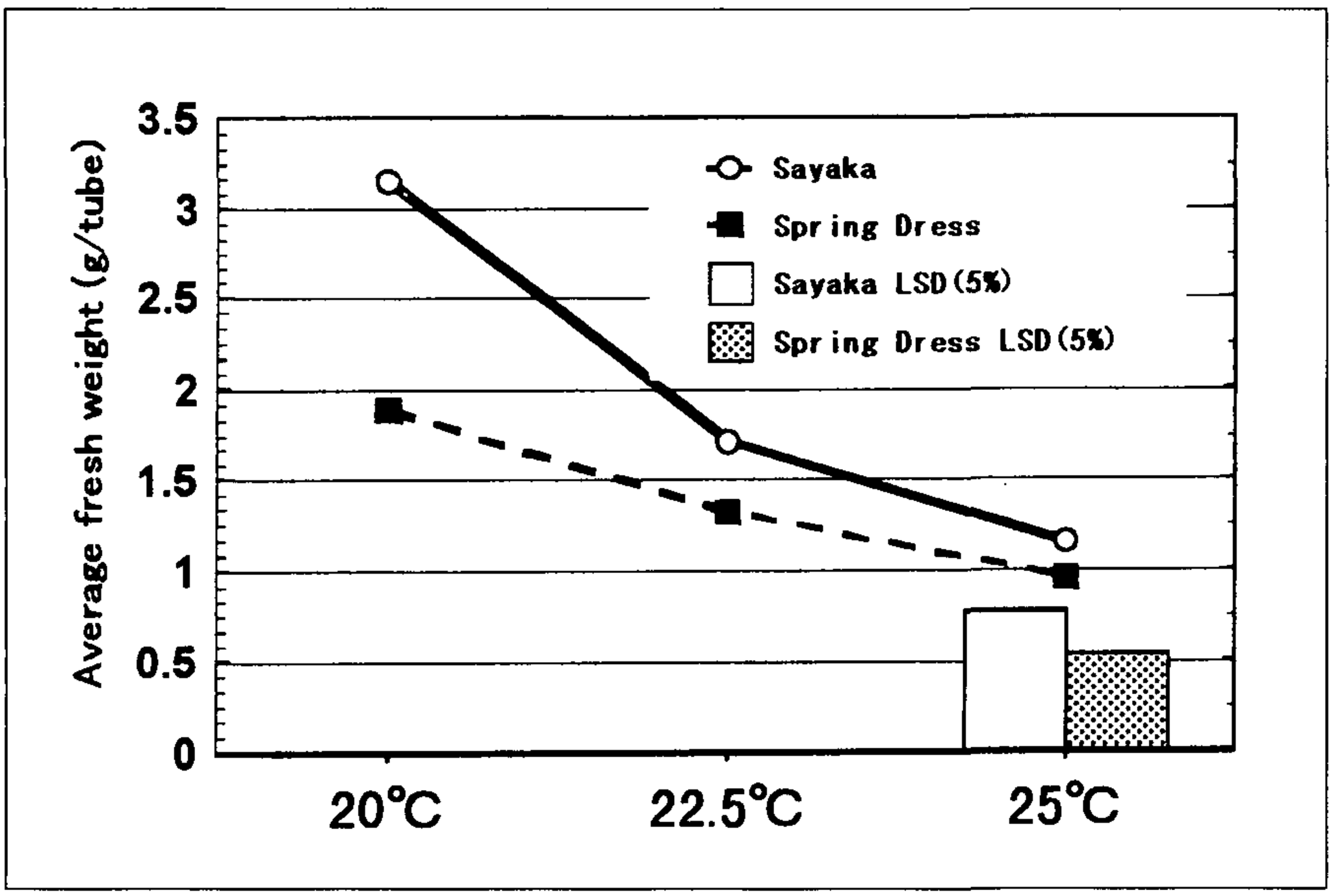

Figure 6. Effect of temperature on protocorm-like bodies (PLB) growth.

The optimum concentration of sucrose was 20 g liter^{-1} both with and without CW (Figs. 1, 2, 3, and 4).

The addition of organic additives to the NP medium supplemented with sucrose (20 g liter^{-1}) stimulated PLBs and plantlet growth of *O.*'Lovely Morning'. Among the additives tested, banana homogenate (75 g liter^{-1}) was the best (Fig. 5).

Of the temperatures tested 20C gave the best results, however, a temperature below 20C would appear to be the optimum temperature for PLB growth of these two cultivars (Fig. 6).

Table 1. Composition of new phalaenopsis (NP) medium.

Components	mg liter^{-1}
Major elements*	
$(NH_4)SO_4$	303.9
KH_2PO_4	462.7
NH_4NO_3	32.0
$Ca(NO_3)_2.4H_2O$	637.6
$Mg(NO_3)_2.6H_2O$	256.4
Fe-EDTA**	
Minor elements**	
Organics/vitamins**	
Solidifier	
Gelrite	3000
Sugar	
Sucrose	20000

* The balance of cations and anions are $NH_4^+ : K^+ : Ca^{2+} : Mg^{2+} = 25 : 38 : 27 : 10$; $NO_3^- : H_2PO_4^- : SO_4^{2-} = 60 : 17 : 23$; and the total ionic concentration of cations and anions is 20 me liter^{-1}.

** The amount of Fe EDTA, vitamins, glycine, and myo-inositol are equivalent to those in Murashige and Skoogs's (MS) medium. The minor elements were reduced to + of those of the concentration in MS. The pH was adjusted to 5.6±0.1.

The Effect of Cytokinin on the Micropropagation of bulblets of *Lilium japonicum*

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Lilium japonicum is a Japanese native plant and a favorite because of the beautiful pink flowers. However, *L. japonicum* has a low multiplication rate by scale propagation, therefore, micropropagation is used for the propagation of this plant. Although many papers have reported on the micropropagation of *L. japonicum*, there are few papers on the effect of cytokinin. In this paper, we report on the effects of various cytokinins on scale multiplication in culture.

Bulblets in vitro were used because *L. japonicum* from the wild is likely to be contaminated by bacteria. The scales were collected from the bulblets and were cut into 2-mm pieces. Three cytokinins; 2iP, BA, and kinetin were used for the experiment. Many green adventitious buds were differentiated when 2iP was used and these adventitious buds rooted and grew when culture was continued. The addition of NAA with 2iP enhanced rooting from adventitious buds, although the number of buds decreased. Benzyladenine enhanced the differentiation of abnormal white/yellow buds which appeared as protuberant domes. This abnormality was not prevented by NAA. Kinetin also enhanced the differentiation of abnormal buds and callus was formed with high concentrations.

Taking into account the mutations induced by some auxins, and that the many roots formed with other auxins decreased the need for handling in subculture and helped acclimatization and growth after transplanting, we decided that the medium supplemented with 5.0 μm 2iP was best suited for the micropropagation of bulblets of *L. japonicum* in scale culture.

Propagation of Nobile-type *Dendrobium*

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Dendrobium nobile **can be multiplied by several methods. In this report the methods of propagation, their various characteristics, and important points are presented.**

SEEDLING PROPAGATION

This is essential for the breeding of new cultivars. Although it is easy to produce seedlings by conventional aseptic culture, it takes a long time and is expensive. If the unwanted seedling plants can be sold, the breeding cost will be reduced. With *Dendrobium nobile*, the unwanted seedlings are usually of no use except from some diploid cultivars, and commercial production by seedlings is risky.

Because of this, breeding should be carried out using elite plants in a place where production costs are low. To select the type of cultivars preferred by the Japanese consumer, the selection of nominated plants should be made by a Japanese breeder.

STEM CUTTINGS

This is the usual method of propagation when production is from selected stock plants. Usually back pseudobulbs removed from the plants before shipment are used for this purpose. These pseudobulbs are laid on sphagnum moss or a mixture of peat-moss and vermiculite (1:1, v/v) in a tray, and kept half shaded, in a warm and moderately humid place.

In cultivars where flower bud initiation is good, the number of dormant buds on back pseudobulbs are limited and it is difficult to obtain enough plantlets. In this case, stem cuttings using lead pseudobulbs before flower bud initiation is an option. However, during October and November the stems used for cutting production will initiate flowers if the temperature falls below 20C. It is important, therefore, to maintain good temperature control in order not to interrupt cutting production.

After 6 months, the 4- to 5-cm-long plantlets with 4- to 5-cm roots are transplanted to pots.

The prevention of diseases such as basal rot and the control of slugs are important.

The amount of sunlight must be carefully controlled, otherwise the pseudobulbs will turn yellow and shrink. Propagation can be considered a success if new buds sprout uniformly.

MICROPROPAGATION

When new cultivars are introduced from breeders or nurseries, or when it is necessary to propagate existing cultivars rapidly, micropropagation is adopted.

A fairly large number of plantlets can be supplied within 2 years by micropropagation, so micropropagated plants are now used in conjunction with cutting-grown plants. However, there is a risk of mutation in micropropagation. When propagation by cuttings is applied again to mericlonally produced stock plants in order to reduce costs, it can take up to 6 years to produce a saleable plant.

OFFSHOOT (KEIKIS)

Propagation from offshoots is rare in commercial production, but it is possible to produce saleable plants within 1½ years using big healthy offshoots.

A major reason for the development of offshoots is damage to the roots of the plants, another is the oversupply of nitrogenous fertilizers during summer. Nonflowered immature pseudobulbs sometimes develop offshoots in spring and summer under high temperature conditions.

Those cultivars in which the lateral buds change their type of growth easily from reproductive (flower) to vegetative (offshoot) under high temperature conditions are not suitable for commercial production and should not be propagated.

When the offshoots reach 6 to 7 cm in length with 3 to 4 roots, they are removed from the stock plants and planted in pots.

DIVISION

In commercial production, division is not an applicable method of propagation except when necessary to maintain the stock plant, because the damage to the plant's roots requires a long time for recovery.

The Cultivation of the Aquatic Plant *Fontinalis antipyretica* and the Red Bee Shrimp

Hisayasu Suzuki
Shrimp Cultivation Center, 61Toshima,Tahara-cho, Atumi-gun, Aichi 441-3417

CULTIVATION

Fontinalis antipyretica occurs between the tropical zone and temperate zones of the world. It is a species related to sphagnum moss and grows around wetlands or in water. The linear stem has many small branches between 1 to 2 mm in length. This species develops many branches and these branches intertwine with one another forming a complex plant. *Fontinalis antipyretica* attaches itself firmly to stones and drift wood and by making use of this characteristic, aquarists can arrange various layouts in their aquariums. The plant is also a good refuge for young fish, so many aquarists use this species for that purpose.

Culture Conditions. Water temperature, 18 to 28C; water quality, weakly acidic or weakly basic with a pH 6.2 too 7.5; soft or medium hard water of a hardness rating between 0 and 5.

CULTIVATION AND BREEDING OF CRYSTAL RED BEE SHRIMP

Aquarists usually keep bee shrimps (*Caridina* sp.) in their aquariums because they eat moss and clean the aquarium. The wild species of bee shrimp is a small 2- to 3-cm shrimp and originated in the Hong-Kong islands, but it seems that no wild stocks exist there any longer and cultivation has recently ceased. I found a crystal red bee shrimp mutant, the original species is black and white in color but the mutant is red and white. We are now trying multiplication and expect it will take 7 years from discovery to having stocks available for sale.

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CULTIVATION AND BREEDING OF CRYSTAL RED BEE SHRIMP

Aquarists usually keep bee shrimps (*Caridina* sp.) in their aquariums because they eat moss and clean the aquarium. The wild species of bee shrimp is a small 2- to 3-cm shrimp and originated in the Hong-Kong islands, but it seems that no wild stocks exist there any longer and cultivation has recently ceased. I found a crystal red bee shrimp mutant, the original species is black and white in color but the mutant is red and white. We are now trying multiplication and expect it will take 7 years from discovery to having stocks available for sale.

The Original Home of the Tea Plant and its Utilization

Satosi Matushita
Department of International Communication, Aichi University, Minamisakae, Toyohashi, Aichi, 441-8107

The original habitat of the tea plant (*Camellia sinensis*) was thought to be the mountains dividing the Chinese province of Yunnan and other southeast Asian countries. However, verifying this information was not possible as access to these areas was restricted for foreigners.

In 1980, the open-door policy of China made it possible to go to Yunnan and search. As a result of my investigations spread over nine visits to the region, I consider the mountains of Yunnan to be the natural habitat of the tea plant. However, the culture of processing tea leaves and tea drinking seems to have originated in Wolingshan, in a mountain area called the land of Bashu, at the north end of Yungui-Gaoyuan in the northern part of Yunnan.

At Wolingshan in the land of Bashu, the Chinese and Chinese culture come together with the tea plant and the culture surrounding tea seems to have had its genesis. The next group of Chinese people to start using tea were the Yaozu, who subsequently spread the use of tea to the rest of the country when they moved southwards from Yunnan to the south Asian mountain area.

It became clear in my investigations that the original habitat of the tea plant and the place where its use started are quite different.

An Attempt to Introduce New Kinds of Flowers for use in the Tea Ceremony

Sigeru Yokouchi
Department of Botany, Meijo University, Siogarnaguchi 1-50 1,Tenpakuku, Nagoya-shi, Aichi 448-0073

The Tea Ceremony is an integral part of Japanese culture. It is carried out in a tea room, chasitu, and traditionally an alcove in the room is adorned with a flower arrangement. This arrangement is known as chabana (flowers for the tea ceremony), and the idea is that these flowers should look as natural as they would in the wild. This idea was handed down from the originators of the Tea Ceremony and fresh flowers collected from the wild are the most sought after.

Traditionally some 200 wild species have been used most often in the Tea Ceremony, along with *Camellia japonica, Hibiscus syriacus*, and *Prunus mume*. Some 20% of the plants included are endangered. Not all of them are collected in the wild, for obvious reasons it is no longer permitted to utilize wild plants for chabana when one fifth of these plants are endangered.

The purchase of flowers for chabana is the new trend. However, the use of nontraditional flowers such as roses and carnations does not have the same appeal to people taking part in the Tea Ceremony, but change would seem to be inevitable with the increasing difficulty of obtaining wild flowers forcing a change to the style of the Tea Ceremony.

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Because of these circumstances, the development of new chabana flowers and the commercial production of these flowers is necessary. It is estimated that there are more than 5 million people who enjoy the Tea Ceremony and if only a proportion of them use bought flowers, the demand would be substantial. The commercial production and supply of flowers for chabana will help in the protection of endangered plants in the wild.

The author has introduced flowers suitable for this purpose from time to time.

Accelerating Rooting by the Pretreatment of Direct Stuck Cuttings of Chrysanthemum

J. Nisio
Institute of Horticultural Research, Aichi Agricultural Research Center, Sangamine, Yasago, Nagakute-cho, Aichigun, Aichi 480-1100

INTRODUCTION

The cultivation of *Dendranthema* 'Seiun', a summer-autumn flowering cultivar, by the direct planting of shoots before rooting is widely adopted for savings in labor costs. However, the rooting of autumn-flowering cultivars grown for late season sale using light-culture techniques and production is not reliable because the planting season in mid summer is too hot. To solve this problem, methods to stimulate the initiation of root primordia by the pretreatment of shoots were investigated.

MATERIALS AND METHODS

Experiment 1: Temperature and Light Condition Before Cutting. Shoots of *D.* 'Set Alps' were kept at 5C in the dark in a cardboard box, at 20C, illuminated with a metal halide lamp and at 25C in natural light in a north-facing room. The shoots were collected 22 Sept. 1997 and 30 shoots were set in #2.5 pots, after the whole shoot was dipped in 40 ppm IBA, drained, and kept in a sealed plastic bag for 9 days.

Experiment 2: Temperature Treatment and Duration. Shoots treated in the same way as above were kept at 15C for 5, 6, and 7 days, also at 20C and 25C for 4, 5, and 6 days, respectively. The shoots were collected 10 March 1998. After dipping in IBA solution the shoots were dried for 4 h because in Exp. 1 some shoots rotted. After treatments the shoots were set in beds, kept at 20C with a 4-h light break for 4 to 5 days and root development was investigated.

Experiment 3: Methods of IBA Treatment. Treatments were by powder (0.5% IBA) applied to the cut surface, as a spray of 0.2% solution to the cut surface, by dipping the cut surface in a 0.2% solution, a spray of 0.04% solution to the cut surface, dipping the cut surface in a 0.04% solution, dipping the shoot in a 0.04% solution, and dipping the shoot in a 0.004% solution were compared. Pretreated shoots were preincubated at 25C for 4 days. The experiment then continued in the same way as Experiment 2.

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RESULTS AND DISCUSSIONS

1) Pre-incubation at 5C showed no effects on root initiation after 9 days, but 50% to 60% of the shoots at 20C and 80% to 85% at 25C, respectively, rooted. Including root primordia initiation, almost 100% of shoots responded at both 20 and 25C. Light irradiation stimulated root development, but additional light during pretreatment is not essential.
2) For root primordia initiation 7 days was required at 15C, 5 days at 20C, and 4 days at 25C. These shoots rooted 100% after being set in beds.
3) Shoots were normal in appearance with the IBA powdered treatment, the 0.04% sprayed solution to the cut surface, the shoot dipped in 0.004% solution, and in the untreated control. With the powder and the control 95% of shoots initiated root primordia while 65% rooted with the 0.04% spray solution to the cut surface and those dipped in 0.004% IBA solution.

   Rooting after 3 days was best in the control (93%), followed by the shoot dipping of 0.004% solution, cut surface dipping in 0.04% solution, cut surface spray of 0.04% solution, and powder dressing. However, in treatments of the cut surface dipped in 0.04% solution, 10% of the cut surface shoots rotted.

   In treatments where no abnormal appearances were observed, all shoots initiated root primordia.
4) It became clear that almost all shoots can form roots by using a pretreatment with IBA powder; a spray of 0.04 % solution to the cut surface; or dipping of the shoot in 0.004% solution, then drying; and keeping at 15C for 7 days, 20C for 5 days, or 25C for 4 days.

The Production and Supply of High Quality Vegetable Plants in Aichi

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The supply of virus-free plantlets produced by meristem culture has increased the productivity and promoted the production of clonally propagated vegetables. In Aichi Prefecture, plants produced in this manner include strawberries (*Fragaria*), Japanese butterbur (*Petasites japonicus*), and Japanese yam (*Dioscorea batatas*). Fifteen years ago, it was expected that the large-scale production of micropropagated plants and seeds would become a commercial reality. However, even today, these propagation methods have yet to overcome the problems of high cost and mutation. This report covers the supply method for virus-free plantlets.

MATERIALS AND METHODS

The Supply of Virus-fee Plantlets. In Aichi prefecture, shoot meristems are excised and cultured to produce virus-free plants in accordance with the estimates of a committee set up to forecast demand. Acclimatized plantlets are cultured at first at the Horticultural Nursery Plant Center and then propagated at the Regional Propagation Farm and Local Propagation Farms, from where the plants are supplied to farmers.

The Effect of Supplying Virus-free Plantlets. By 1996, the area growing strawberries *(Fragaria)* propagated by this system was 405 ha and fruit production was 12,900 tonnes, the fifth largest production area in Japan. The supply of virus-free plants started in 1987, and has steadily increased fruit yield. In 1996, the area planted in butterbur *(Petasites japonicus)* was 150 ha, the largest production area in Japan. By the use of virus-free plants since 1995, production has increased 129%. With the supply of virus-free plants of Japanese yam *(Dioscorea batatas)*, the area planted has increased from 14 ha in 1994 to 15 ha in 1996 and promoted production in the mountain area.

The Selection of Cultivars and Supply of Acclimatized, Uniform Plants. Cultivars for virus-free plant production are selected by the Aichi Agricultural Research Centre.

Promising cultivars of strawberry are 'Tochiotome', Aichi No.4 and Aichi No.5. The Aichi Agricultural Research Centre is supplying virus-free mother plants, 120 plants of strawberry, 400 plants of butterbur, and 250 plants of Japanese yam, to the Horticultural Nursery Plant Center every year.

The Propagation Program of the Horticultural Nursery Plant Center. The Horticultural Nursery Plant Center propagates nursery plants of strawberry, butterbur, and Japanese yam. In 1996, 7500 and 4100 plants, respectively, of

strawberry and butterbur and 86,000 aerial tubers of Japanese yam were propagated. This production was carried out by three full-time and six part-time staff, working in a 1294 m^2 greenhouse and a 360 m^2 isolation house. The budget in 1996 was 28 million yen.

Propagation at the Regional Propagation Farm. There are 23 regional propagation farms for strawberries, and some of them have introduced the rockwool culture system. There are six butterbur regional propagation farms and these supply one third of stock requirements. Twelve Japanese yam regional propagation farms supply 1-year tubers to growers.

The Future Supply of Virus Free Plants. There is no plan to introduce crops other than these three into the propagation program because of lower production levels in Aichi prefecture.

We will continue to improve the system and efficiency to ensure the production of disease-free plants, one example would be the greater utilization of the rockwool system for strawberry production.

Vegetation Control in a Community Complex of *Drosera indica*

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INTRODUCTION

Drosera indica (known in Japanese as nagaba no isimotiso) is facing extinction and was classified in 1997 as a 1B species by the Environmental Agency in Japan. It only grows naturally in a few places in Ibaraki, Chiba, Miyazaki, and Toyohashi City as well as at two locations in Aichi. This species is an insectivorous plant belonging to the Droseraceae. Plant height is between 10 and 20 cm and leaf length between 4 and 6 cm. Glandular hairs on the leaf secrete mucus in which insects become trapped. The insect-catching capability of the leaf is strong enough to catch a medium-sized butterfly.

The habitat in Toyohashi city is located on the north side of Miyuki Park in Satoh-cho, near the center of the city. They grow wild near the Cho-San Pond and the Ishida River running from the pond. About 2500 m^2 of this area is protected by a fence.

This site was discovered by Hoshino in 1971. According to pictures taken at that time, the amount of vegetation cover in the area was low, the place did not look like moorland but rather like wasteland growing just a few pine seedlings. Although the site was left as it was and observed secretly, we appealed to the city government to protect it as it had been earmarked as a parking lot for Miyuki park. As a result of our appeal and the efforts of Mr. H. Kurauti and others, this site was protected and *Drosera indica* was designated a protected plant in March 1993. Before the designation of the area, we were asked to investigate the vegetation (1993). Then after designation, vegetation control was required, we researched this and have been controlling the vegetation since 1994.

In this paper, I will report on the vegetation of the community complex where *D. indica* grows, the experiments which we undertook to recover the vegetation and the ongoing vegetation control.

INVESTIGATION OF THE VEGETATION

1) Methods. In order to undertake a detailed survey of the site, 5 m of mesh was stretched over the area. Inside the mesh 29 square frames of 1 m^2 were established. We then investigated the community complex in detail mainly employing the Braun-Branquet method.

2) Results. The vegetation of the area was divided into the following 14 populations by contents, population, and dominant species.

Communities of the following species were identified, *Moliniopsis japonica, Rhynchospora rugosa, Fimbristylis squarrosa, Bulbostylis dense* var. *capitata, Zosia japonica, Drosera indica, Andropogon virginicus, Imperata cylindrica, Solidago altissima, Miscanthus sinensis, Pleioblastus chino, Lespedeza thunbergii, Pinus* species, and *Quercus serrata*.

Among these communities, we estimated the transition of herbaceous plant populations as follows;

Bare field > *B. densa* var. *capitata* > *Z. japonica* > *A. virginicus* > *I. cylindrica* > *M. sinensis* > *L. thunbergii*. *Drosera indica* is found in the community of *B. densa* var. *capitata* and *Z. japonica*.

RECOVER EXPERIMENTS

We did two seed sowing experiments with *D. indica* in communities of *B. densa* var. *capitata, Z. japonica, A. virginicus, I. cylindrica, S. altissima*, and *L. thunbergii*, at the same time cutting and removing some of each plant community. In this experiment the highest germination percentage was obtained in communities of *A. virginicus*.

The environmental conditions best suited to the growth of *D. indica* is an early stage in natural plant succession. In this experiment, good results were obtained in the communities of *A. virginicus* and *I. cylindrica* which are the earlier phase of transition. In natural conditions, *D. indica* grows in unstable environmental conditions such as where people walk, in places which are at times covered in water, or around ponds. The results of our experiment were the same as those occurring in the natural environment of *D. indica*.

CONTROL OF VEGETATION

We are controlling the vegetation to suit the conditions required for the growth of *D. indica* in light of the results of our experiments.

1) Cutting out pine trees and *Quercus* species to secure sunshine in the growing area.
2) Removal of *A. virginicus* and *I. cylindrica* from among *D. indica* vegetation to stimulate growth.
3) Assisting the spread of *D. indica*, by removing *A. virginicus* and *I. cylindrica* from the surrounding areas to reduce their numbers.
4) Cleaning garbage from the area. We are working on a control program and vegetation control is carried out 2 or 3 times every year, under the supervision of a city officer, by 20 to 30 volunteers who have attended open classes run by the city.

Isolation and Culture of Mesophyll Protoplasts from *Asarum takaoi*

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Although plant regeneration from protoplasts has succeeded in many plant families, there are no reports on protoplast isolation and culture in the Aristolochiaceae. Within the Aristolochiaceae, *Asarum, sensu lato*, is well known as the only food source for *Luehdorfia japonica*, which is faced with extinction from indiscriminate hunting (Iwatsuki, 1994). Since *Asarum* is slow to propagate, improving its growth rate is significant for maintaining both it and *L. japonica*. One of the procedures for this is to produce a somatic hybrid of *Asarum* by protoplast fusion with other plants possessing a high growth rate. In this paper, we describe the isolation and culture of a protoplast from *Asarum takaoi* leaves, as a first step in the process.

Young leaves (2 to 4 weeks after unfolding), old leaves (5 to 10 weeks after unfolding), and petioles were used as the source materials for protoplast isolation. All materials were surface sterilized in 2.5% (w/v) sodium hypochlorite solution for 20 min and washed twice with sterilized water. The material was then cut into 3- to 5-mm strips (leaves) or 5- to 10-mm sections (petioles). Next, a filter-sterilized enzyme solution containing 0.1% pectolyase Y-23 (Seishin Pharmaceutical Co. Ltd., Tokyo, Japan), 1.0% cellulase Onozuka RS (Yakult Honsha Co. Ltd., Tokyo, Japan), and 0.6 M mannitol, pH 5.7, was added (20 ml g^{-1} fresh weight sample), then vacuum infiltrated for 10 min. After incubation for 1 to 12 h at 30C, the mixture was filtered through two layers of gauze, and centrifuged at 100 g for 3 min, followed by washing twice with 0.6 M mannitol solution. The number and viability of the protoplasts was determined by a haemocytometer and fluorescein diacetate staining, respectively.

The highest yield (1×10^6 cells g^{-1} F.W. sample) and viability (85%) of protoplasts was obtained from the younger leaves after 4-h incubation. Older leaves also released a high yield of protoplasts (0.8×10^6 cells g^{-1} F.W. sample), but slightly less than the younger leaves. In contrast, the petiole tissues were hardly digested and released a relatively low yield of protoplasts (1×10^4 cells g^{-1} F.W. sample).

Several culture media with supplements of 3 mg $liter^{-1}$ NAA, 1 mg $liter^{-1}$ BA, and 0.6 M mannitol were tested for culturing mesophyll protoplasts from the younger leaves. In ½ strength Murashige and Skoog (MS) medium (Murashige and Skoog, 1962), 40% of the cells were viable and 20% of them had divided after 2 weeks. No cell division was observed in other media, such as White (White, 1951) or B5 (Gamborg et al., 1975). Clusters of several cells were formed in about ⅔ of the divided protoplasts. Attempts to induce differentiation in the protoplast derived colonies have so far been unsuccessful.

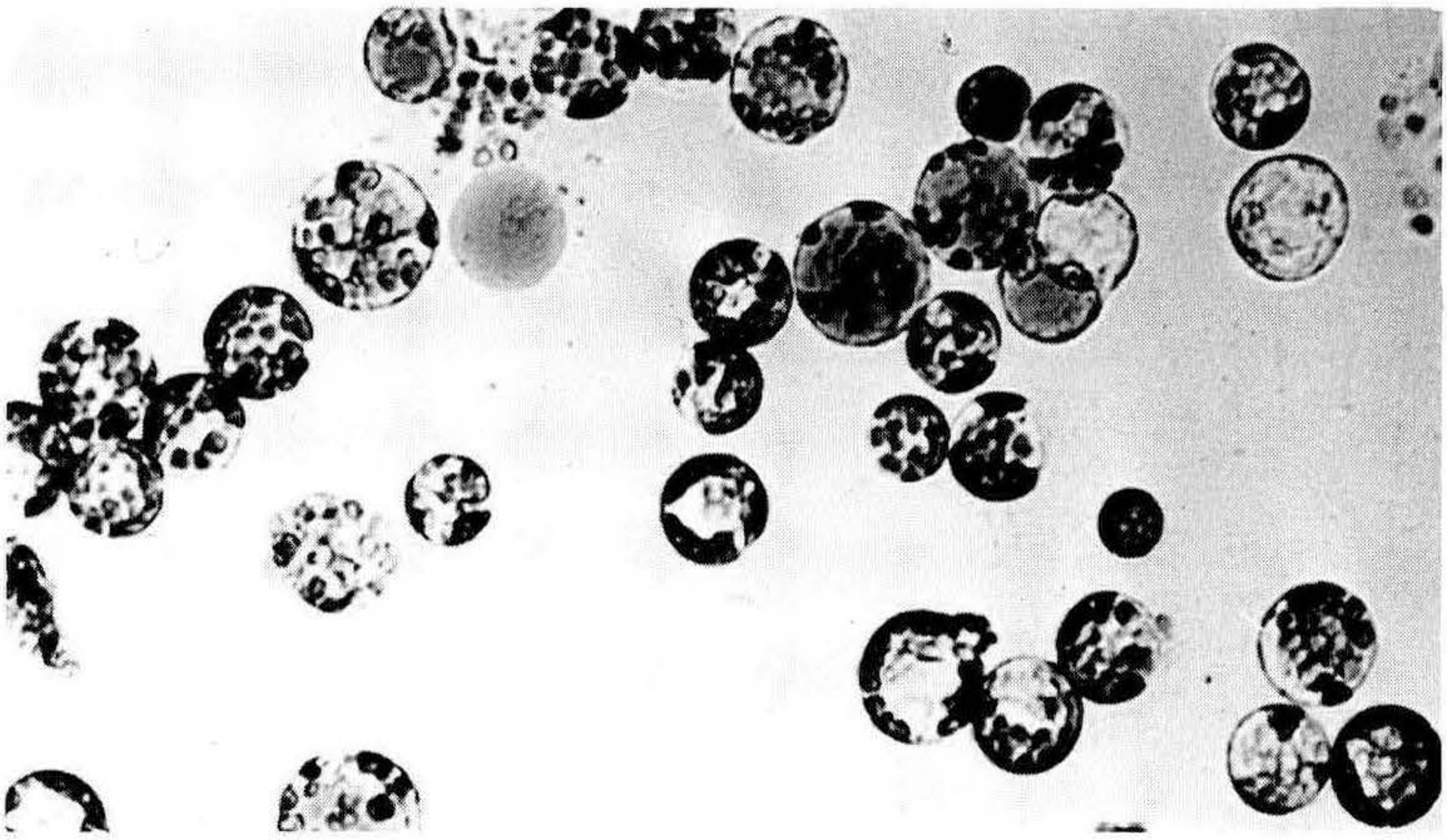

Figure 1. Protoplasts from *Asarum takaoi* leaves.

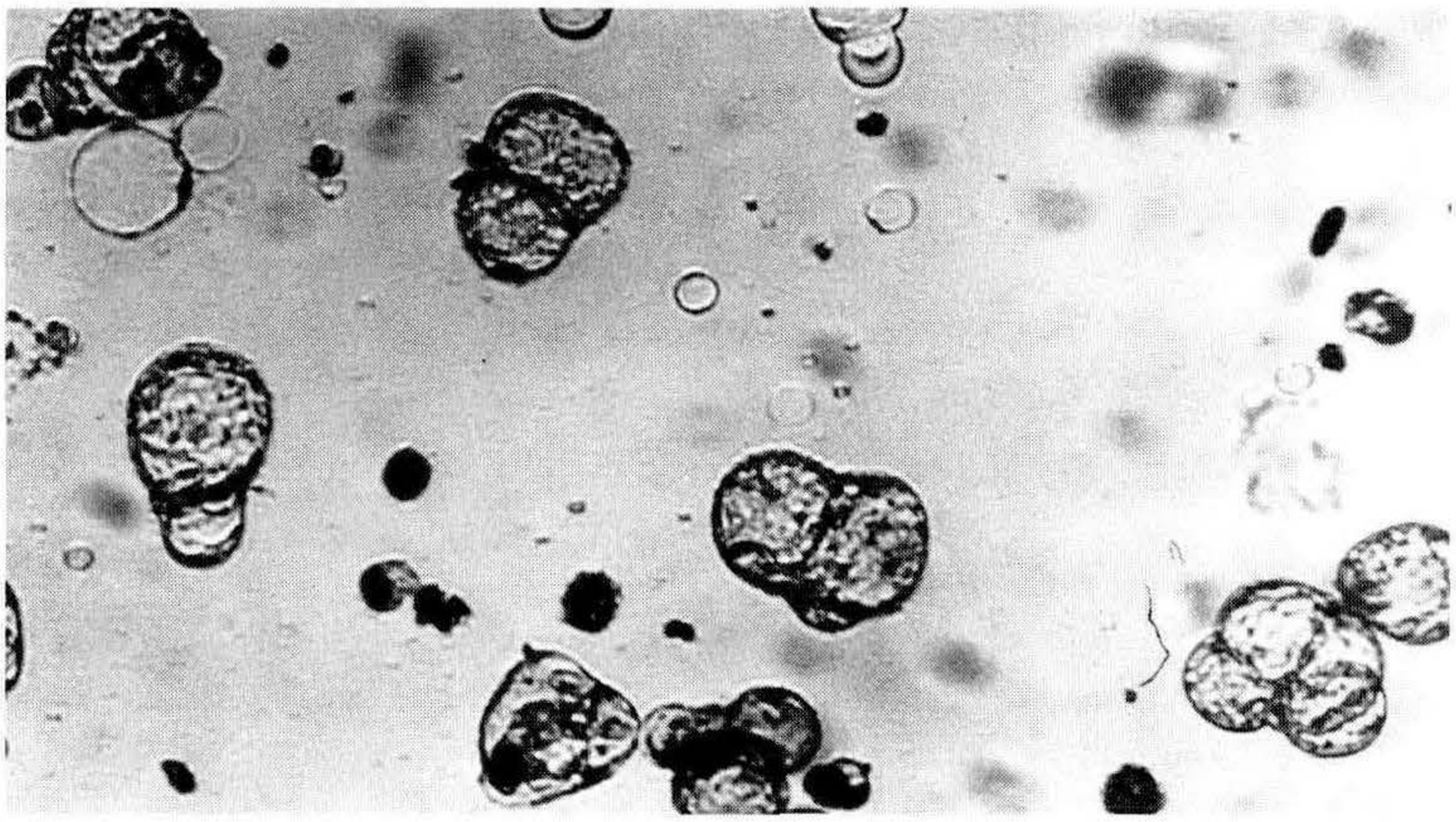

Figure 2. First cell division in *Asarum takaoi* protoplasts cultured for 2 weeks.

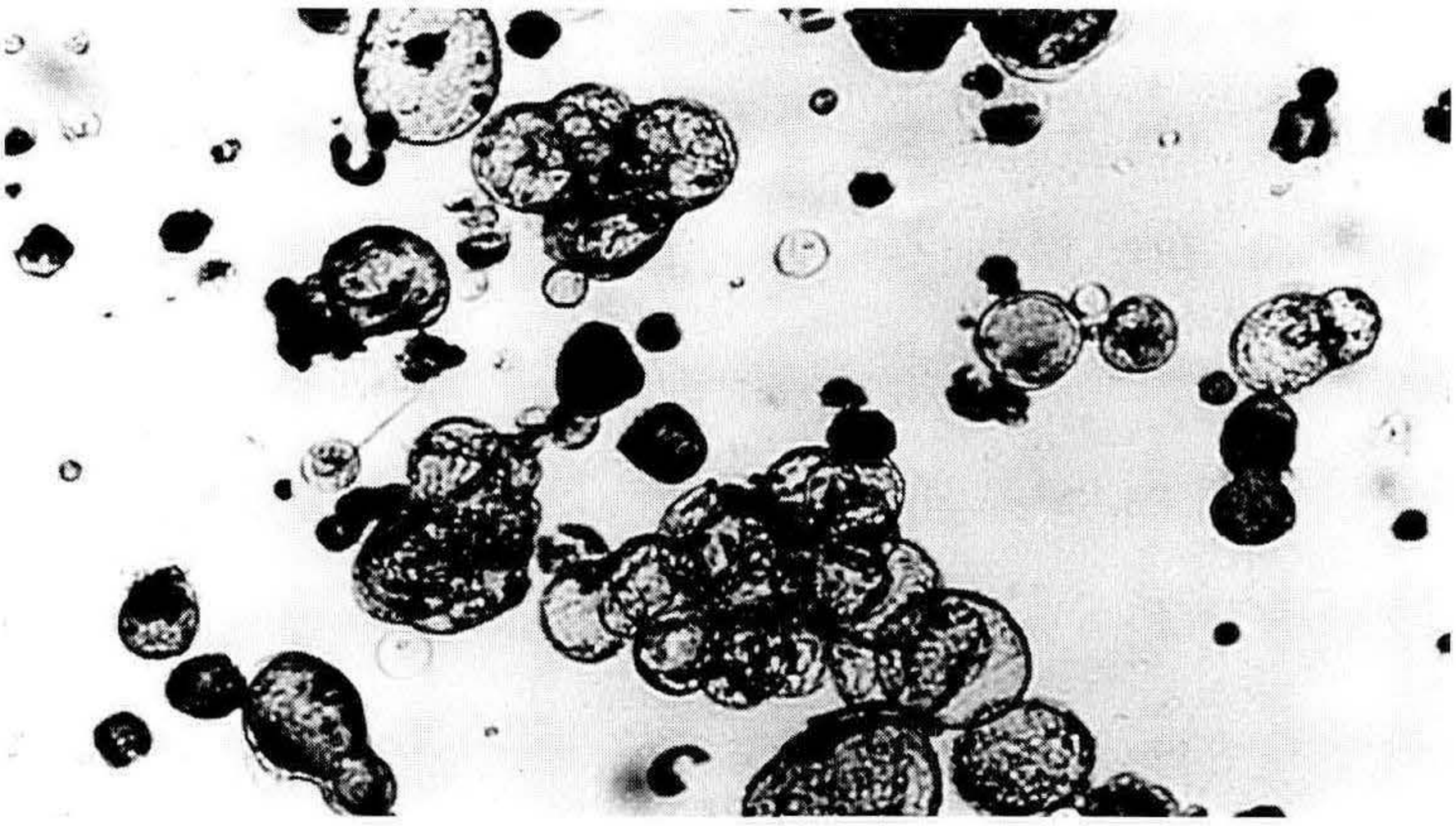

Figure 3. Cell cluster formed after 30 days of culture.

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Propagation and Seed Germination of *Erythronium japonicum*

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Erythronium japonicum is a perennial bulb plant in the Liliaceae, the only member of the genus endemic to Japan. In early spring, *E. japonicum* produces a pale purple flower in which the sepals and petals recurve as in cyclamen flowers. In the wild, flowering occurs 7 to 8 years from seed germination but in cultivation, bulbs can be large enough to flower within 5 years and normally bloom within 6 years. *Erythronium japonicum* occurs naturally throughout Japan but is rather rare in the west. Recently, its natural habitats have been decreasing because of land development; therefore, propagation by tissue culture has been adopted.

In Aichi prefecture, Asuke-cho is well known as having a large wild population and another population is reported around the Moor Imou in Toyohashi city.

In 1994, the late Takeshi Tomita found some *E. japonicum* growing spontaneously in his orchard of Japanese chestnuts at Ishimaki Nisikawa-cho, Toyohashi city. The site is on a north facing slope of about 30°, sunny in spring and changing to a forest floor as the trees leaf out during summer. These plants were left undisturbed and increased in number year by year and by 1972, the population was large enough to produce 300 flowers. In order to spread this colony over the entire slope, we tried to propagate by bulb division. As a result, the transplanted bulbs grew very well and increased considerably so that nowadays the slope is covered with flowers in early spring. But it proved difficult to grow them at other sites, they only grew well on sites where humidity was high such as around ponds. In other conditions they do not bloom every year, or disappear after several years. These results suggest that they are not tolerant of dry soil conditions.

In its original habitat, *E. japonicum* blooms from about the 20 March until 5 April every year. When propagation was started the plants showed no obvious variations, but variations are now apparent — there are two flower colors, purple and light purple. There are also differences showing up in the shape of the flowers, some with larger petals and others about twice the size. In 1998, we found a strain with yellow anthers, as opposed to the normal deep purple, which seems to be a sterile male clone. Most of these variations may be genetic because plants from the same bulb appear the same.

In early May seeds can be harvested. It has been reported that the seed germination rate of this species in the Kanto area was 70% to 90%. Although we tried to propagate by seed, the germination rate was less than 0.1%. At first, we speculated that the seed contained no embryo, however, we found normal embryos in the seeds, so we began experiments on seed germination. The seeds obtained in 1997 were stored in a plastic bag with soil from the sloping site and kept in the dark at 10C. They germinated 2% and 15% after 12 months and 15 months, respectively. This result suggests the possibility of a lack of chilling period for seed germination in Toyohashi. We will, therefore, investigate the effects of chilling on future seed germination.

The Natural Habitat and Breeding of *Iris laevigata*

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INTRODUCTION

Kakitubata, *Iris laevigata*, a wild flower found in Japanese wet lands, has been appreciated for a long time; it is mentioned in the old anthology of Manyoushu as well as the old story Isemonogatari. However, there are fewer cultivars available than of *I. ensata*, and it has not become a commonly grown garden plant because the spread of cultivars and the culture technique were prohibited. I started the pot cultivation and breeding of *I. laevigata* in 1977 with the intention of popularizing the plant and at the same time I began investigating its natural habitats.

HABITAT

The natural habitats of *I. laevigata* are spread through Iwate, Nagano, Aichi, Siga, Kyoto, Hyogo, Tottori, Simane, and Yamaguchi prefectures, and it is specified as a nationally or prefecturally protected plant. It also grows in other places, Kushiro, Uryu, Oze, Iritanizato, Hiruzen, etc., from Hokkaido to the main island. Among these habitats, Iwate, Aichi, and Kyoto were flat lands and near cities, while the other sites were cool wet lands among mountains.

Flower color is normally purple, but a pink-purple flower was found in Aichi, and a white flower in Yamaguchi. The flowering season starts in early May in the flat land sites and is delayed according to altitude and latitude, ending in late June at Hyogo (Tyosigatani). There also exist continually flowering populations in some Japanese seaside areas (Tottori, Simane, and Yamaguchi). The largest flowers were found in Iwate. In Simane and Yamaguchi, it grows on the edge of a pond together with junsai (*Brasenia schreberi*) .

CULTIVARS

Cultivars of *Iris laevigata* were described in two books of the Edo period, *Kadanchikinsyo* and in *Kakitubata Kafu* edited by Akira Hironaka, but they number less than 100. Purple-flowered cultivars are the most common, corresponding to the predominant color found in wild forms, followed by white, or white with purple splashes, and occasionally reddish-purple. The flowering season starts with the blooming of the white cultivars in late April; most cultivars are flowering by the middle of May and the last cultivar to bloom is 'Maikujaku' in late May. There are two flower types with three or six petals, the inner perianth stands up straight and outer perianth hangs down.

BREEDING

At first my aim was to breed flowers of a bright reddish-purple color, and then after 1990, white flowers with a solid perianth became another aim. Consequently, 60 cultivars were bred and 19 were patented (some are still being processed).

Reddish-purple and white-flowered cultivars were used as the parent plants as were flat-flowered cultivars. Although hand pollination is easy and seed production

is good, seed germination percentages were zero for some time. Higher germination rates have been achieved with white and purple-splashed white cultivars, but reddish-purple rates remain low.

Seeds germinate in May when sown in late March. Seedlings are transplanted to No.3 pots in June and transplanted again to a #5.5 pot for overwintering; flowering occurs the following May. Pots are kept in a 20-cm-deep water bed all year round. Flower stalks of the larger-flowered types frequently emerge diagonally, but this can be rectified over several generations of selective breeding.

Root Rot Caused by *Pythium helicoides* in Ebb and Flow Culture of Potted Roses

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Miniature roses growing in an ebb and flow watering system showed die back during the summer growing season in Gifu Prefecture.

The main diagnostic symptoms were leaf chlorosis and a brown water-soaked rot of the roots which finally caused die back. The root rotting occurred from August to September 1997. In a greenhouse in Kaizu, Gifu, the disease incidence peaked from the 18 Aug. until 13 Sep. However, no root rot disease was found when minimum temperatures fell.

Both B-5 and H-5 isolates from the rotted roots of the roses showed similar growth rates at all tested temperatures. They did not grow below 10C or above 45C. Hyphal growth increased with rising temperatures in the range of 15 to 35C. The optimal temperature was 35C and the growth rate was 34 mm per 24 h. There was a sudden drop to about 15 mm per 24 h in hyphal growth at 40C.

The sporangia were terminal, ellipsoidal, papillate, and proliferating inside and outside sporangia. Oogonia were terminal, lateral or intercalary, smooth and 30.5±2.24 mm in diameter. The antheridia were lobulate, elongate, monoclinous or diclinous and 1 to 3 per oogonium. The oospores were aplerotic, smooth, spherica, l and 25.5±1.93 mm in diameter. The isolates were identified as *P. helicoides* Drechsler on the basis of these characteristics.

Three representative isolates were used for pathogenicity tests on the miniature roses ('Lavender Parade'). The isolates showed severe pathogenicity on miniature rose. Seven days after inoculation, the leaves showed both chlorosis and necrosis. No symptoms were observed in the controls. The plants inoculated had 100% disease incidence, and all isolates showed severe pathogenicity. The same isolates were consistently re-isolated from the diseased roots.

Pythium helicoides was not isolated from the soil outside the greenhouse used for potted rose production.

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Pythium helicoides was not isolated from the soil outside the greenhouse used for potted rose production.

Energy Savings in Cutting Propagation Using a Floating System

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INTRODUCTION

The mist propagation system is very popular for the production of nursery stock, however, the maintenance of the water and electricity supplies and clean misting nozzles is very important. This report gives the results in energy savings of a trial of cutting propagation using a floating garden.

MATERIALS AND METHODS

A floating box with small holes in the bottom was filled with cutting compost and placed on the surface of a small pool. After setting the cuttings in the box, no overhead watering was given during the entire experimental period of three months. *Dendranthema, Luculia, Daphne, Rhodotypos, Camellia sasanqua,* and *C. japonica* were used for this experiment. After 2 months and 3 months from setting, the rooting frequency was recorded for about 20 cuttings from the floating and 10 cuttings from the control plot (a conventional cutting bed with overhead irrigation).

RESULTS AND DISCUSSION

Dendranthema, Luculia, and *Daphne* showed similar rooting frequencies after 2 or 3 months (Table 1). However, *Rhodotypos* showed no difference in either plot. *Camellia sasanqua* and *C. japonica* showed higher frequency of rooting in the control plot. So, the adaptability of the floating method of cutting production is limited to certain plants.This method would be useful for a small-scale propagation unit without any misting equipment.

Table 1. Rooting frequency in a floating propagation system.

	Rooting at 2 months (%)		Rooting in 3 months (%)	
Plant	Floating	Control	Floating	Control
Dendranthema	100	100	100	100
Daphne	100	100	100	100
Luculia	65	75	100	100
Rhodotypos	89	33	50	67
Camellia sasanqua	21	100	54	100
C. japonica	17	60	9	57

The Effect of Interstocks on the Growth and Productivity of the Japanese Persimmon Cultivar Maekawa-jiro

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INTRODUCTION

The cultivation of Japanese persimmons is a high-cost and labor-intensive undertaking because of the large size of the trees. Dwarfing the trees will reduce labor costs and the use of dwarfing rootstocks is one method employed. Much research has been done on dwarfing rootstocks and the results have been published. In this paper, we will report on the dwarfing of Japanese persimmons using interstocks.

MATERIALS AND METHODS

Japanese persimmon cultivars Shidaregaki, Nishimura-wase, Shakokushi, Fudegaki, and Maekawa-jiro were used as interstocks. In 1984, interstocks of each cultivar were grafted onto seedlings of 'Fuyu'. In 1985, shoots of these interstocks were cut to 40 cm in height and 'Maekawa-jiro' was grafted onto the interstocks.

RESULTS AND DISCUSSION

The trunk girth of scions on 'Shidaregaki', 'Nishimura-wase', and 'Shakokushi' was 80% of the control 'Maekawa-jiro'. The height of 12-year-old trees was 2.6 to 3 m when 'Shidaregaki', 'Nishimura-wase', and 'Shakokushi' were used as interstocks and the area and volume of the tree canopy was 70% of the control cultivar. These interstocks, therefore, have a dwarfing effect and this effect was evident 5 years after grafting and increased in proportion to the age of the tree.

The productivity of the trees using 'Fudegaki' was the highest and that of 'Shidaregaki', 'Nishimura-wase', and 'Shakokushi' was 65% to 75% of the 'Maekawa-jiro' control, however, production per area of tree canopy was 110% to 120% of the control cultivar for trees on 'Shidaregaki' and 'Nishimura-wase'. There was no difference in harvesting time.

From these results, we decided that 'Shidaregaki' and 'Nishimura-wase' were good for use as dwarfing interstocks because the trees on these interstocks had reduced trunk girth, tree height, and volume of tree canopy as well as increased productivity.

Enhanced Growth of Arbuscular Mycorrhizal Fungus-inoculated Celery Seedlings Transplanted to a Field

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Celery (*Apium graveolens* L Cornell no. 619) seedlings inoculated with arbuscular mycorrhizal (AM) fungus [*Glomus etunicatum* Becker and Gerdemann (GE), *Glomus intraradices* Schenck and Smith (GI), and *Gigaspora margarita* Becker and Hall (GM)] were transplanted to a field in order to test the promotive effect of AM fungus infection on the growth of celery.

Arbuscular mycorrhizal fungus-inoculated plants growing in a greenhouse for 8 weeks were superior to non-inoculated plants in height, leaf (blade and petiole), and root dry weights in each fungus species. The AM fungus infection level of the root systems differed among AM fungus species (Table 1).

Table 1. Effect of arbuscular mycorrhizal (AM) fungus inoculation on greenhouse growth of celery (Cornell no. 619) seedlings[z].

AM fungus inoculation[y]	Plant height (cm)	No. of leaves	Dry weight of leaves (g)	Dry weight of roots (g)	RFIPR[x] (%)
None	12.5 a[w]	8.0 a	1.52 a	0.41 a	0
Glomus etunicatum	17.0 bc	9.3 a	2.08 c	0.93 c	30.4 b
G. intraradices	15.3 b	9.0 a	1.87 b	0.66 b	24.0 a
Gigaspora margarita	18.3 c	8.9 a	1.89 b	0.70 b	37.2 c

[z]Data were obtained from 10 plants at 8 weeks after inoculation.
[y]None, non-inoculated; *G. etunicatum* and *G. intraradices*, inoculated at 1000 spores g^{-1} inoculum; *G. margarita*, inoculated at 100 spores g^{-1} inoculum.
[x]Rate of AM fungus-infected portions in a whole root system (evaluated by the gridline intersection method).
[w]Mean separation within Columns by Duncan's multiple range test, 5% level.

After 10 weeks of field growth (at harvest time), GE- or GM-inoculated plants gave greater values in plant height, number of leaves, maximum length of leaves, length of first internode, and fresh weight of leaves. GI-inoculated and non-inoculated plants gave similar values on the items listed above. The AM fungus infection level in a whole root system rose higher in both GE- or GM-inoculated plants than in GI-inoculated ones (Table 2).

Table 2. Effect of arbuscular mycorrhizal (AM) fungus inoculation on field growth of celery (Cornell no. 619) plants[z].

AM Fungus inoculation[y]	Plant height (cm)	No. of leaves	Length of largest leaves (cm)	Length of 1st internode (cm)	Fresh weight of leaves (g)	RFIPR[x] (%)
None	52.0 a[w]	13.3 a	49.8 a	20.0 a	586.7 a	5.7 a
Glomus etunicatum	60.8 b	16.6 b	55.8 b	26.3 c	915.7 c	35.6 c
G. intraradices	53.4 a	13.4 a	50.5 a	20.4 a	602.9 ab	30.1 b
Gigaspora margarita	59.6 b	15.5 b	54.7 b	23.5 b	736.8 b	40.2 c

[z]Data were expressed oil the basis of 10 plants 10 weeks after transplanting
[y]None, non-inoculated; *G. etunicatum* and *G. intraradices*, inoculated at 1000 spores g^{-1} inoculum; *G. margarita*, inoculated at 100 spores g^{-1} inoculum.
[x]Rate of AM fungus-infected portions in a whole root system (evaluated by the gridline intersection method).
[w]Mean separation Within Columns by Duncan's multiple range test, 5% level.

The analysis of mineral nutrients (N, P, K, Ca, and Mg), in the harvested leaves of celery showed only a little difference among the treatments in concentrations of the mineral nutrients (Table 3).

It was clear that growth enhancement through symbiosis occurred in AM fungus-inoculated field-grown celery seedlings.

Table 3. Effect of arbuscular mycorrhizal (AM) fungus inoculation on mineral nutrient concentrations in harvested leaves of celery (Cornell no. 619)[z].

AM fungus inoculation[y]	Mineral nutrient concentration in leaves (% D.W.) N	P	K	Ca	Mg
None	3.15 a[x]	0.40 a	4.42 a	1.25 a	0.34 a
Glomus etunicatum	2.99 b	0.35 a	4.74 c	1.24 a	0.29 b
G. intraradices	3.04 b	0.39 a	4.39 a	1.28 a	0.36 a
Gigaspora margarita	3.11 a	0.38 a	4.56 b	1.56 b	0.28 b

[z]Data were expressed oil the basis of 10 plants 10 weeks after transplanting
[y]None, non-inoculated; *G. etunicatum* and *G. intraradices*, inoculated at 1000 spores g^{-1} inoculum; *G. margarita*, inoculated at 100 spores g^{-1} inoculum.
[w]Mean separation Within Columns by Duncan's multiple range test, 5% level.

The Effects of the Physical and Chemical Properties of the Growing Media on the Rooting and Growth of Herbaceous Plant Cuttings in Cell Tray Culture

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Though many media for cell-tray culture are now available, the physical and chemical properties of these media are not known and their effects on the rooting and growth of cuttings is not clear.

For this research we made nine media (Table 1) with three percentage air space levels at pF1.0 water tension and three levels of NO_3-N. The minimum concentrations of phosphorus and potassium in the nine media were adjusted to 60 mg 100 g^{-1} and 100 mg 100 g^{-1}, respectively, by the addition of super-phosphate and potassium sulphate.

Thirty stem cuttings of *Campanula* 'Alpine Blue', *Petunia* 'Million Bells', *Impatiens* New guinea hybrid 'Prepona', and *Mentha spicata* (syn. *M. viridis*) were taken on 27 May 1998, set in a 128-cell (five plants of each in each medium), cell tray and the rooting rate, root length, plant height, and fresh weight of the whole plants were recorded on 20 June 1998.

Table 1. Air space percent and NO_3-N concentration in the media.

Media	1	2	3	4	5	6	7	8	9
Air space	63	63	63	79	79	79	105	105	105
NO_3-N (mg 100 g^{-1})	31	58	75	31	58	75	31	58	75

Table 2. Effect of air space in the media on the growth of cuttings.

	Air space(%)	*Petunia*	*Impatiens*	*Mentha*
	6.3	0.25	2.11	0.87
Fresh weight (g)	7.9	0.23	2.39	1.36
	10.5	0.23	2.46	1.55
	6.3	3.09	3.08	7.16
Plant height (cm)	7.9	3.15	2.82	8.09
	10.5	2.54	3.01	11.74
	6.3	8.69	3.97	11.12
Root length (cm)	7.5	7.92	4.03	10.88
	10.5	12.10	3.93	12.41

Table 3. Effect of NO_3-N concentration in the media on the growth of cuttings.

	NO_3-N (mg 100 g^{-1})	*Petunia*	*Impatiens*	*Mentha*
Fresh weight (g)	31	0.22	1.99	1.47
	58	0.28	2.36	1.22
	75	0.20	2.61	2.07
Plant height (cm)	31	2.77	2.79	10.31
	58	3.27	2.84	9.71
	75	2.85	3.25	8.21
Root length (cm)	31	10.25	3.99	11.80
	58	10.10	3.61	10.38
	75	8.35	4.33	12.13

Of the three air-space levels of the media, the fresh weight of *Impatiens* and *M. spicata* were highest in the medium containing 10.5% water. The fresh weight of *Petunia* was almost the same in all water content levels, however, root length was significantly longer in the medium with 10.5% air space. Growth and rooting of all plants was significantly lower in media with 6.3% air space. These results suggest that a 6.3% water content, namely, 6.3% air space at pF1.0 water tension is not sufficient for the rooting and growth of the cuttings, but more than 10.5% air space is sufficient.

In the three NO_3-N concentration levels the fresh weight of *Impatiens* and *M. spicata* was largest in 75 mg 100 g^{-1} and smallest in 31 mg 100 m g^{-1} and 58 mg 100 g^{-1}, respectively. The root lengths of *Petunia* showed no significant difference in any of the three NO_3-N levels.

An interactive effect on the fresh weight of the plants was recognized between the water content levels and the NO_3-N levels in the media, i.e, the weight of *Petunia* was highest with a 10.5% air space and 58 mg 100 g^{-1} NO_3-N, while *Impatiens* and *M. spicata* were largest with a 10.5% air space and 75 mg 100 g^{-1} NO_3-N.

These results indicate that the medium containing about 10% air space at pF1.0 water tension with 75 mg 100 g^{-1} NO_3-N is effective for rooting cuttings of herbaceous plants, however, the mortality rate of *Campanula* was extremely high in all media, so more tests using other species are required to produce a medium suitable for general use.

The Effect of a Photoperiod on the Flower Bud Development of *Spinacia oleracea* Seedlings Produced Under Artificial Light

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INTRODUCTION

In general, long days cause spinach plants to develop flower buds, to elongate the stem (i.e., bolt), and to flower, all of which are detrimental to production in summer. In this study, the effect of a photoperiod on the flower bud development of *Spinacia oleracea* L. seedlings produced under artificial lighting conditions, was investigated.

MATERIALS AND METHODS

Five seeds of *S. oleracea* 'Dimple' were sown in each hole of trays (144 holes per tray, 30 × 60 cm, Taiyo Kogyo Co., Ltd., Japan) filled with granules of rock wool (Taiyo Kogyo Co., Ltd., Japan). They were cultured in three growth chambers (Koitotron 3HN-35MLA, Koito Industries, Ltd., Japan), each had a microwave powered lamp as the lighting source. Photoperiods were 8/16h (Treatment 8H), 12/12h (Treatment 12H), and 16/8h (Treatment 16H), respectively. The photosynthetic photon flux density (PPFD) on the surface of the trays was 350 ±50m mol m^{-2} s^{-1}. Temperature and relative humidity in each growth chamber were set at 20C and 70%, respectively. Twenty days after sowing, the seedlings were sampled destructively to examine flower bud development and to determine the maximum leaf length and shoot and root fresh masses.

Table 1. Effect of photoperiod on flower bud development of *Spinacia oleracea* seedlings 20 days after sowing.

	Number of seedlings at each stage of flower bud development			
Treatment code	No differentiation*	Flower cluster initiation	Flower cluster differentiation	Flower cluster formation
8H	0	4	1	0
12H	0	1	4	0
16H	0	0	0	5

*Five seedlings were sampled from each treatment.

RESULTS AND DISCUSSION

In the 8H and 12H treatments, the growing points were between the flower cluster initiation and flower cluster differentiation stages. The flower cluster initiation stage was dominant in treatment 8H and the flower cluster differentiation stage was dominant in treatment 12H. In treatment 16H, aII of the growing points formed flower clusters (Table 1). All of the seedlings bolted in treatment 16H. The leaf length, root length, and shoot fresh mass were not significantly different among the treatments, while the shoot fresh weight and shoot and root dry weight were greater in treatment 16H than those in treatments 8H and 12H.

In conclusion, the short photoperiod treatment retarded flower bud development of *S. oleracea* seedlings. This result could be beneficial when producing seedlings for transplanting, with the aid of artificial light.

The Growth and Development of Cut-flower Rose Cultivars in Shoot-Tip Culture

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The shoot-tip culture and propagation in vitro of roses for cut-flower production was developed in order to test their resistance to crown gall. Terminal buds were taken from the shoots after they had grown 1 cm following flower harvest. These buds grew well and culturing in May was found to be the most suitable season for *Rosa* 'Carl Red'. After the in vitro culturing of 25 cut-flower cultivars, MS medium containing BAP and GA_3 was found to give the best results. The most suitable medium for maximum viability, leaf number, lateral shoots, and maximum shoot length was in most cases the same one for a given cultivar.

INTRODUCTION

The selection of resistant rose cultivars to crown gall disease by in vivo inoculation has been reported on (Boelema, 1969; Ohta, 1993). However, climate, soil conditions and plant growth affect this method.

Recently, tissue culture techniques have been applied to plant breeding (Toyoda et al., 1989; Isizawa et al., 1992; Chatani et al., 1996).

We have developed an in vitro inoculation method for testing the resistance of roses to crown gall disease (Zhou et al., 1996). For this method, culturing and propagating plant cultivars in vitro is important. Therefore, we have propagated 20 types of rose

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rootstocks by shoot-tip culture and the propagation of these rootstocks has been standardised (Zhou et al., 1997). In this paper, we report on the multiplication of 25 cut-flower rose cultivars and their growth and development in shoot tip culture.

MATERIALS AND METHODS

Experiment 1: The Collection Season, Method of Shoot-Tip Use and Selection of the Medium. The cut-rose cultivar *Rosa* 'Carl Red', grown in the greenhouses of Gifu Takahashi Rose Garden Ltd., in Gifu City, Japan, was used in this experiment.

1) The 2nd, 3rd, 5th, and 7th nodal segments with an axillary bud were excised from the flowering shoots.
2) When the bud from below the cut had grown 1 cm, the segment with a terminal bud was cut off.
3) When the shoot from below the cut had grown 3 cm, the segments with a terminal bud and an axillary bud were cut off. These segments with shoot tips were surface sterilized for 10 min in a 1% (v/v) sodium hypochlorite solution containing 0.01% (v/v) Tween-20 and rinsed three times with sterile distilled water. Under sterile conditions, the shoot tips (1 mm) were cut out from these shoot segments, and put into Murashige and Skoog (MS) medium containing 3% sucrose and 0.2% Gelrite.

Factorial combinations of three gibberellic acid (GA_3) concentrations (0,0.1 μM and 1.0 μM) and three 6-benzylaminopurine (BAP) concentrations (0.1 μM, 1.0 μM, and 10 μM) were used, giving nine treatments. The pH of each medium was adjusted to 5.7 with 0.1 N NaOH and HCl before the addition of Gelrite. The medium was then autoclaved at 120C for 15 min. The cultures were kept at 25C with a 16-h light period for 6 weeks. This experiment was repeated three times, in May and Sept. 1993 and in Jan. 1994.

Experiment 2: The Growth Habit of the Cultivars. Twenty-five cultivars of cut-flower rose cultivars that had been grown in greenhouses in Godo Town in Gifu Prefecture were used in this experiment. In May 1994, the shoot tips were excised from the 5th segments on the flowering shoots and put into MS medium containing 3% sucrose, 0.2% Gelrite, and 10 μM BAP. Two GA_3 concentrations were used, 0.1 and 1.0 μM. The pH of each medium was adjusted to 5.7 with 0.1 N NaOH and HCl before the addition of Gelrite. All media were autoclaved at 120C for 15 min.

RESULTS

Table 1. Growth of shoot-tip cultures by different culture season.

	Culture date		
	September	January	May
Survival rate	70	67	78
Leaves number	0.4	0.3	0.8
Leaves length (mm)	10.5	9.3	11.9

Table 2. Growth of shoot-tip cultures from different bud positions.

	Axillary buds of different node-order on flowering shoots				Elongated shoots (1 cm) after harvesting	Elongated shoots (3 cm) after harvesting	
	2nd	3rd	5th	7th	terminal bud	terminal bud	axillary bud
Survival rate (%)	73	69	78	76	86	70	60
Leaves number	0.2	0.2	0.3	0.3	0.9	0.4	0.4
Leaves length (mm)	11.0	12.2	9.5	10.5	12.3	10.7	9.3

Table 3. Effect of different concentrations of BAP and GA_3 on the growth of shoot tip cultures.

	BAP (μM)			GA_3 (μM)		
	0.1	1.0	1 0	0	0.1	1.0
Survival rate (%)	57	68	93	81	75	65
Leaves (number)	0.6	0.4	0.1	0.3	0.4	0.4
Leaves length (mm)	12.3	9.5	7.0	10.0	12.0	11.0

Experiment 1. For all buds, the growth and development of shoot tips cultured in May were better than those cultured in September and January. The survival rate of shoot tips cultured in May was highest at 78%, whereas the survival rates for September and January were 67% and 70%, respectively (Table 1). The elongation of shoot tips was not found on any cultures. All cultures had induced leaves and the length of these leaves was about 10 mm. The growth of shoot tips collected from different positions is given in Table 2. The terminal buds that had been cut out from the elongated shoots (1 cm) after flower harvest, grew well on all media, with a survival rate of 86%, the leaves were 12.3 mm long and the average leaf number per plantlet was 0.9. The shoot tips excised from axillary buds on the elongated shoots (3 cm) after flower harvest had a survival rate of 60% and a 9.3 mm leaf length. For the flowering shoots, the lateral buds from the upper two segments grew better than those from the lower two segments. Table 3 shows the growth and development of cultures in media containing different concentrations of BAP and GA_3. The viability was high, with 93% survival rate on the media containing 10 μM BAP, but viability was only 57% on media containing 0.1 μM BAP. On media without GA_3, the viability was high (81%), and as the GA_3 concentration increased the viability dropped. The leaf number and the maximum leaf length were no different among media containing different concentrations of GA_3, but they were affected by BAP concentrations. On media containing 0.1 μM BAP, the mean leaf number was 0.6 and the maximum leaf length was 12.3 mm, but these were lower on the other media.

Experiment 2. In primary culture, the shoot tips of 20 cultivars had high viability (over 90%), while 5 cultivars had a viability of 70% to 85%.

Leaves were induced on all of the cultivars. Two or more leaves were produced on 10 of the cultivars. The shoot tips of 60% of all cultivars had elongated and those of 36% had developed lateral shoots. After the third subculture, all of the cultivars were growing well and the growth and development habit of those cultivars was steady. Among the hybrid tea cultivars, 14 had long shoots (10 to17 mm), while the four miniature rose cultivars had shoot lengths under 10 mm. Most cultivars had 10 to 25 leaves, but 'Bekola', Aalsmeer Gold® rose; 'Kardinal', Kardinal® rose; 'Meikola' Livia™ rose; and 'Meihaitoil', Concerto® rose had under 10 leaves. 'Kawamoblue', Purple Rain® rose, and 'Intermoto', Joy® rose had more than three lateral shoots, but Aalsmeer Gold® rose and Kardinal® rose had only 1.4 lateral shoots. The MS medium with BAP and GA_3 was suitable for the shoot tip culture of these cut-flower rose cultivars (Table 3). The most suitable medium for the

maximum viability, leaf number, lateral shoot number, and shoot length was the same in most cases for a given cultivar, but differed between cultivars.

DISCUSSION

From our experiments, it is clear that the position of the buds and their season of collection affect the growth and development of cultures in vitro.

Normally, roses grown in greenhouses during summer became dormant because their growth and development was affected by high air temperatures.

After the plants resumed growth in September, their vitality was lower. In winter, the intensity of solar radiation is lower and the photoperiod is shorter and so the growth of plants is inhibited, leading to dormancy.

For this reason, the growth and development of these shoot tips was inhibited after they were cultured in vitro. However, in May the growth and development of the plants was active and shoot tip vitality high.

For buds taken from different positions, the growth and development in vitro is different. Bressan et al. (1982) reported that the shoot apex of a rose stem functions to regulate the growth and development of the lateral buds subjacent to it even after those buds have been cultured in vitro. From our results it was also observed that the shoot apexes, on the 1-cm and 3-cm shoots that formed after flower harvest, showed high viability, with more and longer leaves. These shoot apexes developed more rapidly than lateral buds subjacent on the elongated 3-cm shoot. The regulatory effect of the shoot apex has been described (Zieslin et al., 1976, 1978) and it is thought that this apical dominance is the result of a number of inhibitors, including auxin and abscisic acid (Zieslin et al., 1978). The MS media used in this experiment was without auxin and abscisic acid.

Therefore, our interpretation is that the buds on the shoots contained different levels of these inhibitors. The buds in acropetal and basipetal positions on the stem were the most inhibited, while those from the middle section of the stem developed most rapidly. The inhibition of development of buds obtained from nodes at the base of the stem may be due to the proximity of these buds to the main stem or trunk of the rose. These buds are under the control of the shoot apex of the main stem (Bressan et al.,1982). In our experiment, the buds in the 2nd, 3rd, 5th, and 7th segments were used, but the uppermost buds were not used, because they are very small.

The results showed that the buds in the basipetal position grew the slowest, while the buds in 7th and 5th sections, those in the middle of the flowering shoot, grew well.

Rout et al. (1989) reported that the growth and development of cultures in vitro of *R.* 'Landorain' were the best on an MS medium with BAP and GA_3. Our experimental results also showed that MS media with BAP and GA_3 was suitable for the shoot-tip culture of these rose cultivars. The most suitable medium for the maximum viability, number of leaves, number of lateral shoots per plantlet, and the maximum shoot length, was in most cases the same one for a given cultivar, but it was different between the cultivars. For some cultivars, the most suitable medium for shoot elongation was different than that for the formation of leaves and lateral shoots. The growth of shoot tips in vitro is different because of the physiological and genetic differences of different rose cultivars (Cai et al., 1984). Our interpretation is that this different reaction to BAP and GA_3 may be due to the special physiological and genetic characteristics of these cultivars.

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Plant Regeneration from Protoplasts Derived from Callus of *Phalaenopsis* Alliance

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Plant regeneration from protoplasts of orchids was very difficult and only succeeded when callus of *Phalaenopsis* was used. On a previous occasion, we reported the efficient isolation and refinement of protoplasts derived from callus, here we examine the cultural requirements.

MATERIALS AND METHODS

Callus of *Phalaenopsis* 'Hanaboushi' × *P. equestris* 'Ilocos' cultured on new phalaenopsis medium (NP) supplemented with coconut water (CW) and sucrose for 4 to 8 weeks was used. Callus which was precultured on NP medium (without CW and sucrose) for 3 weeks was soaked in an enzyme solution and shaken for 1.5 h at 25C on a reciprocal shaker (77 strokes min^{-1}) under reduced light. The enzyme-protoplast mixture, to which was added a washing solution, was filtered through a stainless sieve of 66-mm pore size to remove undigested cell clumps and centrifuged at 100 × g for 5 min. Then the sediment, to which was added fresh washing solution was mixed with ficoll solution and overlayed with washing solution. Next they were centrifuged at 230 × g for 30 min. After centrifuging, the layer of protoplasts in the washing solution was withdrawn with a pipette and washed in washing solution. After washing, the culture medium was added to the protoplast solution and centrifuged at 100 × g for 5 min. Finally, the protoplast solution, with fresh medium added to the sediment, was transferred into a 35-mm plastic dish and cultured at 25C in the dark. The medium was supplemented with 0.3 M sucrose, sorbitol, and maltose in order to examine the effect of osmoticum on the rate of survival of the protoplasts and their rate of division.

RESULTS AND DISCUSSION

The rate of survival was highest when supplemented with sorbitol and the survival rate was 80% at 1 week and 60% at 4 weeks. The next highest survival rates were those with the maltose. Cell division was observed in all supplemented media after 1 week of culture. The rate of division after 4 weeks of culture was highest in the sucrose-supplemented medium, but it did not lead to colony formation. In the sorbitol- and maltose-supplemented media, colony formation and plant regeneration occurred. The rate of division with maltose was higher than that with sorbitol, however, the quantity of protoplasts was higher with sorbitol.

The above result showed that sorbitol was suitable for the culture of protoplasts as osmoticum.

The Root Production Method (RPM) System for Producing Container Trees

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INTRODUCTION

The RPM system (root production method) is a multi-step system of producing container tree seedlings that places primary emphasis on the root system — which ultimately determines the trees survival and performance in the environment it is transplanted into. This particular container production system has been developed to facilitate mass production of high quality seedling trees with an optimum height-caliper balance. Approximately 80% of our production consists of native trees, many of which have transplanting problems using conventional nursery growing systems. We specialize in *Quercus* (oak) production and currently grow 26 taxa.

SEED SELECTION, COLLECTING, PROCESSING, AND GRADING QUALITY SEED

This is accomplished by selecting superior trees growing on specific sites for seed collection. Experience has taught us that most species have ecotypes that are site specific. We look towards the wetlands or floodplains as a prime seed source for native species that are found growing on both wetland and upland sites. Since they have evolved under stress, we find these ecotypes will consistently out perform their upland counterparts on virtually any site — particularly on highly stressed sites.

Step 1: Processing. After basic cleaning and drying procedures are completed, all seed are graded and sized using aspirators or gravity tables. We find the weight of individual seed to be more important than size. Hence, machines that grade seeds based on specific gravity via air separation give optimal results. This initial step grading seed is of great importance to our subsequent production steps to produce uniformity.

Step 2: Seeding, Timing, Stratification, and First Root Pruning. Seed are placed in a bottomless mesh flat measuring 47 cm × 37 cm × 6 cm (18.5 inches × 14.5 inches × 2.5 inches) with a mesh spacing of 1 cm (⅜ inch). Our standard growing medium consists of composted rice hulls, pine bark, and sand (4 : 4 : 2, by volume), plus slow release fertilizer, micronutrients, and a wetting agent. The medium is also inoculated with mycorrhizal spores. The air space of the medium is of utmost importance in this step. Our medium mix has 35% to 40% air space. Seeded flats requiring stratification are stacked on pallets, wrapped in polyethylene, and placed in cold storage at 1C (34F).

The timing for sufficient stratification is critical since our production system requires moving the seeded, stratified flats to heated greenhouses by 1 Feb. so that seed germination can be initiated. As the seeds germinate, their tap roots penetrate the bottom of the flats and are air-pruned. This allows a more fibrous root system to develop. The grading, selection, and transplanting of the seedlings is done by 1 March. The purpose of shallow root pruning into medium with an approximate depth of 3.8 to 5 cm (1.5 to 2 inches) is to force first lateral roots to develop higher

on the root collar, or crown of the seedling. Since most tree roots grow within the first 30 cm (12 inches) of the soil surface, we find this technique beneficial to all our species. This is of extreme importance for wetland plantings where the lack of air in the soil (anaerobic conditions) becomes a critical limiting factor in survival and future growth. This also allows more even distribution of roots of the containerized seedlings, which is one of the prime objectives of our shallow root-pruning process.

Step 3: Grading, Selection, and Transplanting to Bottomless Band Containers. By 1 March when the tree seedlings have made their initial first flush of growth, the seedlings are transplanted to a plastic square bottomless band container. The band container consists of a standard plastic bottomless liner pot measuring 7.3 cm × 7.3 cm × 14 cm (2.9 inches × 2.9 inches × 5.5 inches), which has been modified and reduced to 9.5 cm (3.75 inches) in depth. Plants are carefully graded and selected at this time. Particular attention is given to height, caliper, and root development. On most species the top 50% are used and the remainder are culled and discarded. The shallower liner pots gives us comparable growth, and improves the root distribution in the production container, including better lateral root distribution higher up in the root collar or crown of the seedling. Transplanted seedling bands are placed on bottomless benches for approximately 60 days. This allows additional air pruning of the secondary lateral roots, further enhancing development of a shallow root system. These first two steps are timed so the bands or liner pots are ready to go outside to the container production area by 1 May, thus avoiding any late frosts and freezes.

Step 4: Hardening-off, Canning, and Growing On. Flats holding 36 tree bands are moved from greenhouses on 1.2 m × 1.8 m (4 ft × 6 ft) pallets and placed outdoors in full sun for hardening-off for 48 h. During the hardening-off period the liners are intermittently misted to relieve stress. After 2 days (48 h) the pallets are moved to container production areas where they are dibbled into larger, existing pre-filled containers. A shallow growing container is preferred, realizing that most of the feeder roots will always remain in the upper 15 to 20 cm (6 to 8 inches) of soil after the tree is outplanted. Our standard growing container is a squat container measuring 25 cm (10 inches) across and 18 cm (7 inches) in depth. The 9.5-liters (2.5-gal) container allows more root mass to develop laterally. This system allows us to produce most native species to a marketable size in one growing season, or approximately 210 days from germination.

SUMMARY

The RPM system is a multi-step seedling production program for producing superior container-grown liners of uniform grade and quality. The two phases of air root pruning, along with careful production planning are the critical components of the RPM system. Air pruning of roots at a shallow depth stimulates initiation and growth of more feeder roots higher on the root collar or seedling crown. This allows for better aeration of the root system, faster growth, and near perfect survival after transplanting to final growing sites. The root system of the RPM-produced trees allow for greater tolerance to wet, low-oxygen transplanting sites. Seedlings produced with the RPM system also have more uniform top growth. Uniformity of both the shoot and root system is important in plantings where uniform plant size is required. Seedlings provide a broad genetic base which will insure longevity and protection against diseases and conditions that might occur with certain clonal, asexually produced and other overused seedling produced taxa.

Top Ten Points of Plant Propagation

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INTRODUCTION

Plants, like everything else, require energy. However, plants are self-sufficient and their energy comes from the complex process of photosynthesis which produces carbohydrates. Just as an automobile cannot run without energy from gasoline, neither can a plant "run" unless the energy products produced by photosynthesis are present to support cell division needed to initiate and develop plant parts. Anything we can do as plant propagators and producers, to assist in the energy and related hormonal output of the leaves and buds, helps improve the physiological condition of plant tissues, which is important for rooting of cuttings and subsequent liner plant growth.

Many things have changed since I stuck my first grape cuttings over 40 years ago.

I have had the opportunity of instigating, testing, and/or refining many of the newer procedures. The following 10 points are a reminder of important factors involved in plant propagation.

TEN BASIC FACTORS

1) Increased Light Intensity Generally Improves Rooting, Plant Growth, and Minimizes Production Problems. Cell division requires energy; the more energy, the more rapid root growth occurs. The leaves of cuttings will also make the transition from higher light during propagation to full sun with less stress (Hall and Whitcomb, 1974; Whitcomb, 1978; Whitcomb, 1984). By creating an environment with high light intensity and moderate temperatures, I was able to root, for the first time, cuttings of redbud (*Cercis canadensis)* and sugar maple (*Acer saccharum*) (Whitcomb, 1997).

2) Adding Modest Levels of Slow-release Nutrients during Propagation Aids Root Development and Subsequent Liner Plant Growth. As soon as a new root starts to emerge from the base of the cutting, it can absorb nutrients to support leaf functions and energy production via photosynthesis. With some species, growth of the rooted liner is enhanced by slow-release fertilizers (Carney and Whitcomb, 1983; Diver and Whitcomb, 1981; Hathaway and Whitcomb, 1977; Murray and Whitcomb, 1973; Whitcomb et al., 1978). With others species, both rooting percent and subsequent root growth is improved. My first study of this procedure was in 1970. The response of cuttings to slow-release fertilization was especially dramatic, since the general nutritional conditions of the parent plants were poor, relative to today's recommended nutritional levels (Whitcomb, 1978). It took many years before this practice become standard among many propagators. This is but one more benefit from modern slow-release fertilizers.

3) Direct Sticking of Cuttings Helps Improve Performance and Reduce Transplanting. Direct sticking (direct rooting) cuttings into smaller liner pots helps eliminate root loss and minimize shock at transplanting. Direct sticking reduces the number of plants produced per square foot compared to the propagation

of multi-cuttings in community rooting flats (trays). However, the yield of good quality cuttings with better performance after transplanting is generally much higher per square foot (Bean and Whitcomb, 1973; Bisher and Whitcomb, 1975; Hickman et al.,1982). My first experiments into this began in 1969. Benefits were modest during the early years, but when combined with other factors noted in this paper, the benefits soared.

A major problem with direct sticking still exists today. Many nurserymen fail to move the rooted cuttings from the smaller liner containers in a timely fashion. The "root-bound" problem of overgrown liner plants can be severe and can stress the plant during production and later transplanting into a landscape site (Bean and Whitcomb, 1975; Bowlin and Whitcomb, 1980; Richards and Whitcomb, 1980; Threadgill and Whitcomb, 1982; Threadgill et al., 1985; Whitcomb, 1974; Whitcomb, 1978). The production focus should be on shifting the rooted liner as quickly as possible into a larger container, not how long the rooted cutting can be held in propagation.

4) Proper Care and Nutrition of the Stock/Mother Plants Plays a Big Role in Cutting Success. The physiological conditions inside the cutting can be enhanced by proper nutrition. Excess nitrogen, proportionate to other nutrients, can suppress rooting as tissues are succulent with lower energy reserves. On the other hand, the more ideal the synchronization of all essential nutrient elements, the greater stored energy levels and the greater the natural branching and growth of the resulting young liner plant (Davis and Whitcomb, 1975; Hickman et al., 1982; Ward and Whitcomb, 1979; Whitcomb, 1973; Whitcomb, 1977; Whitcomb, 1978; Whitcomb, 1981; Whitcomb et al., 1981; Whitcomb, 1992).

5) Rooting with Softwood Cuttings, Rather than Semihardwood or Hardwood Cuttings Often Improves Plant Performance. As mist systems, timers, and management of plant nutrition have improved, the success with propagating softwood cuttings has increased (Bisher and Whitcomb, 1975; Glenn et al., 1976; Hall and Whitcomb, 1974; Murray and Whitcomb, 1973; Whitcomb and Davis, 1970; Whitcomb, 1983; Whitcomb, 1985). With softwood cuttings, rooting hormones are being produced naturally by the growing tip and generally exogenous auxins are not needed, or are applied in lower concentrations (Glenn et al., 1976). When the optimum combination of rooting environment and tissue condition occurs, the cutting can root with less stress and without a reduction in the growth of the terminal bud (Hickman et al., 1982; Whitcomb, 1975; Whitcomb, 1977; Whitcomb, 1984). The result is a vigorous plant with natural branching and reduced need for pruning or training. As an example, for years crapemyrtle (*Lagerstroemia indica*) was propagated from hardwood cuttings taken in winter. The resulting plants would struggle to fill a 1-gal container during a growing season. Today, softwood cuttings taken in late May yield full plants in 1-gal containers by early September (Whitcomb, 1978).

6) Deeper Pots Allow for Better Drainage. There is always a saturated zone in the bottom of a container. Because of the textural difference between the propagation medium and the open drain hole, a perched water table occurs and some water is always retained against gravity at the bottom, even with a very porous mix. If the base of the cutting is in or near the saturated zone where anaerobic conditions can occur, the likelihood of rooting is low and incidence of root rot diseases is high

(Whitcomb, 1978). Pots only slightly deeper reduce this problem (Bisher and Whitcomb, 1975; Bowlin and Whitcomb, 1980; Hathaway and Whitcomb, 1977; Threadgill and Whitcomb, 1982; Threadgill et al., 1985; Whitcomb, 1974).

It has been known for many years that oxygen/aeration in the medium is necessary for rooting. Experiences over many years has lead me to conclude that the amount of oxygen/aeration necessary for root initiation is much higher than for normal root function of the same plant at a later stage of development (Whitcomb 1978). This knowledge applies not only to the rooting of cuttings but to transplant success in many landscape settings with poor soil aeration, especially with B&B and bareroot stock.

7) Water Chemistry Affects Rooting. The purer the water, the better it is for mist propagation. Minerals dissolved in the water used for intermittent mist accumulate on leaf, stem, and bud surfaces with each mist cycle (Whitcomb, 1978). Minerals also accumulate in the rooting medium. For years I heard nurserymen relate problems of propagation. One would have a problem with species X, but not Y, while another would have problems with species Y, but not X. Eventually these comments led to a study where cuttings were taken from a large block of stock plants and divided and transported to four locations with different water sources, where water was the main variable. The cuttings did root differently at the different sites. This led to a series of studies on how water chemistry affects plants (Whitcomb, 1985; Whitcomb, 1988; Whitcomb 1991).

8) Timing — The Perpetual Challenge of When to Take Cuttings. Conditions in plant tissues can change rapidly with physiological development and fluctuating environmental conditions (Davis and Whitcomb, 1975; Hall and Whitcomb, 1974: Hathaway and Whitcomb, 1977; Hickman et al., 1982; Whitcomb, 1977; Whitcomb, 1997). For example: lilacs (*Syringa*) and several tree species have a very narrow window where cuttings root quickly and with high success. Cuttings taken earlier or later may not root at all. Environmental conditions can also change abruptly. For example, in North Central Oklahoma in May 1998, temperatures went abruptly from 21C (70F) highs to 35C (95F), with little rain for the remainder of the summer. This caused tissues to acclimatize and harden quickly, plus the conditions within the propagation environment became much less favorable for rooting. As a result, propagation success for cuttings taken after mid-May 1998 was much lower than for 1997. Crapemyrtle are generally considered as easy to root from cuttings. However, once the heat triggered plants to flower, rooting slowed, overall rooting success declined, and the growth of any resulting liner plants decreased (Whitcomb, 1978).

9) Air pruning of roots of cuttings is beneficial. Containers designed for air pruning allows root manipulation and increased root branching without open wounds or abrupt loss of roots. As roots are guided into openings, the tip of the root desiccates and eventually dies. When a root apex is air-pruned, more lateral branching occurs just as when a twig or branch is pruned (Hathaway and Whitcomb, 1977; Threadgill and Whitcomb, 1982; Whitcomb and Williams, 1984; Whitcomb, 1989). This benefit may be in part due to a more extensive lateral root system and the greater nutrient absorption capacity of younger roots (Shiyu et al., 1998). In some cases, air pruning and perhaps improved aeration have led to significant improvement in overall rooting. The yield of useful Leyland cypress liners was 15% higher in the air-root-pruning RootMaker® container compared to the conventional containers during a 2-year growing season study in Alabama (Tilt 1998, pers. commun.).

10) Rooting Hormones—A Mixed Bag: Sometimes Helpful, Sometimes Not Needed. In general, the softer the tissue, the less auxins are needed (Whitcomb, 1997). Semihardwood and hardwood cuttings have minimal terminal bud activity, thus adding a hormone generally aids rooting by speeding up the rooting process and improving root development. However, most softwood cuttings benefit little, if any, from the use of auxins because of the activity of the soft tissues and the natural production of auxins (Davis and Whitcomb, 1975; Glenn et al., 1976; Hickman et al., 1982; Ward and Whitcomb, 1979; Whitcomb, 1975; Whitcomb, 1978; Whitcomb, 1984). Remember — it is not how many cuttings you stick that is important, rather how many cuttings end up as useful plants and in the shortest production time.

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Disease-Resistant Cultivars of Crapemyrtle and Dogwood

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Severity of powdery mildew (*Microsphaera penicillata*) and spot anthracnose (*Elsinoe corni*) was assessed from 1995 through 1997 in a simulated landscape planting of 37 selections or cultivars in five dogwood (*Cornus* sp.) taxa. Concurrently, susceptibility of 43 cultivars of three crapemyrtle (*Lagerstroemia* sp.) taxa to powdery mildew (*Erysiphe lagerstroemia*) and Cercospora leaf spot (*Cercospora lythracearum*) was recorded. Selected cultivars of both crapemyrtle and dogwood were resistant to both diseases and would be excellent candidates for low maintenance landscapes and nursery production.

INTRODUCTION

Brightly colored blooms and brilliant fall color have made crapemyrtle and dogwood important plant materials for southern landscapes. Diseases, such as powdery mildew and Cercospora leaf spot on crapemyrtle as well as spot anthracnose and powdery mildew on flowering dogwood often mar the beauty and value of these popular woody plants (Alfieri, 1969; Alfieri, 1976; Jenkins and Bitancourt; 1948, McRitchie, 1994). Disease resistance is an effective, inexpensive, and often pesticide-free means of producing and maintaining landscape plantings of dogwood and crapemyrtle. Recently, cultivars of crapemyrtle with resistance to powdery mildew have been released (Knox et al., 1992). However, the resistance of most cultivars of dogwood, particularly the flowering dogwood, to common foliar diseases is not well documented (Ranney et al., 1995). The objective of these studies was to determine resistance to common foliar diseases of selected cultivars of dogwood and crapemyrtle.

MATERIAL AND METHODS

Bareroot dogwood and crapemyrtle liners approximately 0.6 to 1.0 m (2 to 3.3 ft) tall were planted in March 1993 in a Marvyn loamy sand on 2.4-m (7.9-ft) centers in rows spaced 3.7 m (12.2 ft) apart. Cultivars of crapemyrtle and dogwood are listed in Tables 1, 2, 3, and 4. A trickle irrigation system with two emitters per plant was installed at planting and trees were watered as needed. In March and May each year, 80 g of 13N-13P-13K fertilizer was distributed around each plant. In 1996, all plants were mulched with 5 to 7 cm (2 to 2.8 inches) of aged pine bark. Disease rating scales are described and included in the tables.

RESULTS

Overall, cultivars of *Lagerstroemia indica* proved more susceptible to powdery mildew than those in the two other crapemyrtle taxa (Tables 1 and 2). Mildew ratings for the hybrid *L. indica* × *L. fauriei* cultivars and the single cultivar of *L. fauriei* were similar in all 3 years. Incidence of Cercospora leaf spot was lowest in

all 3 years with the single cultivar of *L. fauriei*, than among culitvars of the other two *Lagerstroemia* taxa; resistance among cultivars of the other two taxa were similar (data not shown). Sizable year to year variations in powdery mildew ratings were observed among most cultivars of *L. indica*. Lowest disease ratings were recorded over the 3-year test period for 'Cherokee' and 'Glendora White'. Moderate to severe disease incidence was noted in at least 1 year on the remaining 18 cultivars of *L. indica* (Table 1). Moderate to heavy spotting of the leaves along with varying levels of defoliation due to Cercospora leaf spot were observed in at least 1 year on all cultivars of *L. indica* except 'Dodd #1', 'Glendora White', and 'Velma's Royal Delight'.

Powdery mildew levels on most of the hybrid *Lagerstroemia* cultivars were very low (Table 2). Light to moderate outbreaks were seen only on 'Zuni' and 'Pecos'. For most remaining hybrid cultivars and the single selection of *L. fauriei* 'Fantasy', this disease was limited to a few widely scattered fungal colonies on the foliage. Only 'Caddo' was mildew free in all 3 years. On most hybrid crapemyrtle cultivars, Cercospora leaf spot caused heavy leaf spotting and premature leaf drop. Damage on the leaf-spot-resistant cultivars 'Tonto', 'Tuscarora', and *L. fauriei* 'Fantasy' was limited to light spotting of the leaves around the base of each plant.

Among the five dogwood taxa, *Cornus florida* (flowering dogwood) and *C.* 'Eddie's White Wonder' (*C. nuttallii* × *C. florida*) were more susceptible to both powdery mildew and spot anthracnose than the other three dogwood taxa (Table 3). Low spot anthracnose and powdery mildew ratings for the *C. kousa*, *C. controversa* (giant dogwood), and C. ×*rutgersensis* (*C. kousa* × *C. florida*) hybrids clearly illustrates their high level of resistance to these two diseases (data not shown).

Incidence of powdery mildew and spot anthracnose varied significantly among cultivars of flowering dogwood and often from year to year on a given cultivar (Table 4). Only 'Cherokee Brave' remained almost mildew-free over the 3-year evaluation period. In 2 of 3 years, powdery mildew on 'Super Red', Cherokee Chief[PP] eastern dogwood; Cherokee Daybreak[TM] eastern dogwood; and 'Springtime' was light and unobtrusive. Cultivars of flowering dogwood that suffered the least spot anthracnose damage to both the bracts and leaves were 'Super Red', Cherokee Chief[PP] eastern dogwood ; 'Cherokee Brave'; 'Weaver' (syn. 'Weaver's White'); Cherokee Sunset[TM] eastern dogwood; and 'Bay Beauty', Welch Bay Beauty[TM] eastern dogwood (syn. 'Welch Bay Beauty'). Moderate to severe outbreaks of powdery mildew and spot anthracnose were seen in at least 1 of 3 years on all remaining cultivars of flowering dogwood and the hybrid 'Eddie's White Wonder' (Table 3).

Little or no powdery mildew and spot anthracnose were noted on the foliage of nearly all cultivars of *C. kousa*, 'Eddie's White Wonder', and giant dogwood (Table 3). Noticeable powdery mildew development was noted in only 1 year on the hybrid cultivars Aurora® hybrid dogwood and Galaxy® hybrid dogwood. With the exception of the cultivars Ruth Ellen® hybrid dogwood and Constellation® hybrid dogwood, leaves of the *C. kousa* and hybrid dogwoods were nearly free of spot anthracnose. Although the above dogwood taxa have excellent disease resistance, they may be much more sensitive to winter injury than *C. florida* (data not shown). By May 1997, few individuals of *C. kousa*, hybrids, or giant dogwood remained healthy, while similar levels of tree death were not observed among the cultivars of flowering dogwood.

Table 1. Susceptibility of cultivars of crapemyrtle (*Lagerstroemia indica*) to powdery mildew and Cercospora leaf spot.

Cultivar	Powdery mildew[1]			*Cercospora* leaf spot[2]		
	1995	1996	1997	1995	1996	1997
Carolina Beauty	2.3[3]	1.6	1.2	5.8	6.3	5.8
Catawba	0.7	0.1	1.2	3.6	4.6	3.0
Centennial Spirit	1.6	0.0	0.8	2.2	4.8	5.0
Cherokee	0.0	0.0	N.R.[4]	2.3	4.0	N.R.
Country Red	2.8	2.5	0.9	4.0	4.6	5.0
Dodd #1	0.1	0.1	0.5	3.3	2.7	1.9
Dodd #2	0.4	0.2	0.9	N.R.[4]	6.3	3.2
Glendora White	0.4	0.4	0.5	2.3	3.7	3.8
Gray's Red	2.2	0.8	1.0	3.5	3.9	4.3
Hardy Lavender	1.1	1.1	1.8	4.2	5.1	5.0
Hopi	0.2	0.0	1.7	3.9	5.7	5.4
Majestic Beauty	1.7	1.0	1.0	3.7	5.3	5.0
Near East	0.3	0.0	1.3	5.0	5.4	4.7
Orbin Adkins	2.4	0.7	1.2	5.8	6.7	6.8
Peppermint, (Pepermint Lace[PP] crapemyrtle)	1.7	1.0	1.6	4.0	5.6	4.9
Potomac	1.8	0.3	0.9	2.7	4.5	3.6
Powhatan	1.3	1.1	1.8	3.4	5.5	5.5
Raspberry Sundae	3.1	1.5	1.5	4.6	5.7	5.3
Regal Red	0.6	1.2	1.3	2.1	4.0	4.2
Seminole	0.8	0.3	2.2	3.3	5.6	4.5
Velma's Royal Delight	1.2	0.6	1.4	2.0	3.3	3.7
Wm. Toovey	1.9	1.3	1.8	3.7	4.4	3.6
Wonderful White	2.4	1.5	1.3	5.0	6.8	6.8
LSD (P = 0.05)	0.7	0.5	0.6	1.1	0.9	0.6

[1]The severity of powdery mildew was assessed on a scale of 0 to 4 where 0 = no disease, 1 = 1% to 25%, 2 = 26% to 50%, 3 = 51% to 75%, 4 = 76% to 100% of the leaves damaged or colonized by *Erysiphe lagerstroemia*.

[2]Cercospora leaf spot was evaluated using the Barratt and Horsfall System: 1 = 0%, 2 = 0% to 3%, 3 = 3% to 6%, 4 = 6% to 12%, 5 = 12% to 25%, 6 = 25% to 50%, 7 = 50% to 75%, 8 = 75% to 87%, 9 = 87% to 94%, 10 = 94% to 97%, 11 = 97% to 100%, 12 = 100% of leaves diseased or lost prematurely due to leaf spot.

[3]Mean separation within columns according to Fisher's protected least significance (LSD) test (P 0.05).

[4]N.R. = not rated.

Table 2. Susceptibility of cultivars of crapemyrtle (*Lagerstroemia indica* × *L. fauriei* and *L. fauriei*) to powdery mildew and Cercospora leaf spot.

	Powdery mildew[1]			*Cercospora* leaf spot[2]		
Cultivar	1995	1996	1997	1995	1996	1997
Lagerstroemia indica × *L. fauriei*						
Acoma	0.0[3]	0.0	0.1	5.3	6.3	6.2
Apalachee	0.2	0.0	0.2	2.7	2.8	1.3
Basham's Party Pink	0.2	0.2	0.4	2.8	2.5	1.7
Biloxi	0.4	0.3	0.8	4.4	5.3	4.0
Caddo	0.0	0.0	0.0	2.4	2.9	4.6
Choctaw	0.0	0.1	0.3	4.5	4.6	3.5
Comanche	0.0	0.0	0.4	5.6	6.6	4.9
Lipan	0.3	0.0	0.0	2.9	5.1	2.6
Miami	0.1	0.0	0.7	3.5	4.7	3.2
Muskogee	0.2	0.0	0.6	4.7	4.8	4.2
Natchez	0.0	0.1	0.0	4.3	4.6	2.6
Osage	0.0	0.0	0.4	2.8	4.0	1.3
Pecos	0.4	0.1	1.3	2.8	5.1	2.6
Sarah's Favorite	0.0	0.0	0.1	3.5	3.8	3.3
Sioux	0.1	0.0	0.0	4.3	5.2	1.3
Tonto	0.1	0.0	0.0	2.3	1.3	1.2
Tuscarora	0.5	0.0	0.4	1.7	2.4	1.8
Tuskegee	0.1	0.4	0.2	1.8	1.5	1.3
Wichita	0.3	0.0	0.8	2.8	3.6	2.6
Yuma	0.4	0.0	0.4	4.9	5.0	5.2
Zuni	1.3	0.3	1.8	4.8	4.4	3.5
Lagerstroemia fauriei						
Fantasy	0.4	0.0	0.2	1.4	1.1	1.7
LSD (P 0.05)	0.7	0.5	0.6	1.1	0.8	0.6

[1]The severity of powdery mildew was assessed on a scale of 0 to 4 where 0 = no disease, 1 = 1% to 25%, 2 = 26% to 50%, 3 = 51% to 75%, 4 = 76% to 100% of the leaves damaged or colonized by *Erysiphe lagerstroemia*.

[2]*Cercospora* leaf spot was evaluated on using the Barratt and Horsfall System: 1 = 0%, 2 = 0% to 3%, 3 = 3% to 6%, 4 = 6% to 12%, 5 = 12% to 25%, 6 = 25% to 50%, 7 = 50% to 75%, 8 = 75% to 87%, 9 = 87% to 94%, 10 = 94% to 97%, 11 = 97% to 100%, 12 = 100% of leaves diseased or lost prematurely due to leaf spot.

[3]Mean separation within columns according to Fisher's protected least significance (LSD) test (P 0.05).

Table 3. Susceptibility of several dogwood taxa to powdery mildew and spot anthracnose.

Cultivar	Powdery mildew[1]			Spot anthracnose[1]				
				Bracts		Leaves		
	1995	1996	1997	1996	1997	1995	1996	1997
Cornus nuttalli × *C. florida* hybrid dogwood								
'Eddie's White Wonder'	1.3	0.5	1.9	2.0	N.B.[2]	0.3	1.4	1.3
C. kousa								
f. *chinensis* 'Milky Way'	0.3	0.0	0.0	0.0	0.0	0.2	0.0	0.0
'Satomi'	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
f. *chinensis* 'Milky Way Select'	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
'National'	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. ×*rutgersensis* (*C. kousa* × *C. florida*)								
Stardust® hybrid dogwood	0.2	0.0	0.4	0.0	0.7	0.0	0.0	0.0
Ruth Ellen® hybrid dogwood	0.1	0.1	0.2	1.1	0.9	0.0	0.3	0.8
Galaxy® hybrid dogwood	0.1	0.0	0.8	0.0	0.5	0.0	0.0	0.1
Constellation® hybrid dogwood	0.0	0.1	0.0	1.0	1.8	0.2	1.1	0.8
Stellar Pink® hybrid dogwood	0.0	0.0	0.0	0.0	0.3	0.0	0.2	0.0
Aurora® hybrid dogwood	0.0	0.0	0.8	0.0	0.8	0.0	0.0	0.7
Cornus controversa	0.0	0.0	N.R.[3]	N.B.	N.R.	0.0	0.7	N.R.
LSD (P 0.05)	0.8	0.9	0.7	0.9	1.0	0.6	0.6	0.8

[1]Severity of powdery mildew and spot anthracnose was assessed on a scale of 0 to 4 where 0 = no disease, 1 = 1% to 25%, 2 = 26% to 50%, 3 = 51% to 75%, and 4 = 76% to 100% of leaves damaged or diseased.
[2]N.B. = no blooms.
[3]N.R. = not rated.

Table 4. Susceptibility of cultivars of flowering dogwood (*Cornus florida*) to powdery mildew and spot anthracnose.

Cultivar	Powdery mildew[1]			Spot anthracnose[1]				
				Bracts		Leaves		
	1995	1996	1997	1996	1997	1995	1996	1997
White bracts								
'Dwarf White'	3.0	0.0	2.0	2.0	4.0	0.0	2.0	2.0
Wonderberry® eastern dogwood	2.2	0.5	1.8	1.8	2.2	0.4	0.6	2.1
'World's Fair'	1.9	0.8	1.8	1.9	2.0	0.0	1.8	1.8
'Bay Beauty', Welch Bay Beauty™ eastern dogwood	1.8	0.8	1.1	0.9	0.3	0.2	0.4	0.2
'Ozark Spring'	1.8	1.2	2.0	2.3	2.8	0.2	2.0	2.9
'Fragrant Cloud'	1.8	1.0	1.3	1.3	1.7	0.0	1.3	2.1
Cloud 9™ eastern dogwood	1.7	1.3	1.4	2.6	2.3	0.0	2.6	2.4
'Barton White'	1.5	0.7	1.6	3.3	2.5	1.0	2.7	2.0
'White Princess', Cherokee Princess® eastern dogwood	1.5	1.1	1.8	2.3	2.3	0.0	1.3	2.1
Double White	1.5	0.5	1.2	0.5	0.8	0.5	1.3	2.2
'Weaver' (syn. 'Weaver's White')	1.1	1.0	1.4	1.1	1.5	0.0	0.8	1.1
'Springtime'	0.8	0.3	1.0	2.3	2.4	0.0	2.3	2.6
White bracts/variegated leaves								
'Autumn Gold'	2.9	0.7	1.8	N.B.[2]	N.B.	0.7	1.4	1.8
'First Lady'	2.1	0.6	2.4	1.8	2.0	0.3	1.5	2.2
'Rainbow'	1.6	1.3	1.1	2.0	1.9	2.8	3.0	3.7
Cherokee Daybreak™ eastern dogwood	0.9	0.0	1.5	3.0	1.7	0.5	1.1	1.4

Pink bracts								
'Pink Beauty'	2.6	1.5	2.8	1.6	2.4	0.0	1.1	1.8
'Pink Flame'	2.5	1.2	2.7	2.0	1.5	0.0	1.2	2.0
f. *rubra* (syn. 'Rubra Pink')	2.0	1.6	2.0	0.5	1.5	0.3	1.1	2.0
'Welch's Junior Miss', Junior Miss™ eastern dogwood	1.7	0.9	2.2	1.3	1.3	0.0	0.9	1.1
'Stoke's Pink'	1.5	1.8	2.6	1.5	2.8	0.0	0.9	0.2
Red bracts								
Red Beauty™ eastern dogwood	2.0	1.4	1.8	1.0	0.8	0.3	1.4	2.0
'Purple Glory'	2.0	1.3	2.3	1.5	2.0	0.0	1.0	1.1
'Super Red', Cherokee Chief™ eastern dogwood	1.4	0.6	1.6	0.7	1.0	0.0	0.6	1.3
'Cherokee Brave'	0.2	0.0	0.0	1.0	1.1	0.0	0.6	1.5
Red bracts/variegated leaves								
Cherokee Sunset™ eastern dogwood	1.3	0.5	2.4	0.0	0.5	0.2	0.9	1.4
LSD (P 0.05)	0.8	0.9	0.7	0.9	1.0	0.6	0.6	0.8

[1]Severity of powdery mildew and spot anthracnose was assessed on a scale of 0 to 4 where 0 = no disease, 1 = 1% to 25%, 2 = 26% to 50%, 3 = 51% to 75%, and 4 = 76% to 100% of leaves or bracts damaged or diseased.
[2]N.B. = no blooms.

DISCUSSION

The production, marketing, and establishment of disease-resistant cultivars of dogwood and crapemyrtle make good economic and environmental sense for nursery producers, as well as retail outlets, landscape managers, and homeowners. Disease resistance allows the nursery producer to grow a quality and attractive container- or field-grown dogwood or crapemyrtle with fewer costly pesticide and labor inputs. For consumers and landscape managers, disease-resistant dogwoods and crapemyrtles are a welcome addition to the growing list of low maintenance landscape shrubs and trees.

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Seedling Propagation in Bottomless Bands

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INTRODUCTION

S & S Nurseries, Inc., produces both container- and field-grown trees and shrubs for the landscape and garden center industries. For many years our tree production started with bareroot seedlings purchased from other nurseries. The quality of these plants was variable at best, and often poor. Because of the need to improve on the quality and the availability of bareroot seedlings, our own tree seedling production was started 11 years ago. It was determined from the beginning that a bottomless container for air pruning the roots was the way to go.

Seedling Containers. When we first started, a tray with 38 cone shaped cells 5.1 cm (2 inches) wide at the top and 12.7 cm (5 inches) deep, was used. After 3 years and numerous problems, we switched to the Anderson bottomless bands. This container is 9.2 cm (3.6 inches) square at the top by 15.2 cm (6 inches) deep with a very slight taper. Twenty-five of these fit in a Lerio 46-cm (18-inch) square tray.

Greenhouse Propagation Facilities. We construct frames 1.2 m (4 ft) wide, which rest on concrete blocks placed two high [38 cm (15 inches)]. The frames are made of 5 cm × 10-cm (2 inch × 4 inch) treated lumber, which is laid on top of the blocks. A 1-cm (0.5-inch) hardware cloth is stretched and nailed to the framework. Last year, because of the cost of materials and labor, we tried using two rows of 5 cm × 5 cm (2 inch × 2 inch) treated lumber under each row of trays. The hardware cloth benches worked very well for air pruning the seedling roots, but due to age, water, and people walking on the wire, the first ones we built needed to be replaced. The 5 cm × 5 cm-(2 inch × 2 inch) treated lumber has worked well the past 2 years. We can utilize 19,700 bands (liner pots) per 7.3 m × 29.3 m (24 ft × 96 ft) house at three trays wide per bed and four beds per house. We have 29 houses dedicated to seedling production.

Seed Requirements and Pretreatment. It is important to know the approximate number of seeds per pound and average viability for each species in order to calculate your requirements. We buy most of our seed from seed specialists. Several genera do not do well if the seed is not immediately collected and used fresh. For this reason I specify fresh seed with all our species, when possible. *Acer rubrum, A. palmatum, Cornus florida*, and *Prunus caroliniana* are collected on or near our nursery. Until last year, seedling oak production had been a problem. Frequently 20% to 50% of the acorns we bought had weevil holes. Last year we changed our seed source. Not only was the price as much as 50% less, there were virtually no bad acorns. It is very important to compare price and quality from several seed sources, and to keep good records on performance. Seed orders are placed each September.

As the seed start arriving they are placed in airtight containers in our cooler at 1.7 to 4.4C (35 to 40F) until we are ready to use them. Preplanting treatments vary by species and condition of the seed. Seed of species such as *Betula, Metasequoia,* and *Cercidiphyllum* require no pretreatment. Hence, they are sown in flats and placed in a heated house early enough in the year to have seedlings ready to transplant by March 15th.

The medium used for stratification is either 100% sand or sand and peat (1 : 1, v/v). The fungicide captan is added at 149 g m^{-3} (4 oz yd^{-3}). The sand is sifted through a fine wire screen so there are no large particles to separate from small seed after propagation. The peat is also sifted through a 0.6-cm (0.25-inch) screen to break down any large pieces. The medium is moistened to a point where water drips out when a hand full is tightly squeezed.

Information on seed count, stratification, and media can be found in Table 1. The complied information was initially taken from references (Dirr 1990; Dirr and Heuser 1987: Schopmeyer, 1974; and Vertrees, 1987), and then modified by our experience over the years as to what best fits our propagation systems.

Seed Propagation Schedule. A schedule is established each year so that rather than having all seed ready to plant at the same time, seed propagation is staggered over a 6- to 8-week period. This schedule is based on length of stratification, planting to emergence time, hardiness, and average growth rate. We usually start planting seed and seedlings during the first week in March. We try to be finished before the 1st of May. Timing and early planting is very important. This year because of a delay in receiving new bands, part of our dogwoods were not planted until after the 1st of June. After 4 months, those seedlings were only about 0.3 m (1 ft) tall. All seed and seedlings planted before April 10th are maintained in a covered, unheated house. We have never had any cold damage, although a couple of years we have had to use temporary heat for short periods because of late, hard freezes.

Seed Sowing. As the seed are removed from the cooler, the medium used in stratification is removed. The seed are spread out and allowed to dry just enough to be able to handle easily. The seed are then carried to the houses and planted by hand. Our people work in pairs, one on each side of the bed. With most species each team can plant seed into 15,000 to 16,000 bands per day. Because we plant four birch seedlings per band (for clumps), transplanting this genus is very slow and labor intensive. We experimented this year with broadcasting the seed on top of the media-filled bands, and later thinning to 4 to 5 seedlings. This worked very well with much less labor.

After the oaks have received their required stratification, the acorns are spread out on burlap and covered with more burlap in a heated house. They are watered 3 to 4 times per day. We do not plant acorns until the radical has emerged and turned. The acorns are then planted one per band on their side with the radical downward. This assures us a very high percentage of bands with plants, and gives us a good straight plant.

Because of frequent poor percentages with *Cercis canadensis,* this species is planted 8 seed per band. All other species are planted 2 to 4 seed per band depending on past germination experience. When the seedlings are 5 to 7.6 cm (2 to 3 inches) tall they are thinned, leaving only the strongest seedling in each band.

Volume of Seedling Production and Finished Seedling Liner Size. Our production was less than 100,000 plants the first couple of years, but has increased annually since that time. Seedling production is now up to 500,000 tree bands and 150,000 pots this year. Flowering dogwood (*C. florida)* is the primary species (300,000) that we propagate. We use about one-third of the plants ourselves and sell the rest. Overall, we cull-out approximately 20% as inferior plants.

By the end of the growing season, most of the trees are 0.9 to 1.2 m (3 to 4 ft) tall with a 0.6- to 1-cm (0.24 to 0.38 inch) caliper. Some species, *Betula, Cercidiphyllum,* or *Metasequoia*, will be 1.5 to 1.8 m (5 to 6 ft) tall. This compares to a maximum of 0.5 to 0.6 m (1.5 to 2 ft) height obtained when we were using the smaller cone-shaped liner cells. By the time the plants go dormant in the fall, they have a very good fibrous root system due largely to air pruning during propagation. We go directly to 19-liter (5-gal) containers or to the field in October-November. We experience virtually no loss, which certainly could not be claimed when trees were planted bareroot. We also get more growth during the following year compared to bareroot seedlings.

One thing we have observed is that every year one species of oak grows much slower than other species. What is peculiar is that slower growth occurs in different species each year, but never the same species for two consecutive seasons.

Our other major seed crop is *Hydrangea quercifolia* (100,000 were propagated this year). Seed are collected in late December and planted in seed flats under heat and mist. As soon as seedlings are 1.9 to 2.5 cm (0.75 to 1 inch) tall they are transplanted into 10-cm (4-inch) pots in April in clumps of 4 to 5 seedlings. They are pruned heavily 2 to 3 times during the growing season, and produce a heavy 20- to 25-cm (8- to 10-inch) tall plant by fall.

Sanitation, Disease, and Weed Control During Propagation. During propagation we reuse as many bands as possible to reduce our production costs. These are thoroughly cleaned before use. Regretfully, we do not have the capacity to sterilize the large volume of soil 688 m^3 (900 yd^3) required to produce a half million liner bands. However, the bark used does go through a heat treatment.

After planting, all bands are treated with fungicide every 7 days during the first month to 6 weeks, after which, they are treated as needed. Dogwoods are treated every 7 days throughout the growing season. One note of interest — we tried growing dogwood under shade to get more growth, but were unable to control powdery mildew. Insecticides are applied only as needed. Most years we have few insect problems, although this year we have had major problems with white flies. All houses are cleaned and treated with an herbicide 2 to 3 weeks before the seedling trays are moved in. No herbicide is used until the seedlings are approximately 1 ft tall. At that time an application of Scott's Ornamental Herbicide II is applied (mid June). A second application is applied in mid September.

Soil Mix and Fertilization for Seedling Production. The bands are set up in the Lerio trays and filled with soilless medium using a Bouldin and Lawson canning machine. The mix consists of peat moss, perlite, and bark (2 : 5 : 11, by volume). To this is added 4.8 kg m^{-3} (8 lb yd^{-3}) of Nutricote Total 18N-6P-8K, 2.1 kg m^{-3} (3.5 lb yd^{-3}) dolomitic lime, and 1.2 kg m^{-3} (2 lb yd^{-3}) magnesium sulfate. Seedlings are top-dressed usually two times during the growing season with 17N-17P-17K fertilizer.

Concerns. The chance of poor germination is always a concern. No matter where you acquire your seed, nor how careful you are in handling the seed, there is always something that can go wrong. Rodents and birds are always a potential problem. A fungal pathogen can wipe out an entire species within a few days if not monitored closely.

This year consistently high temperatures [97 days at 32C (90F)] slowed seedling growth, particularly with species such as *Betula* and *Magnolia*.

Table 1. Seed count, seed handling, and stratification requirements of species propagated at S&S Nurseries.

Plant	Seed per pound	Special seed pretreatment	Cold stratification (days)	Propagation medium
Acer burgerianum	29,000	Soak in warm H_2O for 2 days	90	Sand : peat
A. tartaricum subsp. ginnala 'Flame'	17,000	Soak in warm H_2O for 2 days	90-150	Sand : peat
A. palmatum f. atropurpureum	19,000	Soak in warm H_2O for 2 days	120	Sand : peat
A. palmatum (small seed)	25,000	Soak in warm H_2O for 2 days	120	Sand : peat
A. rubrum	22,000	Collect and plant in spring		
A. saccharinum	1700	Collect and plant in spring		
A. saccharum	7000		40-90	Sand : peat
A. truncatum	6400	Soak in warm H_2O for 2 days	120	Sand : peat
Betula nigra	375,000	Sow on surface of flats under mist	30-60	Sand
B. platyphylla var. *japonica*	410,000	Sow on surface of flats under mist	30-60	Sand
Cedrus deodora	3700	Use dryer propagation media	14	Sand
Cercidiphyllum japonicum	64,000	Sow on surface of flats under mist		
Cercis canadensis	18,000	Scarify for 30-60 min with H_2SO_4, followed by hot H_2O soak for 24 h	60-90	Sand : peat
Chionanthus retusus	14,400	Warm stratification for 1-3 months	90	Sand : peat
Cornus florida	4500		120	Sand
C. kousa var. *chinensis*	9700		120	Sand : peat
Cotinus coggygria Rubrifolium Group	44,000	Scarify for 30-60 min with H_2SO_4	80	Peat
Crataegus phaenopyrum	29,000	Scarify for 30-60 min with H_2SO_4	120	Sand : peat
Fraxinus pennsylvanica	17,000	Soak in H_2O for 14 days, change H_2O daily	90	Sand : peat
Gymnocladus dioica	230	Scarify for 8 h with H_2SO_4, followed by 24 h water soak		

Koelreuteria paniculata	2900	Scarify for 60 min with H_2SO_4	90	Sand : peat
Liquidambar styraciflua	82,000		30	Sand
Liriodendron tulipifera	15,000		90	Sand : peat
Magnolia grandiflora	6400		120	Sand : peat
Magnolia virginiana	7500		120	Sand : peat
Metasequoia glyptostroboides	300,000	Sow on surface of flats under mist		
Myrica cerifera	84,000	Remove wax coating	90	Sand : peat
Nyssa sylvatica	3300		90	Sand : peat
Oxydendrum arboreum	2,000,000+	Plant on surface of flats, cover flat with plastic and use continuous light		
Pinus densiflora	52,000	Soak in H_2O for 2 days	20-30	Sand
P. elliottii	13,500	Soak in H_2O for 2 days	60	Sand
P. nigra	26,000	Soak in H_2O for 2 days	60	Sand
P. strobus	26,500	Soak in H_2O for 2 days	60	Sand
P. thunbergii	34,000	Soak in H_2O for 2 days	30-60	Sand
P. virginiana	55,400	Soak in H_2O for 2 days	30	Sand
Pistacia chinensis	7200		90	Sand : peat
Platanus occidentalis	149,900	Sow in flats—cover with 0.6cm (0.25 inch) medium, propagate under mist	60	Sand
Prunus caroliniana	1200		90	Sand : peat
Pyrus calleryana	41,000		60-90	Sand : peat
Quercus acutissima	110		90	Sand : peat
Q. lyrata	140		40	Sand : peat
Q. nigra	400		30-60	Sand : peat
Q. texana (syn. *nuttallii*)	110		60-90	Sand : peat

Q. palustrus	410		90	Sand : peat
Q. phellos	480		90	Sand : peat
Q. rubra	125		30-60	Sand : peat
Q. shumardii	100		30-60	Sand : peat
Q. virginiana	350	Plant in fall as soon as collected		
Sophora japonica	480	Soak in hot H_2O for 2 days		
Taxodium distichum	5200	Soak in ethyl alcohol for 30 min, then soak in H_2O for 3 days, daily changing water. Use very wet peat.	90	Peat
Ulmus parvifolia	120,600		60-90	Sand : peat
Zelkova serrata	32,000		60-90	Sand : peat

SUMMARY

Tree production in bottomless bands has become an important part of our business. We are always looking for ways to improve the quality of our production system. Cost of materials, seed, and labor are always a concern. As with all other aspects of our industry, production cost, plant quality, and profit margin must be watched closely and kept in balance.

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Pruning Liriope Leaves During Division Reduces Subsequent Growth

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Two experiments were conducted to determine if pruning the shoots of liriope [*Liriope muscari* (Decne.) L.H. Bailey 'Big Blue'] at division affected subsequent growth of roots and shoots. Plants were divided into single bibbs and shoots were left uncut or cut 5 cm above the crown of the plant. Plants with shoots pruned at division took 42% more time to develop 25 new root tips, and had smaller root masses, and had fewer bibbs per container. Root system size at the time of division was also evaluated. Plants with larger roots systems (10 or more roots at division) developed 25 new roots faster, had larger systems at the end of the experiment, and produced more bibbs than plants with smaller root systems (3 to 5 roots at division).

INTRODUCTION

Liriope is a popular and versatile perennial for most of the United States. It can be used as a groundcover, in edging and massing, an understory plant for woody plants, and in combination with a wide range of perennials, shrubs, and trees. This plant is commonly sold under several names in the trade such as "lilyturf", "monkey grass", and "Aztec grass". With its increasing popularity, liriope is becoming an important landscape crop in today's market.

Liriope is commonly propagated by division. A common industry practice is to divide a stock plants into 3.8-liter (1 gal) containers with single shoot divisions called bibbs. Shoots and roots are pruned to within 2 inches of the crown of the plant, potted into liner pots, and placed on production beds. Generally, plants are sold within 6 months, depending on cultivar and time of year.

Several experiments have been conducted evaluating the effect of pruning on subsequent root growth. Gilliam et al. (1986) tested the effects of pruning on root and shoot growth of *Ilex crenata* 'Compacta' and found that shoot pruning at potting reduced root growth of transplanted rooted cuttings. Another study by Young and Werner (1982) with *Malus ×domestica* 'Golden Delicious' reported shoot pruning resulted in very little root dry weight increase up to 8 weeks after planting, indicating competitive inhibition between root growth and rapid new shoot growth. Kandiah et al. (1984) also demonstrated that pruning treatments reduced feeder root development in tea (*Camellia sinensis*). All three of these studies were conducted using woody plant species; no similar research could be found in the literature with nonwoody perennials. The objective of our study was to determine whether pruning shoots of *Liriope muscari* slows subsequent regeneration of roots and shoots.

MATERIALS AND METHODS

Experiment 1. Trade gallon (3.8 liter) containers of *L. muscari* 'Big Blue' were divided into single bibbs on 6 June 1997. Shoots were either pruned back to 5 cm (2 inches) of the crown of the plant or left unpruned. Bibbs were selected for uniform root systems: either 10 or more roots, or 3 to 5 roots at division; any roots over 10 cm (4 inches) length were cut. Most roots ranged in length from 5 to 10 cm (2 to 4 inches). Bibbs not cut back had an average leaf length of 31 cm (12.5 inches). Medium used was a pinebark and sand (6 : 1, v/v) medium amended with 5.7 kg m^{-3} (10 lb yd^{-3}) 18N-2.6P-10K (18-6-12) Osmocote (Scotts Co., Marysville, Ohio), 2.3 kg m^{-3} (5 lb yd^{-3}) dolomitic lime, and 0.9 kg m^{-3} (1.5 lb yd^{-3}) Micromax (Scotts Co., Marysville, Ohio).

After division each bibb was potted into a 45 cm (18 inches) deep, 10 cm (4 inches) diameter PVC root chamber with a 17.5-cm (7-inch) window covered with acetate. Root chambers were placed on a tilted bench in full sun under overhead impact irrigation, where the tilt of the bench directed root growth toward the window.

Root tips numbers were counted every other day beginning when the first root appeared in the window and continued until 25 new root tips were present. The bareroot plants were rated at the end of the study (18 Aug. 1997) on a scale 1 to 5 where 1 = small root mass, 3 = moderate root mass, and 5 = large root mass. Bibbs numbers and shoot and root fresh weights were also collected at this time. The experiment was a 2 × 2 factorial with a completely randomized design with 12 single plant replications.

Experiment 2. The second experiment was conducted similarly to the first experiment with a few exceptions. The cultivar *L. muscari* 'Evergreen Giant' was added. In addition to the two root systems evaluated in the 1st experiment [10 or more roots, or 3 to 5 roots], a third root system was added with 0 roots at division, making the experiment a 2 × 3 factorial. Bibbs were potted into 369 cm^3 (22.8 $inches^3$) plastic pots (Lerio SR 325, Lerio Co., Mobile, Alabama). Root ratings were collected 45, 60, and 75 days after potting (DAP) using a scale of 1 to 5, where 1 = 0%, 2 = 25%, 3 = 50%, 4 = 75%, and 5 = 100% of the root coverage of the substrate-container interface. Plants were completely randomized by cultivar with six single plant replications.

RESULTS AND DISCUSSION

Experiment 1. The analysis showed no pruning × root interactions, only pruning or root main effects. 'Big Blue' liriope with shoots not pruned developed root systems faster than plants with shoots pruned to 5 cm. For example, plants with shoots pruned took 14 days or 42% longer to develop 25 new root tips than plants with shoots not pruned (Table 1). Plants with 10 or more roots at division also took fewer days (6) to develop 25 new root tips than plants with 3 to 5 roots at division. By developing earlier root systems, plants with the shoots not pruned also had larger root systems at the end of the experiment as shown by the root rating. Plants with shoots pruned had 66% less fresh root weight at the end of the experiment than plants with shoots pruned. Plants with 10 or more roots or 3 to 5 roots at division had similar fresh root weights. With bibb numbers, plants with shoots not pruned or plants with 10 or more roots also produced more bibbs

Table 1. Experiment 1: The influence of shoot pruning and number of roots at division on subsequent growth of 'Big Blue' liriope.

	Days to produce 25 roots[z]	Root rating[y]	Bibb number[x]	Shoot fresh wt. (g)	Root fresh wt. (g)
Shoots not pruned	40*** [w]	3.5***	6.4***	15.7***	9.3***
Shoots pruned	48	2.1	3.6	5.9	3.2
>10 roots	38**	3.1**	5.6**	10.8 NS	6.5 NS
3-5 roots	46	2.6	4.3	10.8	6.0

[z]Number of days from potting until 25 new root tips appeared in the root chamber windows.
[y]Roots were rated at the end of the experiment, 18 Aug. 1997, on a 1 to 5 scale where 1 = small root mass, 3 = moderate root mass, and 5 = large root mass.
[x]Bibbs per container and shoot and root fresh weights were collected 75 days after potting.
[w]NS, *, **, and *** nonsignificant or significant at the 0.05, 0.01, and 0.001 level, respectively.

Table 2. Experiment 2: The influence of shoot pruning and number of roots at division on subsequent growth of 'Evergreen Giant' and 'Big Blue' liriope.

	Root Rating[z]			Bibb number[y]	Shoot fresh wt (g)	Root fresh wt (g)
	45 DAP	60 DAP	75 DAP			
'Evergreen Giant'						
Shoots not pruned	1.4* [x]	1.8***	2.0**	1.3 NS	12.9**	7.7***
Shoots pruned	1.1	1.3	1.4	1.1	3.6	2.9
<10 roots	1.2 NS	1.4b [w]	1.7ab	1.5 NS	7.6ab	7.1a
3-5 roots	1.4	1.7a	2.0a	1.2	12.5a	6.9a
0 roots	-	1.2b	1.5b	1.0	5.0b	2.2b
'Big Blue'						
Shoots not pruned	1.5***	-[v]	-	-	6.6***	9.6***
Shoots pruned	1.2	-	-	-	1.9	2
>10 roots	1.6a	-	-	-	5.9a	9.1a
3-5 roots	1.3b	-	-	-	3.8b	4.3b
0 roots	-	-	-	-	2.4b	2.8b

[z]Root ratings were collected 45, 60, and 75 days after potting (DAP) and were rated on a 1-5 scale were 1 = 0%, 2 = 25%, 3 = 50%, 4 = 75%, and 5 = 100% coverage of the container media interface.

[y]Number of bibbs per container, shoot and root fresh weights were collected 75 days after potting.

[x]NS, *, **, *** nonsignificant or significant at the 0.05, 0.01, and 0.001 level, respectively.

[w]Means were separated using Duncans Multiple Range Test ($P \leq 0.05$).

[v]Prune × root interaction significant; data shown in Table 3.

Table 3. Experiment 2: Effect of pruning shoots and root number at the time of division on subsequent root ratings and bibb number of 'Big Blue' liriope at 60 and 75 days after potting (DAP).

	Root rating [z]		Bibb number
	60 DAP	75 DAP	75 DAP
Not pruned, 10 roots	3.3a[y]	4.2a	4.5a
Not pruned, 3 to 5 roots	2.5b	3.6b	1.3b
Not pruned, 0 roots	1.7c	2.4b	2.0b
Pruned, 10 roots	1.6c	2.0bc	1.7b
Pruned, 3 to 5 roots	1.2c	1.5c	1.0b
Pruned, 0 roots	1.2c	1.3c	1.0b

[z]Roots were rated on a 1-5 scale where 1 = 0%, 2 = 25%, 3 = 50%, 4 = 75%, and 5 = 100% coverage of the container media interface.
[y]Means were separated using Duncans Multiple Range Test ($P \leq 0.05$).

than plants with shoots pruned or plants with 3 to 5 roots at division, respectively. Even though inherent differences existed between not pruned (larger) and pruned (smaller) plants, shoot fresh weights followed a similar trend to bibb numbers.

Experiment 2. Overall, results from Experiment 2 were in general agreement with those of Experiment 1. 'Evergreen Giant' liriope roots had greater coverage of the container-media interface at 45, 60, and 75 DAP and greater root and fresh and dry weights when shoots were not pruned back than when shoots were pruned (Table 2). At the end of the study, plants with 3 to 5 roots at division had similar root ratings and fresh root weights as plants with 10 or more roots at division. Plants with 3 to 5 roots had higher root ratings and more fresh shoot weight than plants with 0 roots at division while plants with 10 or more roots were similar to both treatments. There were no treatment effects on bibb numbers.

As seen in Experiment 1 and with 'Evergreen Giant', 'Big Blue' liriope with unpruned shoots had greater root and shoot fresh weights than plants with shoots pruned. While this was an expected result with shoot fresh weight, root fresh weight was increased 365% by not pruning the shoots. Also, plants with the largest root systems at division had the greatest shoot fresh weight at the end of the experiment. For example, plants with 10 or more roots had 55% more shoot fresh weight than plants with 3 to 5 roots at division.

'Big Blue' liriope had significant pruning × root interactions with root ratings at 60 and 75 DAP and with bibb numbers at 75 DAP (Table 3). Plants with shoots not pruned had greater root ratings with 10 or more roots or 3 to 5 roots compared to all other treatments. When shoots were pruned, root ratings were similar regardless of initial root number. With bibb numbers, plants with unpruned shoots and 10 or more roots had more bibbs per container than any other treatment.

This study shows that liriope with unpruned shoots grew new roots and shoots more rapidly compared to liriope with shoots pruned to 5 cm (2 inches). To a lesser extent, plants with a larger root systems at the time of division generated new growth faster than plants with smaller root systems. These results suggest that shoots play an important role in the generation of new shoots and roots. Hence, liriope producers should minimize pruning shoots at division.

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Postemergence Control of Bittercress

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Three experiments were conducted to evaluate the effectiveness of postemergence applied herbicides for controlling bittercress (*Cardamine* sp.) in container-grown crops. 'Big Blue' and 'Variegata' liriope (*Liriope muscari*), China Girl™ holly (*Ilex* China Girl™ holly), and 'Midnight Flare' azalea (*Rhododendron* 'Midnight Flare') were also treated to evaluate herbicide phytotoxicity. When comparing bittercress control in variegated liriope in Experiment 2 and bittercress control at 15 days after treatment (DAT) in Experiment 3, Gallery™ provided excellent postemergence bittercress control (98% to 100%) at the recommended rate [1.1 kg ai ha^{-1} (1.0 lb ai acre^{-1})] with no injury to liriope, holly, or azalea. Manage™ provided good bittercress control (89% to 90%) at [0.03 kg ai ha^{-1} (0.03 lb ai acre^{-1})] but caused slight injury to liriope. Image™ provided good bittercress control (73% to 99.5%) at 0.07 kg ai ha^{-1} (0.062 lb ai acre^{-1}), but caused severe injury to azalea. Trimec Southern™ provided good bittercress control (77% to 100%) at 0.31 kg ai ha^{-1} (0.28 lb ai acre^{-1}), but caused severe injury to liriope and azalea.

INTRODUCTION

Bittercress (*Cardamine* sp.) is a serious weed problem in container nurseries (Ryan, 1977). Though it is considered a winter annual, it has become a season-long problem in nurseries due to the favorable environment provided by daily overhead irrigation. Ryan (1977) demonstrated that an herbicide program consisting of frequent and repeated applications of a preemergence herbicide is necessary for season-long bittercress control. When a proper weed management program is not maintained, bittercress can be one of the most prolific weeds to infest nursery containers (Cross and Skroch, 1992). Infestation can occur just after plants are removed from overwintering, when preemergence applications are made to unweeded containers, when a scheduled herbicide application is postponed or skipped, or towards the end of the season when the chemical barrier from previous applications begins to wear off.

Since preeemergence weed control programs fail to control all weeds, alternatives are needed that provide postemergence control. Research with imidazolinone and sulfonylurea herbicides demonstrated effective postemergence control of nutsedge in container-grown plants, with little to no phytotoxicity on landscape crops (Hurt and Vencill, 1994; Hurt and Vencill, 1994). However, limited herbicide research has evaluated postemergence control of broadleaf weeds in container-grown landscape crops. The objective of this study was to evaluate herbicides for postemergence control of bittercress in container-grown landscape crops.

MATERIALS AND METHODS

Three experiments were conducted to evaluate bittercress control with various rates of herbicides applied postemergence. All treatments were applied with a CO_2 backpack sprayer using an 8004-flat fan nozzle tip, with a pressure of 193 kPa (28 psi) and calibrated to deliver 193 liters ha^{-1} (20 gal acre^{-1}).

Experiment 1. On 25 June 1997, variegated liriope (*Liriope muscari* 'Variegata') liners were selected from Flowerwood Nursery, Loxley Alabama, which also contained uniform populations of bittercress that ranged from 0.5 to 2 cm (0.2 to 0.8 inches) tall. Plants were treated with the following herbicides: Manage™ (halosulfuron) at 0.03, 0.07, 0.15 kg ai ha^{-1}(0.03, 0.06, and 0.13 lb ai $acre^{-1}$) (Monsanto); Image™ (imazaquin) at 0.29, 0.58, 1.2 kg ai ha^{-1} (0.25, 0.5, and 1.0 lb ai $acre^{-1}$) (American Cyanamid); Action (fluthiacet-methyl) at 0.16, 0.31, 0.63 kg ai ha^{-1} (0.14, 0.28, and 0.56 oz ai $acre^{-1}$) (Novartis); and Resource (flumichlorac pentyl ester) at 0.03, 0.07, 0.13 kg ai ha^{-1} (0.03, 0.05, and 0.11 lb ai $acre^{-1}$) (Valent). Manage and Image are postemergence herbicides labeled for broadleaf weed and nutsedge control in established turf grasses. In other studies evaluating postemergence nutsedge control, these products caused no phytotoxicity to liriope (Hurt and Vencill, 1994; Hurt and Vencill, 1994). Action™ and Resource™ are new postemergence herbicides used for broadleaf weed control in corn and soybeans. The low and middle rates of all treatments reflect the lower and upper limits of the manufacturer's recommended rate. All treatments consisted of 10 single plant replicates in a completely randomized design.

Data collected included weed counts at 15 and 50 days after treatment (DAT), top fresh weight (TFW) and top dry weight (TDW) of both bittercress and liriope at 50 DAT. Liriope was evaluated for phytotoxicity, with ratings from 1 to 5 (1 = no damage, 2 = slight damage, 3 = moderate damage, 4 = severe damage, and 5 = dead plant) at 15 DAT.

Experiment 2. Container-grown 'Big Blue' and variegated liriope were over seeded with bittercress on 15 May 1998, and placed in 47% shade. At the time of treatment (15 June), bittercress in the containers with the 'Big Blue' liriope were 4.6 to 5.6 cm (1.8 to 2.2 inches tall) and beginning to flower; while bittercress in the containers with variegated liriope were 2.3 to 3.3 cm (0.9 to 1.3 inches) tall and not flowering. In experiments 2 and 3, there were 10 to 20 bittercress seedlings per pot.

Containers were treated with the following herbicides: Manage™ at 0.02, 0.03, 0.07 kg ai ha^{-1}(0.02, 0.03, and 0.06 lb ai $acre^{-1}$); Image™ at 0.07 0.15, 0.29 kg ai ha^{-1}(0.06, 0.13, and 0.25 lb ai $acre^{-1}$); Trimec Southern™ at 0.16, 0.31, 0.66 kg ai ha^{-1} (0.14, 0.28, and 0.57 lb ai $acre^{-1}$); and Gallery™ (isoxaben) at 0.6, 1.2, and 2.3 kg ai ha^{-1}(0.5, 1.0, and 2.0 lb ai $acre^{-1}$). Rates of Manage™ and Image™ were lowered so that the low and middle rates of the previous test were the same as the middle and high rates of this test. Trimec Southern™ rates were all lower than the manufacturer's recommended rate (PBI/Gordon). Low and middle rates of Gallery™ represent the lower and upper limits of the manufacturer's recommended rate (Dow Elanco). Gallery™ is labeled as a preemergence herbicide for controlling broadleaf weeds in nursery crops and was used in this test based on a suggestion by Albert Van Hoogmoed (Overlook Nursery, Mobile, Alabama) that it provided postemergence bittercress control. This suggestion was supported by earlier research by Schneegurt, et al. (1994) on the postemergence activity of isoxaben. All treatments consisted of 10 single plant replicates in a completely randomized design.

Data collected included percent bittercress control at 7 and 15 DAT, bittercress TFW and TDW at 20 DAT, and a phytotoxicity rating from 1 to 5 on the liriope at 7, 15, 30, and 60 DAT (1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = heavy injury, and 5 = plant death).

Experiment 3. One-gallon containers were filled with a medium consisting of pinebark and sand (7 : 1, v/v) amended with 8.9 kg m^{-3} (15 lb yd^{-3}) of Osmocote 17N-7P-12K , 3.0 kg m^{-3} (5 lb yd^{-3}) of dolomitic limestone, and 0.9 kg m^{-3} (1.5 lb yd^{-3}) of Micromax micronutrients. Containers without plants were overseeded with bittercress

on 15 May 1998. The following herbicides were applied on 10 June 1998 when bittercress plants were between 0.5 to 2 cm (0.2 to 0.8 inches) tall: Manage™ at 0.02, 0.03, and 0.06 kg ai ha^{-1} (0.02, 0.03, and 0.06 lb ai $acre^{-1}$) ; Image™ at 0.07, 0.15, and 0.29 kg ai ha^{-1} (0.06, 0.13, and 0.25 lb ai $acre^{-1}$) ; Trimec Southern™ at 0.16, 0.31, and 0.66 kg ai ha^{-1} (0.14, 0.28, and 0.57 lb ai $acre^{-1}$); and Gallery™ at 0.58, 1.2, and 2.3 kg ai ha^{-1} (0.5, 1.0, and 2.0 lb ai $acre^{-1}$). In addition, six single plant replications of 'Midnight Flare' azalea (*Rhododendron* 'Midnight Flare') and China Girl™ holly (*Ilex* China Girl™ holly) were treated to evaluate injury to azalea and holly.

Data collected included percent bittercress control at 7 and 15 DAT, bittercress TFW and TDW at 20 DAT, and phytotoxicity to holly and azalea at 7, 15, 30, and 60 DAT (1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death).

Data from all tests were subjected to analysis of variance. Contrast analysis was used to determine if there was a significant difference between the herbicides and the control, and regression analysis was used to determine if there was a rate response within a herbicide.

RESULTS

In Experiment 1 at 15 DAT, all rates of Manage™ and the two lower rates of Image™ resulted in bittercress weed counts lower than the nontreated control. At 50 DAT, all rates of Manage™ and Image™ resulted in 100% bittercress control, while Action™ and Resource™ provided poor control with all rates (data not shown).

However, all Manage™ and Image™ treatments resulted in injury ratings higher than the nontreated controls. Injury was characterized by necrosis and leaf rotting in the plant crown. This caused about 50% reduction in TFW of liriope compared to nontreated controls. Top fresh weight of variegated and 'Big Blue' liriope from Manage™ treatments were 4.6 and 7.8 g, respectively, 3.7 and 7.2 g from Image™ treatments, and 10.1 and 14.6 g for nontreated controls. These data are in contrast to Hurt and Vencill, who reported no visual injury to liriope 4 weeks after treatment from Manage™ and Image™ applications (this test used similar Image™ rates to those used by Hurt and Vencill (1994), however, our Manage™ rates were higher).

In Experiment 2, Manage™ and Image™ rates were lowered to determine if injury could be reduced and bittercress control maintained. At 15 DAT with 'Big Blue' liriope, only the middle and high rates of Gallery™ provided 90% bittercress control or greater, with control increasing linearly and quadratically with increasing rate (Table 1). Bittercress control also increased linearly with Manage™, however, 83% control with the highest rate was considered unacceptable. In the variegated liriope where the bittercress had not begun to flower, bittercress control was generally better. For example, the middle and high rate of Manage™, the high rates of Image™ and Trimec Southern™, and the middle and high rate of Gallery™ all provided 90% control or greater. Control increased linearly with increasing Manage™ rates, and increased linearly and quadratically with increasing rates of Image™ and Gallery™. There was no rate response with the Trimec Southern™ treatments. Improved bittercress control in variegated liriope was likely due to the smaller, nonflowering bittercress, compared to flowering bittercress in 'Big Blue' liriope containers.

At 30 DAT, the highest Image™ rate and all rates of Trimec Southern™ caused statistically significant, though slight, injury to 'Big Blue' liriope. On a rating scale of 1 - 5 where 1 = no injury, the highest Image rate received an injury rating of 1.5,

Table 1. Postemergence bittercress control in container-grown *Liriope muscari* and *Rhododendron* 'Midnight Flare' landscape crops.

		Experiment 2				Experiment 3			
		Bittercress control (%)		Bittercress TFW[y](g)		Bittercress control (%)		'Midnight Flare' injury[z]	Bittercress TFW[x] (g)
	Rate	15 DAT				7 DAT	15 DAT		
Treatments	lb ai acre^{-1}	'Big Blue'	'Variegata'	'Big Blue'	'Variegata'				
Control		0.0	0.0	16.5	10.3	0.0	0.0	1.0	3.29
Manage™	0.02	14.0	66.0	3.4	1.9	9.0	89.0	1.0	1.68
	0.03	55.0	90.0	2.2	2.3	7.0	89.0	1.0	0.53
	0.06	83.0	99.0	0.7	0.0	48.0	99.0	1.0	0.14
Significance[w]		L^{*}	L^{*}	NS	NS	Q^{*}	NS	NS	NS
Image™	0.03	3.0	5.0	9.2	5.2	56.0	93.0	2.0	0.24
	0.06	6.0	73.0	7.4	1.1	61.0	99.5	2.2	0.01
	0.13	43.0	95.0	2.3	0.2	82.0	99.8	2.7	0.02
Significance		NS	$L^{***}Q^{***}$	NS	$L^{***}Q^{**}$	NS	NS	L^{*}	NS
Trimec Southern™	0.14	55.0	58.0	3.4	2.1	90.0	100.0	3.2	0.00
	0.28	50.0	77.0	2.1	0.8	100.0	100.0	3.2	0.00
	0.57	72.0	97.0	0.8	0.1	100.0	100.0	4.3	0.00
Significance		NS	NS	NS	NS	L^{*}	NS	NS	NS

Treatments	Rate lb ai acre^{-1}	Experiment 2 Bittercress control (%) 15 DAT 'Big Blue'	'Variegata'	Bittercress TFW^{y}(g) 'Big Blue'	'Variegata'	Experiment 3 Bittercress control (%) 7 DAT	15 DAT	'Midnight Flare' injury^{z}	Bittercress TFW^{x} (g)
Gallery™	0.5	29.0	78.0	5.0	1.6	82.0	94.0	1.0	0.07
	1.0	90.0	98.0	0.8	0.2	85.0	100.0	1.0	0.00
	2.0	98.0	100.0	0.2	0.0	84.0	100.0	1.0	0.80
Significance		$L^{***}Q^{***}$	$L^{***}Q^{**}$	$L^{***}Q^{***}$	$L^{***}Q^{**}$	NS	$L^{*}Q^{*}$	NS	NS

[z]Scale from 1 to 5 where 1 = no injury, 2 = slightly injury, 3 = moderate injury, 4 = severe injury, 5 = plant death.
[y]Top fresh weight recorded 15 DAT (July 1, 1998).
[x]Top fresh weight recorded 20 DAT (June 30, 1998).
[w]Indicates a linear or quadratic response from the rate applied.
*Significant P ≤0.05
**Significant P ≤0.01
*** Significant P ≤0.001

and the low, medium, and high rates of Trimec Southern™ received a rating of 1.3, 1.3, and 2.0, respectively. Manage™ and Gallery™ caused no injury to liriope at any rate. There was no injury to variegated liriope (data not shown).

In Experiment 3 at 7 DAT, only the three rates of Trimec Southern™ provided 90% bittercress control or greater. However, by 15 DAT, the low and middle rates of Manage™ provided 89% control, and all other treatments provided greater than 90% control. At 15 DAT, only Gallery™ provided a linear and quadratic increase in percent control with increasing rates.

Manage™ and Gallery™ caused no injury to 'Midnight Flare' azalea or China Girl™ holly at any rate throughout the experiment. By 30 DAT, comparison of injury ratings (scale from 1 to 5) from Image™ and Trimec Southern™ with contrast analysis showed that both Trimec Southern™ (3.6) and Image™ (2.0) caused significant injury to azalea when compared to nontreated controls (1.0). Injury from Image™ increased linearly with increasing rate, and was first detected at 15 DAT and was characterized by chlorosis and red spotting of the new foliage. By 30 and 60 DAT, signs of injury were more pronounced and were characterized by stunting and rosetting of new foliage. Injury from Trimec Southern™ was detected at 7 DAT and became progressively worse. It was characterized by twisting of the stems near the apical tip, red coloration of the foliage throughout the plant, early defoliation, and eventual plant death. No injury from any treatment was detected on the China Girl™ holly.

DISCUSSION

Our results show that effective postemergence bittercress control can be obtained with little or no phytotoxicity by using spray applied herbicides. Gallery™ provided excellent bittercress control at the recommended rate with no injury to liriope, azalea, or holly. However, our tests also indicated that postemergence control from Gallery™ could be dependent on the size and growth stage of bittercress. This would agree with reports received from growers that control varies from application to application. Nonetheless, postemergence bittercress control from Gallery™ has great potential due to its broad label for use in container-grown landscape crops.

The other herbicides tested showed promise, but had limitations due to injury. Manage™ at the recommended rate provided good bittercress control with slight injury to liriope, and no injury to azalea and holly. Image™ at low rates (0.03, 0.06, and 0.125 lb ai $acre^{-1}$) controlled bittercress with no injury to liriope and holly, but caused significant injury on azalea. Trimec Southern™ gave excellent control of bittercress, but caused slight injury to liriope and severe injury to azalea.

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The Plant Introduction Program of Chicagoland Grows®, Inc.

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INTRODUCTION

In recent years, there has been an increased level of interest among the green industry in the development and activities of regional plant introduction programs. A number of botanic gardens, arboreta, academic institutions, and public as well as private research facilities, have joined forces with the nursery industry to select and introduce new plant cultivars for the landscape.

Following in the footsteps of recognized plant introduction programs at the University of British Columbia Botanical Garden in Vancouver, Canada, and the University of Minnesota Landscape Arboretum in Chanhassen, Minnesota, two botanical institutions and the nursery industry in the Chicago area have established a successful plant introduction program called Chicagoland Grows®.

The Program's mission is to introduce new and recommended plant cultivars that are well adapted to growing conditions of the Upper Midwest.

PROGRAM HISTORY

In March of 1986, Dr. Roy L. Taylor, Director of the Chicago Botanic Garden, initiated discussions with representatives from The Morton Arboretum and the Ornamental Growers Association of Northern Illinois (OGA), to develop a plant introduction program for the Chicago region. Following a series of planning and organizational meetings, a nonprofit corporation, Chicagoland Grows®, Inc., was established among the three partners. This unique collaboration combined the resources and research facilities of the two botanical institutions, with the knowledge and growing experience of 18 field and container production nurseries located within an 176 km (80 mile) radius of Chicago.

In addition to the partnership with OGA, the program currently works with a network of 10 contract liner producers in four states, and 41 licensed growers in 19 states, for the production and sale of plants approved for release. In 1999, the program will finalize a formal agreement with Selection New Plants (SNP), a consortium of growers based in D'Anjou, France, for the sale and sublicensing of released plants in the United Kingdom and Western Europe.

PROGRAM STRUCTURE AND INTERNAL OPERATIONS

Representatives from the three corporate partners participate on the Executive Committee and operational committees. The Executive Committee is responsible for establishing policies and providing overall program management. The other committees (Research and Development, and Production and Scheduling) are

responsible for selecting potential new plants, and systematically reviewing their progress through all phases of evaluation and production, until approved for release. Eligible new releases are registered with the Federal Patent and Trademark Office, followed by the assignment of royalty and marketing fees. All income generated from the sale of registered plants is used to support the Program's operating expenses.

PLANT SELECTION, EVALUATION, AND PRODUCTION

In order for a plant to be considered by the Program, its origin, history, and general characteristics must be documented prior to review by the operational committees. If a plant is approved by the operational committees, it is assigned an accession number and propagated for initial distribution to a network of ten regional evaluation cooperators. Evaluation sites are concentrated in Illinois, Iowa, Minnesota and Wisconsin, where the plant is tested under a range of conditions.

Upon completion of the initial evaluation phase, stock plants are distributed to contract liner producers to determine the most efficient and economical propagation methods for large-scale production. Liners produced by these nurseries are then sold to OGA members and licensed growers. As finished stock inventories are established among licensed nurseries, a final committee review is completed, and the plant is assigned a market release date.

PROMOTION AND MARKETING

Once a market release date is established, a promotional schedule and marketing plan are developed. Although testing has ensured that the plant is worthy of introduction, the potential customer must be educated about its attributes and uses. This is accomplished through publication of *Plant Release Bulletins*, articles, and ads in trade publications, promotion at regional trade shows and field days, and presentations at conferences, seminars, and educational workshops for wholesale and retail merchandisers. The marketing goal is to pique consumer interest when large quantities of the plant are available, promoting a rapid and thorough distribution of the plant. As more consumers become aware of the plant's attributes and uses in the landscape, demand increases; growers in turn will be able to justify increased production to meet the demand.

RECOMMENDED PLANTS FOR THE SOUTHERN UNITED STATES

To date, the program has released and promoted nine plants. An additional 18 plants have met the standard for release and promotion, but market release dates have yet to be assigned. Based upon evaluation data and observations of performance under nursery and landscape conditions, the following Chicagoland Grows® plants are recommended for use in the southern U.S.A.

CURRENT PLANT INTRODUCTIONS (PLANT RELEASE BULLETINS ARE AVAILABLE)

***Acer* ×*freemanii* 'Marmo' (Marmo Freeman maple).** Marmo was selected from the collections of The Morton Arboretum, Lisle, Illinois. Characteristics include a vigorous growth rate, a strong central leader, excellent branching character, and a uniform upright habit. Fall color is an interesting mottled blend, ranging from

combinations of red and green, to burgundy, yellow, and gold, depending on temperature changes and site conditions. Marmo is being promoted as a more ornamental and desirable alternative to *A. saccharinum,* and a more adaptable alternative, in heavy clay soils, to most cultivars of *A. rubrum*. The parent tree, planted at The Morton Arboretum in the mid-1920s, measured 21 m (70 ft) in height with a 10.5 m (35 ft) lateral spread.

***Betula nigra* 'Little King', Fox Valley® river birch.** Selected by King Nursery, Oswego, Illinois, for its uniform compact habit, adaptability to varied soils, good heat/drought tolerance and disease/pest resistance, and ornamental exfoliating bark. Bark character becomes evident at an early age, exhibiting colorful patterns of cinnamon-red, and pale salmon on trunks and main branches. Grows 2.4 to 3 m (8 to 10 ft) in height with an equal or greater lateral spread in 10 years.

***Buxus* 'Glencoe', Chicagoland Green® boxwood.** Selected by the Chicago Botanic Garden, Glencoe, Illinois, for excellent cold-hardiness, a uniform broad-oval habit, good winter color, and ease of propagation. Grows 0.9 to 1.2 m (3 to 4 ft) in height with a 1.5 m (5 ft) lateral spread in 15 years.

***Euonymus alatus* 'Timber Creek', Chicago Fire® euonymus.** Selected by Timber Creek Nursery, Woodstock, Illinois, for excellent cold-hardiness and heat/drought tolerance, fine-textured branching, and bright red fall color. As the plant matures, young twigs and branch tips become an attractive mahogany-red. Established landscape specimens often produce abundant quantities of ornamental orange-red fruit, lasting into early winter. Grows 8 to 10 ft (2.4 to 3 m) in height with a 1.8 to 2.4 m (6 to 8 ft) lateral spread in 15 years.

***Fraxinus americana* 'Tures', Windy City™ white ash.** Selected by Matt Tures Sons Nursery, Huntley, Illinois, for its uniform upright habit and resistance to frost-cracking. Other attributes include a strong central leader, attractive semi-glossy foliage, and good fall color. Fall color is an attractive blend of bronze and burgundy, highlighted by copper, orange, gold, and yellow accents. The upright habit provides for a greater range of landscape applications due to reduced branch spread. Mature size is estimated at 12.2 to 15.2 m (40 to 50 ft) in height with a 7.6 to 9.1 m (25 to 30 ft) lateral spread.

Arrowwood Viburnum Selections

All three selections were made by Ralph Synnestvedt, Sr., of the Synnestvedt Nursery Company, Round Lake, Illinois. Arrowwood viburnums grown from seed are highly variable. Our clonal selections are consistent in form and ornamental attributes.

***Viburnum dentatum* 'Morton', Northern Burgundy® arrowwood viburnum.** Selected for its uniform oval-rounded habit, attractive foliage, strong branching, and wine-red to burgundy fall color. Creamy white flowers appear in early to mid-June, followed by ornamental clusters of blue-black fruit in autumn. Extremely wet sites should be avoided. Grows 2.4 to 3 m (8 to 10 ft) in height with an equal lateral spread in 10 years.

***Viburnum dentatum* 'Ralph Senior', Autumn Jazz® arrowwood viburnum.** Selected for its uniform upright-oval habit, and an impressive kaleidoscope blend of

yellow, orange, red, and burgundy fall colors. Creamy white, flat-topped flowers appear in mid-to-late May, followed by ornamental clusters of blue-black fruit in autumn. Exhibits excellent adaptability to a broad spectrum of soil types. Grows 2.4 to 3 m (8 to 10 ft) in height with a 1.8 to 2.4 m (6 to 8 ft) lateral spread in 10 years.

***Viburnum dentatum* 'Synnestvedt', Chicago Lustre® arrowwood viburnum.** Selected for its upright, round habit, and glossy dark green foliage. Creamy white flowers appear in mid-to-late June, followed by ornamental clusters of blue-black fruit in autumn. Extremely wet sites should be avoided. Grows 3 to 3.6 m (10 to 12 ft) in height with an 2.4 to 3 m (8 to 10 ft) spread in 10 years.

LIMITED RELEASES (MARKET RELEASE DATES TO BE ANNOUNCED)

***Acer miyabei* 'Morton', State Street® Miyabe maple.** Selected from the collections of The Morton Arboretum, Lisle, Illinois, for excellent branching character, a uniform broad-pyramidal habit, excellent heat/drought tolerance, clean foliage, and good yellow fall color. The parent tree, planted at The Morton Arboretum in the 1920s, measures 18 m (60 ft) in height with a 15 m (50 ft) spread at the base. This selection is a more cold-hardy alternative to *A. campestre* in northern growing conditions, and a more heat/drought resistant alternative to *A. platanoides.*

***Diervilla rivularis* 'Morton', Summer Stars™ Georgia bush-honeysuckle.** Selected from the collections of The Morton Arboretum, Lisle, Illinois, for its dense, compact habit, and an impressive display of sulfur-yellow flowers in late June to early July. Fifteen-year-old plants are 0.9 m (3 ft) in height with a 1.2 m (4 ft) lateral spread.

***Malus* 'Hub Tures', Spring Sensation™ crabapple.** Selected by Hub Tures & Sons Nursery, Kingston, Illinois, from open-pollinated *M. sargentii.* Characteristics include a dense, wide-spreading habit, excellent disease resistance, dark rose to rose-magenta flower buds, abundant pink-tinted flowers (with excellent weather resistance), and attractive red-tinted foliage. Fruit production is minimal to none. Grows 2.4 to 3 m (8 to 10 ft) in height with a 3 to 3.6 m (10 to 12 ft) lateral spread in 15 years.

***Rhus copallina* var. *latifolia* 'Morton', Prairie Flame™ shining sumac.** This male clone was selected from the collections of The Morton Arboretum, Lisle, Illinois, for its dwarf compact habit, clean glossy foliage, attractive yellowish-white flowers in late July, and brilliant red-orange fall color. The parent plant originated from seed collected in the Iroquois County Conservation Area, near the Illinois/Indiana border. Matures at 1.2 to 1.8 m (4 to 6 ft) in height, spreading laterally from the roots, forming dense colonies.

***Ulmus* 'Morton', Accolade™ elm.** Selected from the collections of The Morton Arboretum, Lisle, Illinois, for its graceful vase-shaped habit, vigorous growth rate, dark green glossy foliage, excellent disease and pest resistance, excellent drought tolerance, and good yellow fall color. The parent tree, known to be a hybrid of *U. japonica* × *U. wilsoniana,* measures 18.2 m (60 ft) in height with a 12.2 m (40 ft) lateral spread. This clone originated from seed distributed in 1924 by the Arnold Arboretum, Boston, Massachusetts.

***Ulmus* 'Morton Glossy', Triumph™ elm.** This selection resulted from a controlled cross conducted by Dr. George Ware at The Morton Arboretum between Vanguard™ elm and Accolade™ elm. Attributes include lustrous dark green foliage, good upright form, strong branching, and excellent disease and pest resistance.

***Viburnum rufidulum* 'Morton', Emerald Charm™ viburnum.** Selected from the collections of The Morton Arboretum, Lisle, Illinois, for its cold-hardiness, glossy foliage, excellent flower display, and superb burgundy fall color. This clone originated from seed collected in Webb City, Missouri. Mature size is 3 to 3.6 m (10 to 12 ft) in height with an 2.4 to 3 m (8 to 10 ft) lateral spread.

FUTURE GROWTH OF THE PROGRAM

In order for the Program to achieve long-term growth and expansion into new markets, it must diversify the palette of new plants being offered. To accomplish this, breeding programs have been established with herbaceous perennials at the Chicago Botanic Garden (*Baptisia, Boltonia, Echinacea, Liatris,* and *Penstemon*), and with the woody plant breeding program at The Morton Arboretum, which has expanded to include small stature trees (primarily *Ulmus* and *Acer*), suitable for street and parkway plantings. Another important component of long-term goals involves the selection and eventual introduction of new plants from collecting trips. Thus far, the Chicago Botanic Garden has participated in trips to South Korea, Siberia, and Far East Russia. The Morton Arboretum has participated in the previously mentioned trip to Siberia, as well as several trips to the People's Republic of China.

The ultimate goal is a timely and regular introduction of a palette of groundcovers, perennials, trees, and shrubs with excellent adaptability and ornamental attributes for the landscapes of the Midwest and beyond.

Successful Japanese Maple Grafting: From a Grafter's Apprentice

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INTRODUCTION

Japanese maples (*Acer palmatum*) are among the aristocrats in our landscapes. We often consider them as status symbols in our yards. When a plant reaches this level of celebrity, it allows nurseries to get a little added value for their efforts. Japanese maples seldom fall into the category of hollies, junipers, or azaleas. These plants are often specified by the hundreds by landscape designers. Typically Japanese maples are specimen trees or shrubs with only one or two plants specified per landscape job. However, with some additional marketing and landscape demonstrations, mass planting of 'Tamukeyama' or 'Waterfall', a screen row of 'Moonfire' or a small border hedge of 'Shaina' could be a possibility. Like many of our other plant groups, there is probably a Japanese maple with a form, texture, size, color, and site tolerance to fit almost any landscape requirement. There are opportunities for imaginative, artistic nursery producers to create some unique plants by training limbs into artistic forms, or using the vast array of cultivars to select plants to put on standards such as 'Shaina' or 'Koto No Ito'. Opportunities also exist to develop container gardens with Japanese maple cultivars as the center of attention for patio and business entrances. Production of bonsai plants is also a possible niche.

The toughness of Japanese maples belies its price. They are very drought tolerant when established, with few insect and disease problems. Most Japanese maples do not do well in wet sites and many cultivars suffer in the South when planted on southern or southwest exposures. This paper is about propagation of these special plants with an emphasis on grafting.

This information is not my own success story but comes from my observations and view as an apprentice grafter. I have done hundreds of grafts whereas the individual I worked with performs several thousand grafts each year at his nursery and as a contract grafter for other nurseries. Harold Johnston of Johnnies Pleasure Plants, in Tallassee, Alabama, has a small back yard mailorder nursery with a collection of close to 300 cultivars, including a recently patented cultivar he released under the name of 'Beni Shien' ('Purple Smoke'). It is true that there is an art and science to grafting. I learned the science at school but I needed a professional grafter and repetition to begin to learn the "art" and "feel" of grafting. I am not sure if the "art" is taught as much as it is absorbed through observation and practice.

TOOLS OF THE TRADE

The tools of the trade include a sharp grafting knife, sharpening stone, leather strap, 15-cm (6-inch) budding rubbers or grafting tape, hand pruning shears, a 20-cm (8-inch) concave bonsai cutter, small cooler, 1 qt zip-lock [5.1 cm × 15 cm (2 inch× 6 inch) or 5.1 cm × 20 cm (2 inch × 8 inch)] 2-ml plastic bags, twist ties or clothes pins, plant or pot tags, fine point Sharpie® pen or water-proof marker, comfortable back supporting chair, work bench or grafting table, and a shaded area or comfortable place to work.

A very sharp knife made of good steel that will hold an edge is crucial for obtaining a smooth cut. Ragged cuts from dull knifes can cause poor contact and graft failure. Not being a knife expert, I went to A.M. Leonard Tool catalogue (phone:800-543-8955) and bought one of their most expensive Tina 640T grafting/budding knifes for around $50. This reasoning has worked well for me. Some people use razor blades and exchange the blades as they become dull. The plastic bags along with the twist ties are used to form a mini-greenhouse to cover the scion and graft, and can be purchased from National Bag Company, Inc. (phone:800-247-6000) or Consolidated Plastics Company, Inc (phone: 800-352-1000). The bonsai concave cutter has been very helpful in removing the understock after the graft has "taken". It allows you to make a closer, more precise cut. This tool can be purchased from John Vermeulen and Son, Inc., Neshanic Station, New Jersey for $35 (phone:800-824-2306). One tool that another individual, Robert Eiland, with 30-years grafting experience relies on is a micro visor (MFD Enterprises, Kerryville, Texas, phone:800-210-6662, which costs $35). This is a big help if you wear reading glasses and have to constantly tilt your head back to see what you are doing. It also helps with the smaller scion wood. The other items are obvious or will become apparent with further description of the process.

UNDERSTOCK

One of the first steps in grafting Japanese maples is to get a source of understock. Harold either produces his from seed or purchases liners from Heritage Seedlings in Oregon. Seeds are collected in October just as wings begin to turn brown, but before the seed turns brown and dries out. Seeds are placed in hot water and soaked as water cools for about 48 h. They are then placed in Zip Lock plastic bags containing slightly moist sphagnum peat moss, labeled with the date and seed name and put into a cooler at temperatures between 0.6 to 4.4C (33 and 40F). Stratification continues for 100 to 130 days. Seed is broadcast and planted 0.6 to 1.3 cm (¼ to ½ inch) deep in 6.4 cm (2.5 inch)deep trays in February and placed under mist (6 sec every 10 min) in the greenhouse. The medium used is pine bark or peat and perlite (1 : 1, v/v). As seedlings germinate, they are fertilized with 150 to 200 ppm of Peter's 20N-20P-20K soluble fertilizer, once or twice per week. Seedlings are ready for transplanting by mid April and are transplanted to 10-cm (4-inch) or 3.9-liter (1-gal) containers and placed pot to pot under 50% shade. With fertilization and care, many of these seedlings are ready for grafting by August, which continues through February and March.

GRAFTING

Harold has tried many different methods of grafting but has settled on a side or side veneer graft on 1- to 4-year-old seedlings. He has used clonal rooted cuttings as understock but has not noticed a clear advantage over seedling rootstock. In a survey of several nurseries in England, France, and Italy, M. Studd (1997) reported successful field and container grafts using whip and tongue, shield, and side veneer grafts with graft wax. Vertrees (1992) reported successful grafts through chip budding, patch budding, and T-budding. Some Oregon nurseries graft in the field using a stick bud with 2 to 3 nodes. As with many other nursery practices, there are numerous acceptable production methods which achieve successful results. The method used depends on personal preference, the market, how it fits a nursery production system, climate, and other site conditions at the nursery.

Depending on the cultivar, Harold has found that he can begin grafting as early as late July when scion wood matures to a semihardwood condition. Harold continues to graft through March by using understock kept in an unheated greenhouse. Scion wood for February and March grafting is collected and submersed in water. Excess water is shaken off and put in a labeled zip lock bag. Scionwood can last up to 2 months or more in storage. Harold will often go through his stockplants and collect a hundred or more scions, stuff them in his pocket and take them to the grafting bench for grafting. I need all the insurance I can get, so I go by the book and collect the scions, put them in bags with labels and then place them in a cooler to take to the grafting bench. Harold's method does show that you have a large margin for error in collecting scionwood. Harold grafts onto understock in 10.2-cm (4-inch), 3.8-liter (1-gal), and 11.4-liter (3-gal) containers. The rootstock range from 0.6 cm (inch) diameter to 1.5 to 1.8 m (5 to 6 ft) tall trees. The larger trees are top worked with weeping cultivars or shrub cultivars to be used on a standard. As many as 8 to 10 grafts may be used on a large, branched understock to get a well branched, quick-maturing, weeping plant. Harold also creates vertical specimens by grafting up and down the stem using the same or different color and texture cultivars.

Harold's grafting is similar to textbook side veneer instructions. He locates a long, straight, smooth internode (either high or low on the stem depending on the cultivar and the desired results) and makes a shallow cut (15° or less depending on the thickness of the stem) about 2.5 to 3.8 cm (1 to 1.5 inches) with a sharp knife. He angles in a little at the base of the cut to get greater tension on the scion when it is placed on the understock. The cut should be done with a single stroke. Try to avoid whittling. Harold keeps his resulting flap on the understock. I like to remove about two-thirds of the flap so that I can better view the cambium layer and align my graft. After removing all but one or two leaves from the scion, the same shallow cut is made at the base of the scion wood with an additional cut of 45° made on the lower 0.6- to 1.3-cm (¼ to ½ inch) opposing side. This forms a wedge to fit under the flap at the base of the understock cut. The short cut side of the scion is inserted under the flap on the understock and aligned with the scion at the edge so that the cambium matches. On large understock, the cambium layer is further from the edge. On finer scions like 'Filagree Lace', be careful to move the scion closer to the edge and not pull it out of position when wrapping.

Although grafting tapes can be used, Harold prefers budding rubbers. This is because of the tension you can apply and the ease of removal. If you fail to remove the budding rubbers, they often rot with no damage to the graft. Everyone develops their own style of wrapping. Harold begins at the base of the graft and secures the end of the budding rubber by overlapping the end during the first two wraps. He then adjusts the scion and makes the next wrap at the top of the graft. This secures the scion in position. He continues to wrap down the stem with good tension until he reaches the base. However, I continue to wrap from the bottom to the top and adjust the scion as I go. The final tie is completed by wrapping the budding rubber over the tip of your fingernail of your index finger on the last wrap around the stem. As you complete the last wrap, wedge the budding rubber beneath your index finger and release the tension. Pull your index finger back along the stem rolling the wedged budding rubber under the portion on top of your finger. The budding rubber rolls off your fingernail and pinches the tailing end, thus completing the tie. However, this is much easier said than done! The graft is completed by taking a plastic bag, placing

in over the scion, and pulling it down over the graft. This is secured by a twist tie or a clothes pin. It is an extra step but pulling the bag over the scion is easier if you make a 2.5- to 3.8-cm (1- to 1.5-inch) slit at the bag opening. The finished grafts are placed back under the shade structure. Within 7 to 10 days it is possible to tell if the graft has taken. The wood at the graft union dries and turns brown to black if the union fails. The bag should be left on the grafted plants for 3 to 4 weeks. Gradually untie, then remove the bags over the next 2 weeks. If dormant, leave the understock above the graft intact to protect the graft from accidental breakage. As buds begin to swell, cut the understock with the bonsai cutter and shift the plants to a larger container. Harold, with help, can graft between 500 to 600 plants in a day, and about 50% less if he is transporting all his plant materials and gathering his own scion wood.

GRAFTING TABLE

Our usual method of grafting was to grab a rickety chair, put it under a pecan tree, flip over a 5-gal paint or lard can, and bring a worn-out cardboard box of assorted grafting supplies along with a cooler of scionwood. We scattered 1-gal understock around the chairs to be grafted. This "system" was inefficient and hard on my back. I was always looking for where I put my knife or the marking pens. Grafted plants were mixed with the ungrafted plants. The chair was too tall for the bucket which made it hard to hold the understock at the right angle to make the proper cuts. My bad back, being inherently disorganized, and having a desire to make a day of grafting a comfortable and less frustrating experience, led me to the design of a grafting table (Figs.1, 2, 3, and 4). The grafting table design is pictured below along with a new industrial, adjustable chair or stool (Global Equipment Co., Suanee, Ga., phone:800-645-1232, Model CG252375, $252). The cost of the materials for constructing the table was about $70. A more thorough illustration of the design is available on our web site at www.ag.auburn.edu/landscape.

The table was designed for 1 or 2 people to graft at a time. The four pockets or trays in the center of the table hold your knife, sharpening stone, bags, twist ties, budding rubbers, markers, and tags. The trays can be removed when you are finished grafting and stored until next time. Your leather strap is attached to the table. Cut outs in the center are placed so you can get closer to your work. The shelf underneath the table allows you to take a 3.8-liter (1-gal) container and lean it against the table to give you a good 45° to make your cuts and wrapping easier. It also is a good place for your knife while you are wrapping the graft. Although it was not part of the design idea, the support board under the table was perfect for a footrest. The table is 1.1 m (3.5 ft) high which allows one to stand up and comfortably work in this position. You can put 30 to 40 1-gal, understock plants on one side. As you finish the grafts, you push them to the finished side. If you are grafting by yourself, there is a slide bar that pulls the hard to reach pots to you. After completing the 30 to 40 pots, you shift the completed grafts to a trailer and reload the understock. If you are fortunate enough to have some help, the other individual can keep the plants moved andrestocked. It is a simple system that has worked well. If you do not have a good shade tree or air conditioned room, you may need to add a large umbrella to the design.

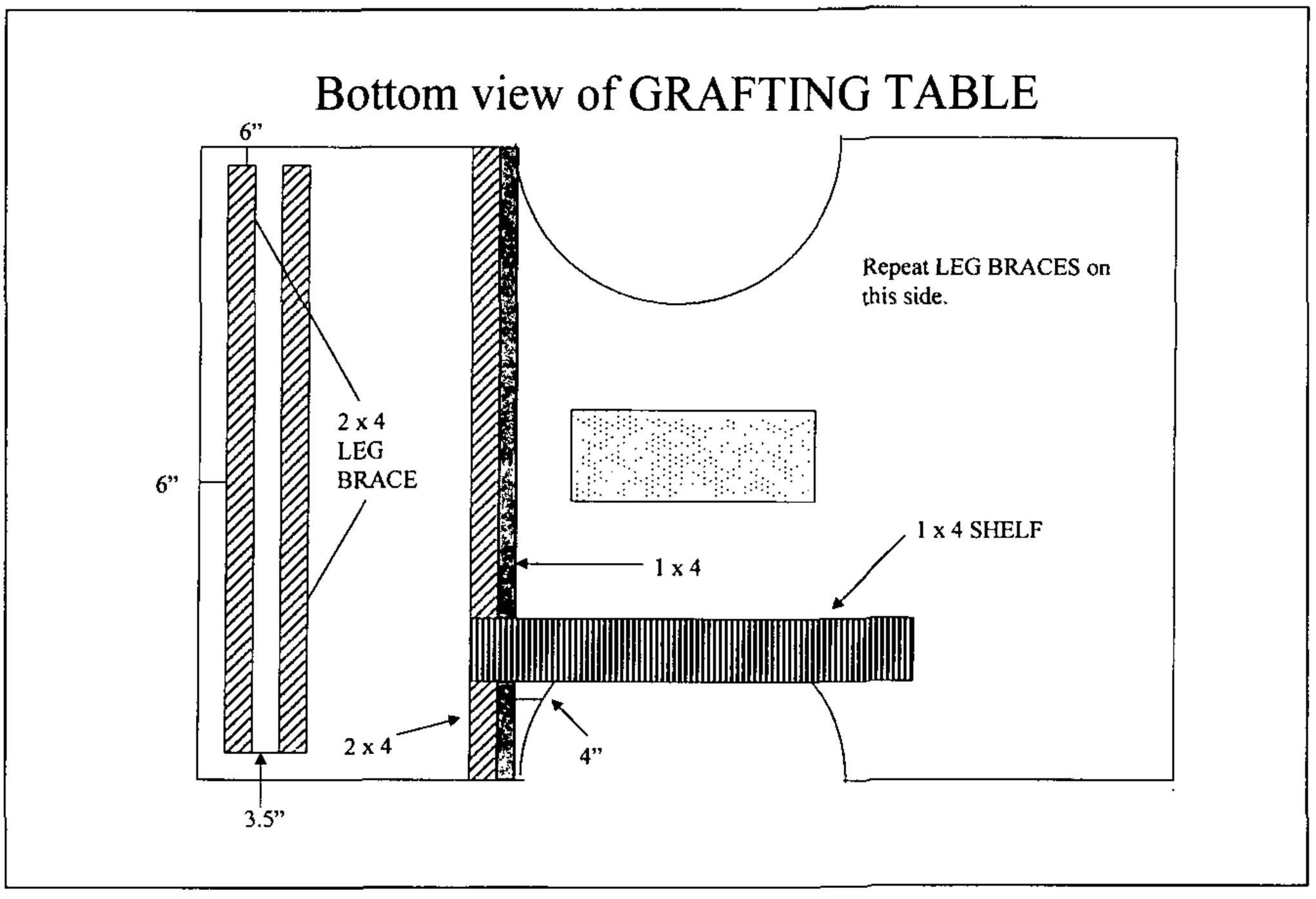

Figure 1. Bottom view of grafting table.

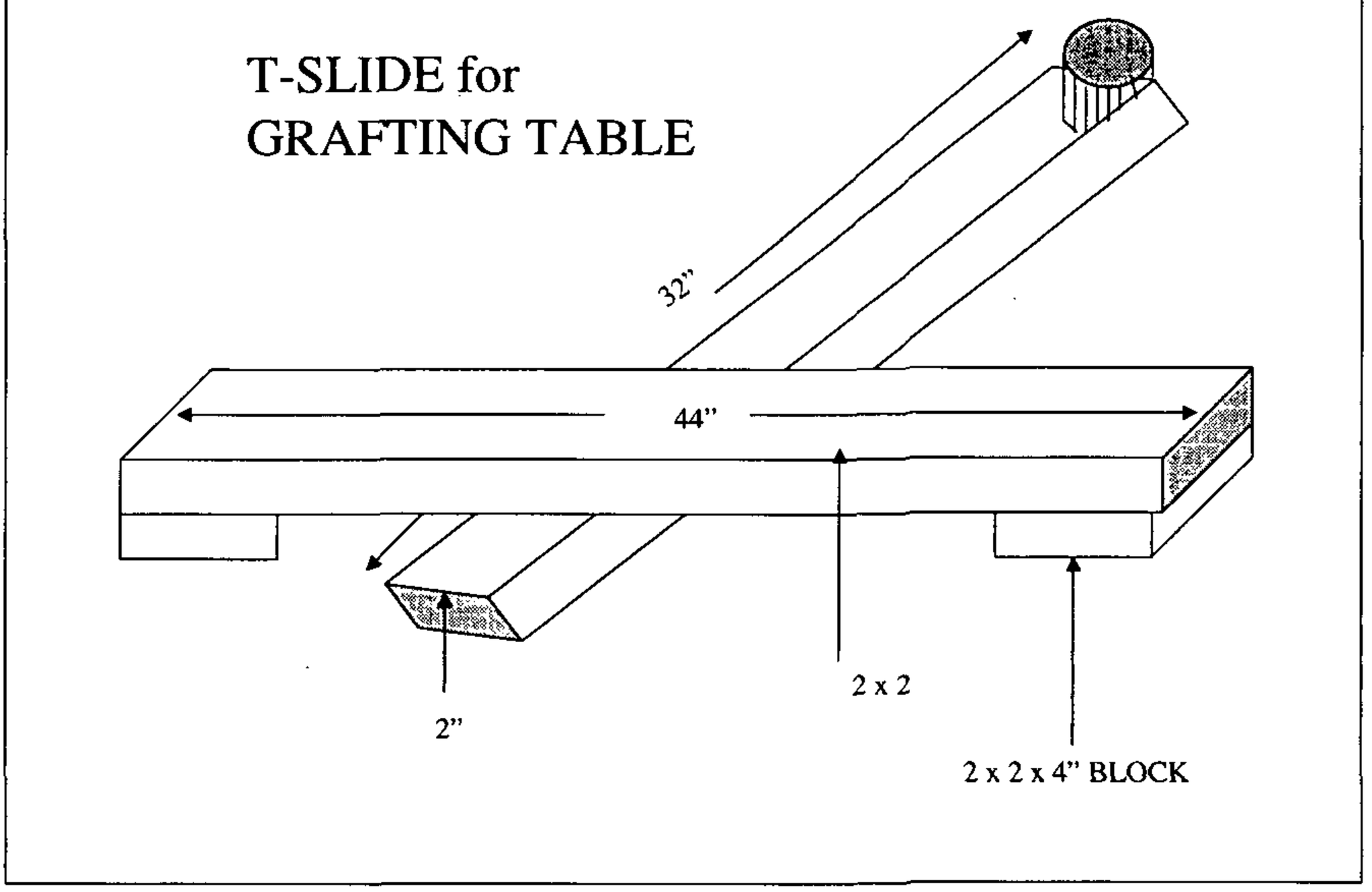

Figure 2. T-Slide for grafting table.

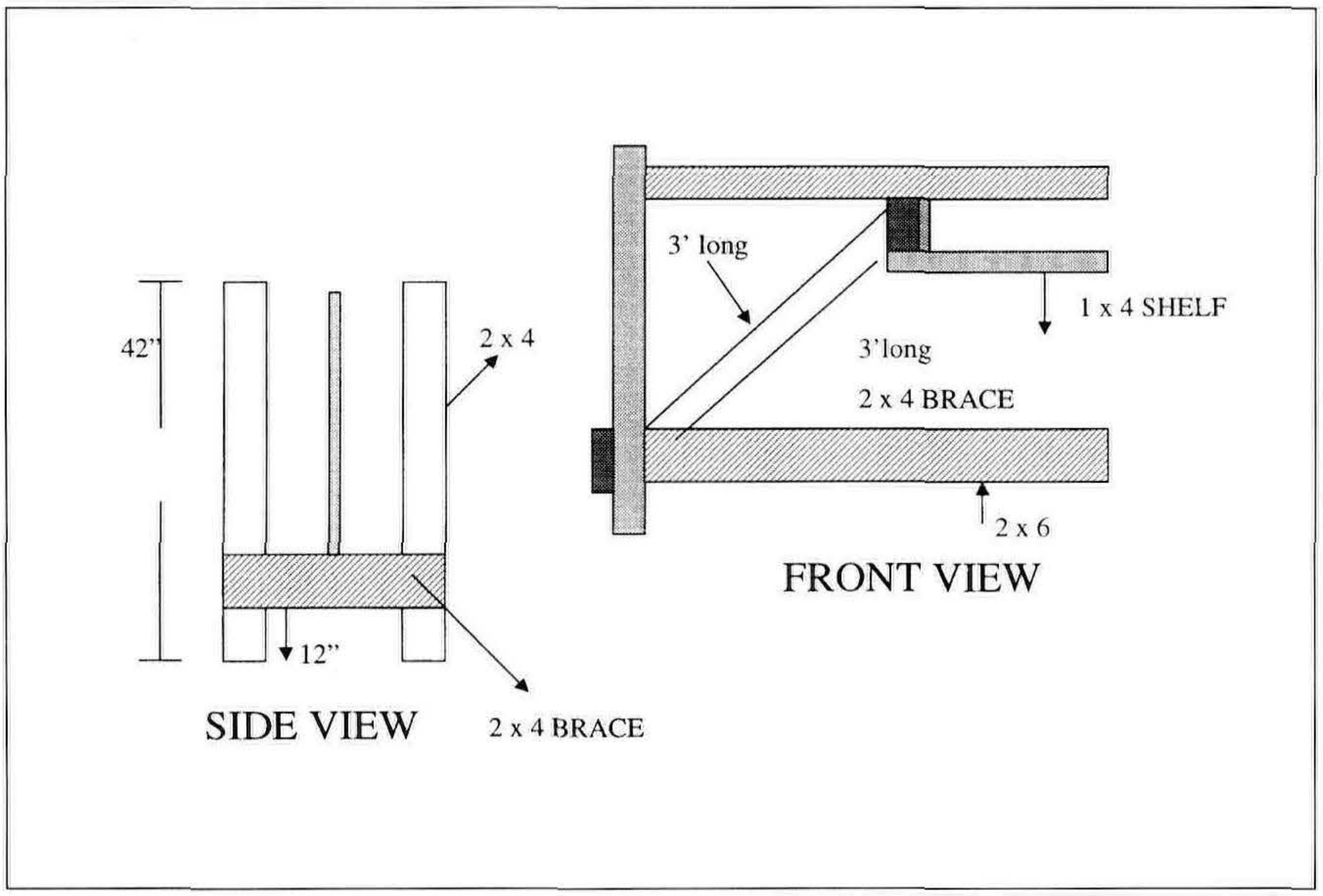

Figure 3. Side and front views of grafting table.

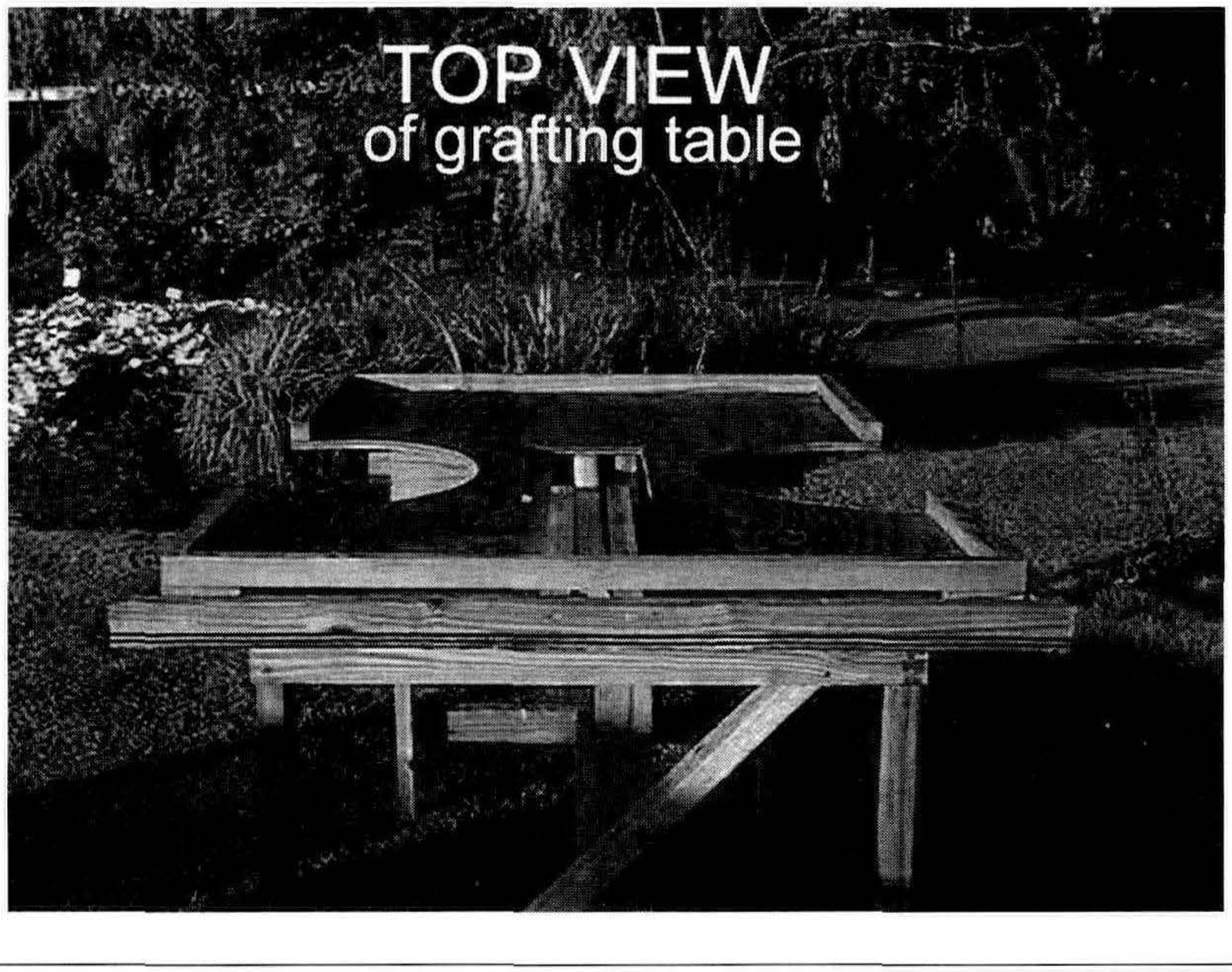

Figure 4. Photo of top view of grafting table.

CONCLUSION

Japanese maples are a special group of plants. With imagination, study, good marketing, and grafting practice, a nice niche can be carved out for a family nursery business.

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Plant Propagation Research at Greenleaf Nursery

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INTRODUCTION

Greenleaf Nursery has been propagating quality liners for 51 years. Currently at our Park Hill, Oklahoma location, we propagate about 900 taxa from cuttings, seed, division, or grafting. Cuttings constitute the largest source of new plant material with approximately 18 million on the 1998 propagation schedule. Due to the large numbers of cuttings we need to produce yearly, we are always conducting research in an effort to increase our rooting percentages.

EFFECT OF ALCOHOL VS. TALC WITH VARIOUS IBA RATES ON AUTUMN BLAZE® FREEMAN MAPLE

Greenleaf Nursery currently propagates cuttings from several *Acer* taxa that are commonly bought as tissue culture liners by other nurseries. These include *A. rubrum* 'Franksred', Red Sunset® red maple; *A.* ×*freemanii* 'Jeffersred', Autumn Blaze® Freeman maple, and *A. rubrum* Autumn Flame® red maple. In an attempt to determine optimum rooting compounds for *Acer* cuttings we compared the effect of four IBA rates prepared using 70% isopropyl alcohol or talc. Softwood *A.* ×*freemanii* 'Jeffersred', Autumn Blaze® Freeman maple cuttings were harvested on 17 July 1998 from trees growing in 26.5-liter (7-gal) containers. Cuttings were trimmed to 7 cm (2.8 inches) and bundled into groups of 25. The basal 2 cm (0.8 inch) of the cuttings were dipped into one of the following treatments: (1) alcohol control, (2) talc control, (3) 0.8% IBA in alcohol, (4) 0.8% IBA in talc (Hormex 8), (5) 1.6% IBA in alcohol, (6) 1.6% IBA in talc (Hormex 16), (7) 3.0% IBA in alcohol, and (8) 3.0% IBA in talc (Hormex 30). Cuttings receiving the alcohol treatments were given a 3-sec quick dip. Cuttings given the talc treatments were moistened with water prior to dipping, then gently tapped to remove excess powder. Cuttings were stuck in randomized blocks of 5 rows by 25 cuttings and repeated five times for a total of 625 cuttings per treatment. Cuttings were placed in sand and bark (1 : 1, v/v) medium under 63% shade and intermittent mist. Cuttings were misted for 6 sec each hour from 8:00 AM to 11:00 AM, then 6 sec every 12 min from 11:00 AM to 20:00 PM. On 25 Aug. 1998, rooted, live cuttings were counted (Table 1). Little or no difference was seen between the alcohol and talc used with 0.8 and 1.6% IBA concentrations. At 0 and 3% IBA, there was a difference in the effect of alcohol compared to talc. Alcohol with 0% IBA produced the lowest rooting percentage.

EFFECT OF AUXIN ON ROOTING OF 'BROADMOOR' JUNIPER

Based on auxin levels used in the past, a study was done to determine the optimum auxin level for rooting *Juniperus sabina* 'Broadmoor' cuttings. Since cuttings take many months to root without bottom heat, fungicide treatments were added to determine beneficial effects on controlling stem rot in the cuttings. On 20 Nov. 1997, 'Broadmoor' juniper cuttings were taken from 2-year-old plants in 3.8 liter (1 gal) containers, stripped of lower foliage, sorted into bundles of 25, then placed on a mist bench. Cuttings were given one of the following treatments: (1) 4.5% IBA talc + 1%

Cleary's 3336, (2) 3.0% IBA talc, (3) 3.0% IBA +3.0% NAA Talc + 1% Cleary's 3336, (4) 3.0% IBA + 1.6% NAA talc + 1% Cleary's 3336, (5) 2.5% IBA in alcohol, (6) 2.5% IBA in alcohol + 1% Cleary's 3336, (7) 2.5% IBA + 1.25 NAA in alcohol, (8) 1.9% IBA in alcohol, (9) 1.9% IBA liquid + 1% Cleary's 3336, or (10) control — without hormone fungicidal application. Treatments with talc applications had fungicide (1% Cleary's 3336), auxin, and talc mixed together.

Alcohol treatments were given an auxin dip and were then dipped into the dry fungicide (Cleary's 3336). The ten treatments were repeated four times with 2500 cuttings per treatment. Two randomized repetitions (50,000 cuttings) were placed in ground beds in one quonset and two randomized repetitions were place in another quonset. Cuttings were stuck in blocks of 50 rows with 50 cuttings per row. The medium was sand and bark (1 : 1, v/v). Phytotronic® mist clocks were set to allow misting at 4 sec every 15 min. Rooting percentages of the cuttings were estimated 15 July 1997.

It was concluded that 2.5% IBA in alcohol solution produced the highest mean rooting percentage and 1% Cleary's 3336 had no beneficial effect (Table 2). The 1% Cleary's 3336 appeared to have adversely affected rooting when used with the 1.9% alcohol treatment. There was no effect between the two locations of the repetitions.

INFLUENCE OF REMOVING THE TERMINAL PORTION OF CONIFER CUTTINGS

In the winter of 1996, an experiment was done to compare rooting of *J. chinensis* 'Hetzii Columnaris' and *J. procumbens* 'Green Mound' using different types of cuttings. Three-fourths of each cultivar had terminals cut out of the cuttings, while one-fourth had the terminal end left intact. The 'Hetzii Columnaris' cuttings without terminals were approximately 8 cm (3.2 inches) and cuttings with their terminals intact were approximately 18 cm (7.1 inches). The 'Green Mound' cuttings were 6 cm (2.4 inches) and 10 cm (3.9 inches), respectively. It was concluded that cuttings with their terminal ends intact rooted in higher percentages and in less time than ones with terminal removed.

In 1997, the experiment was repeated except that most of the plants had their terminals left intact and a smaller percentage had their terminals removed. The following cultivars were tested: *J. chinensis* 'Armstrong Aurea', *J.* ×*pfitzeriana* 'Armstrong' (syn. *J. chinensis* 'Armstrong'), *J.* ×*pfitzeriana* 'Old Gold', J. virginiana 'Hetz' [syn. *J. glauca* 'Hetzi' (understock)], *J. scopulorum* 'Skyrocket', *J. procumbens* 'Green Mound', *J. chinensis* 'Hetzii Columnaris', *J. procumbens*, *J. procumbens* 'Nana', and *J. procumbens* 'Variegata'. Results showed that leaving the terminal portion of the cuttings intact did not affect rooting in 'Old Gold', 'Armstrong', 'Hetz' understock, or 'Skyrocket' junipers. Leaving the terminal portion of the cutting intact enhanced rooting in 'Hetzi Columnaris', 'Green Mound', *J. procumbens*, 'Variegata' and 'Nana'. Since 'Skyrocket' did not get sheared, leaving the terminal provided a much larger, transplantable liner. There were no instances where uncut tops reduced rooting percentages. Cuttings with tops intact needed less mist and had less dieback and disease incidence.

WHITE PLASTIC BAFFLES VS. CLEAR PLASTIC BAFFLES ON WESTERN EXPOSURES

Plastic baffles 1.2 m (4 ft) high are used to reduce the wind's effect on mist patterns in our quonset propagation houses. During the hottest periods of summer, clear plastic baffles act like magnifying glasses, desiccating newly rooted cuttings along

west edges of the houses. In 1996, we conducted a comparison using 10 houses with white baffles on west sides and clear baffles on the east and compared them to houses with clear baffles on both sides. Results showed a 2.8 to 8.3C (5 to 15F) cooler propagation medium temperature on west sides with white plastic (compared to clear plastic baffles), depending on temperature, time of day, and angle of the house to the sun. The amount of leaf burn and plant loss on sides with white plastic was negligible, while west sides with clear plastic had losses up to 30% in rows within 18 cm (7.1 inches) of the clear plastic. Due to white plastic providing shade in late afternoon, cuttings in houses with white baffles on the west looked better overall. In 1997, white baffles were used on west sides of quonsets containing heat-sensitive taxa. It is now practice at Greenleaf Nursery to use white plastic baffles on west sides of all quonsets from June through August.

TRAY MEDIUM TRIALS

At Greenleaf Nursery we use approximately 90,000 TLC polyform trays each year. It is quite challenging finding a medium that is cost effective, yet allows optimum propagation of hundreds of plant taxa. This study compared the effect on rooting and survivability of five different tray media while considering the cost. The experiment was done on 12 taxa, but due to space limitations the results of only nine are listed in Table 4. Cuttings were stuck from 15 July to 31 July 1997, depending on plant with two liners per cell in a 24-cell tray. Cuttings were evaluated after they were removed from mist and acclimated. Cuttings that rooted and were still alive were evaluated on 16 Aug. 1997. Cuttings were again evaluated on 22 Oct. 1997 to determine any further medium influence on survivability. The media compared are shown in Table 3. Readings were taken on macronutrients and pH weekly. Results varied among taxa, but Medium 1 and Medium 2 consistently produced the highest percentage of rooted cuttings across the 12 taxa tested (Table 4). Medium affected cuttings survivability, but the response was plant specific. It was concluded that due to price differences between media, Medium 1 [perlite and peat (1 : 1, v/v)] would be used as a primary tray medium with hard-to-root taxa. Medium 5 [perlite, fine pine bark, and peat (1 : 5 : 1, by volume)] proved most cost effective and satisfactory for propagating easy-to-root taxa, such as 'Lynwood Gold' forsythia, crapemyrtles, and golden barberry — where propagation medium didn't significantly influence rooting percentage or survivability.

Table 1. Response of *Acer* ×*freemanii* 'Jeffersred', Autumn Blaze® Freeman maple cuttings to selected IBA concentrations and solvents.

IBA concentration	Auxin carrier	Rooted cuttings (no.)	Rooting (%)
0	Alcohol	291	46
	Talc	371	76
0.8%	Alcohol	529	85
	Talc	555	88
1.6%	Alcohol	556	89
	Talc	557	89
3.0%	Alcohol	535	86
	Talc	463	74

Table 2. Effect of auxin and fungicidal treatment on *Juniperus sabina* 'Broadmoor'.

Auxin carrier	IBA (%)	NAA (%)	Fungicide application	Rooting (%)
Talc	4.5	0	yes	70.0
	3.0	0	yes	80.5
	3.0	3.0	yes	62.5
	3.0	1.6	yes	76.0
Alcohol	2.5	0	no	83.0
	2.5	0	yes	81.5
	2.5	1.3	yes	78.5
	1.9	0	no	79.5
	1.9	0	yes	69.5
Water control	0	0	no	77.5

Table 3. List of five propagation media utilized and their cost per cubic yard.

Medium	Components	Cost per yard
Medium 1	Perlite and peat moss (1 : 1, v/v)	$42.50
Medium 2	Perlite, pine bark, and peat moss (3 : 2 : 1, by volume)	$29.10
Medium 3	Perlite, fine pine bark, and peat moss (2 : 4 : 1, by volume)	$22.11
Medium 4	Perlite, fine pine bark, and vermiculite (4 : 32 : 1, by volume)	$17.19
Medium 5	Perlite, fine pine bark, and peat moss (1 : 5 : 1, by volume)	$17.85

Table 4. Effect of five propagation media on rooting and survivability on *Berberis japonica* 'Nana', *B. thunbergii* 'Aurea', *Myrica pensylvanica*; *Spiraea japonica* 'Little Princess', *Cornus sericea* 'Isanti', *Hibiscus syriacus* 'Minerva', *Lagerstroemia* 'Tonto', *Forsythia* ×*intermedia* 'Lynwood', and *Cotoneaster adpressus* 'Little Gem' (syn. 'Tom Thumb').

Taxa	Propagation medium (no.)	Cuttings stuck (no.)	Root (%) 16 July	Root (%) 22 Oct.	Lost (%) 16 Jul. - 22 Oct.
Berberis japonica 'Nana'	1	1440	84.0	63.9	20.1
	2	1680	81.0	60.2	20.8
	3	1680	74.6	63.7	10.9
	4	1680	55.8	43.5	12.3
	5	1680	76.2	66.4	9.8
B. thumbergii 'Aurea'	1	1680	98.8	97.3	1.5
	2	1680	92.7	89.8	2.9
	3	1680	93.0	92.7	0.3
	4	1680	90.6	89.9	0.7
	5	1680	94.5	93.3	1.2
Cornus sericea 'Isanti'	1	1680	97.3	85.7	11.6
	2	1680	90.6	83.8	6.8
	3	1680	92.7	88.9	3.8
	4	1680	96.6	95.0	1.6
	5	1980	83.6	72.9	10.7
Cotoneaster adpressus 'Tom Thumb'	1	1680	80.8	62.6	18.2
	2	1680	80.2	47.6	32.6
	3	1680	65.3	46.7	18.6
	4	1680	35.7	14.5	21.2
	5	1680	52.5	49.0	3.5

Forsythia × *intermedia* 'Lynwood Gold'	1	1248	99.8	99.8	0.0
	2	1248	98.8	96.6	2.2
	3	1248	98.3	98.3	0.0
	4	1248	97.9	97.9	0.0
	5	1248	96.1	96.1	0.0
Hibiscus syriacus 'Minerva'	1	840	97.0	92.9	4.1
	2	840	88.0	81.4	6.6
	3	840	91.0	51.5	39.5
	4	840	90.0	67.0	23.0
	5	840	84.0	50.2	33.8
Lagerstroemia 'Tonto'	1	1680	99.8	99.7	0.1
	2	1680	97.4	96.0	1.4
	3	1680	98.3	98.0	0.3
	4	1680	90.6	89.4	1.2
	5	1680	93.1	92.7	0.4
Myrica pensylvanica	1	1440	99.4	98.6	0.8
	2	1680	98.2	96.4	1.8
	3	1680	98.0	86.4	11.6
	4	1680	91.7	86.4	5.3
	5	1680	91.4	86.3	5.1
Spiraea japonica 'Little Princess'	1	1680	99.0	98.2	0.8
	2	1680	99.0	92.8	6.2
	3	1680	99.5	98.9	0.6
	4	1680	98.6	95.6	3.0
	5	1680	94.0	80.7	13.3

Does Container Drainage Hole Size Affect Your Water Quality?

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One component of production influencing water quality at container nurseries is the amount of container leachate from the container substrate. The potential exists for reduced water use and less leachate volume by altering the container design. This project compares container leachate volume from a standard, 11.3 liter (# 3), container with seven 1.9-cm (¾-inch) diameter drainage holes to containers with one, three, five, or seven holes with diameters of 1.9, 0.9 and 0.5 cm (¾,⅜,and 3/16 inch). Leachate volume was about 41% less (312 ml to 182 ml) when the diameter of the drainage hole was reduced from 1.9 cm to 0.5 cm (¾, to 3/16 inch). Nitrate-nitrogen was about 70% less (6.4 ppm compared to 1.9 ppm) when container drainage holes were reduced from 1.9 cm to 0.5 cm (¾ to 3/16 inch). Plant growth of *Lagerstroemia fauriei* × *L. indica* 'Hopi', *Forsythia* ×*intermedia* 'Lynwood', and *Rhododendron* 'The Honorable Jean Marie de Montague' was similar in all container modifications.

INTRODUCTION

Water quality concerns are paramount in the nursery industry. Handling irrigation effluent on the nursery and measures to prevent effluent from leaving the nursery has become one of the top issues facing the industry as a whole. Researchers and producers are investigating the benefit of changing irrigation methods, modifying container media, and altering fertilizer recommendations to improve water quality at container nurseries. This project was to determine if modifying the container drainage hole size could impact the quality of the container leachate.

MATERIALS AND METHODS

Blow-molded plastic containers, 11.3 liter (#3), were obtained from Lerio Corp., Mobile, Alabama prior to the company drilling the drainage holes. We used drill bits with diameters of 1.9 cm (¾ inch), 0.9 cm (⅜ inch), and 0.5 cm (3/16 inch) to bore drainage holes in the containers. The number of drainage holes per container was 1, 3, 5, or 7 with each respective hole diameter. A standard 11.3 liter (#3) container has seven drainage holes with 1.9 cm (3/4 inch) diameters (six along the side edge and one in the center bottom).

Uniform liners of *Lagerstroemia indica* × *L. fauriei* 'Hopi' (3½-inch pot), *Forsythia* ×*intermedia* 'Lynwood' 9-cm (3-inch) pot, and *Rhododendron* 'The Honorable Jean Marie de Montague' 10.2-cm (4-inch) pot were potted in a pine bark and sand (12 : 1, v/v) substrate. Substrate was amended with 7.1 kg m^{-3} (12 lb yd^{-3}) of 18N-2.6P-10K controlled-release fertilizer (Osmocote 18N-6P-12K, Grace-Sierra, Milpitas, Calif.), 2.4 kg m^{-3} (5.0 lb yd^{-3}) dolomitic lime, and 0.9 kg m^{-3} (1.5 lb yd^{-3}) Micromax. Plants were grown in full sun and irrigated as needed with overhead irrigation. Each irrigation event applied about 1.3 cm (½ inch) of water.

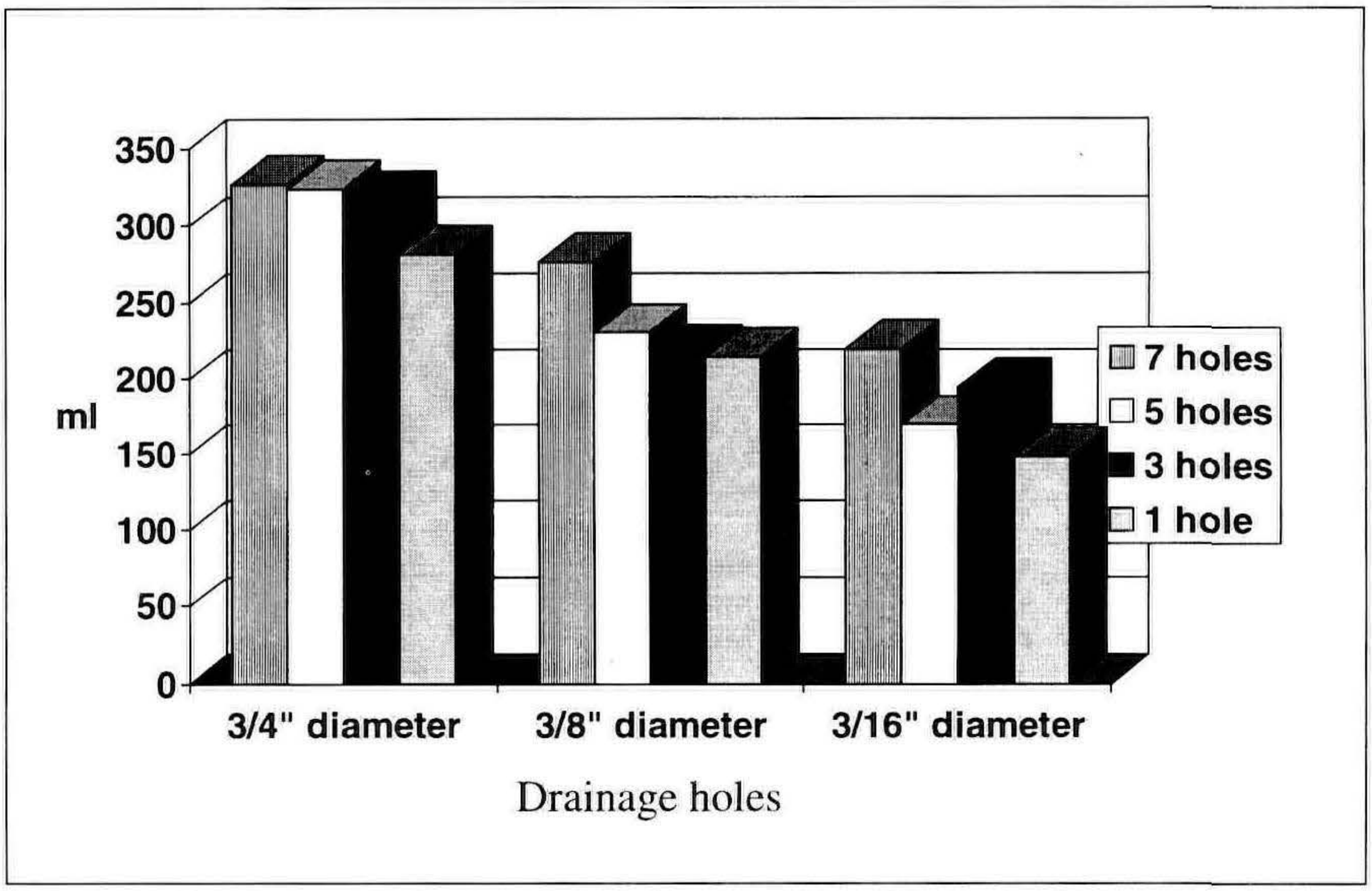

Figure 1. Average container leachate volume per sampling dates.

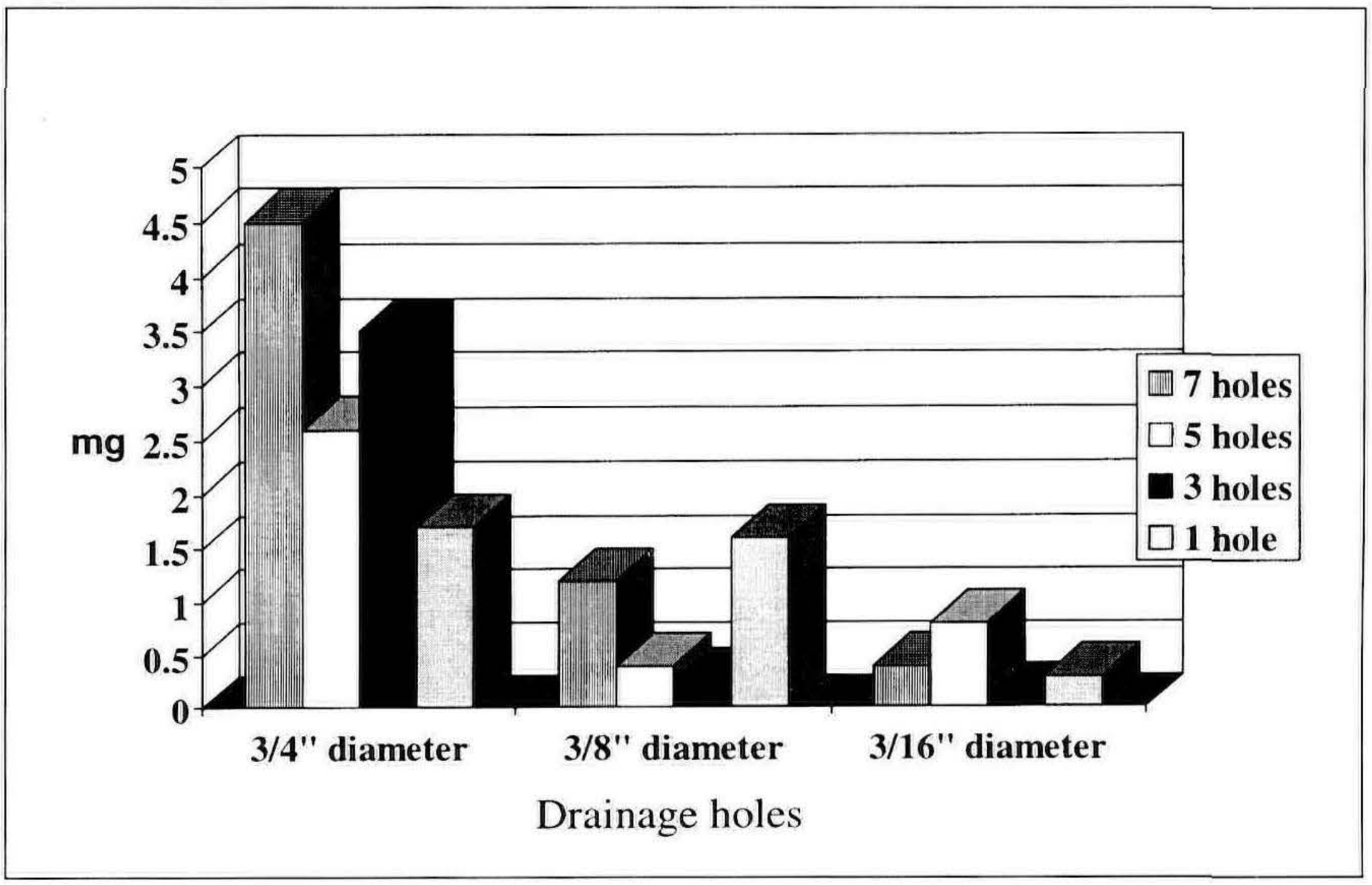

Figure 2. Average nitrate losses per container in container leachate.

Container leachate volume was collected at 15, 30, 45, 60, 90, 120, and 150 days after potting (DAP). During the irrigation cycle two containers from each treatment in each experimental unit were used to collect the leachate. An insulation board 0.9 m × 4.7 m × 1.6 cm (36 inches × 72 inches × ⅝ inch) was placed over two 5-gal buckets. Holes were cut in the insulation board to allow the containers to be suspended over the buckets such that container leachate could be collected without dilution from the irrigation system. Leachate volumes were measured about an hour after the irrigation event. Leachate was analyzed for pH, electrical conductivity, and nitrate- and ammonium-N levels (only nitrate-N data is shown). Plants were measured at 150 DAP to determine growth indices [(height + width at the widest point + perpendicular width)/3] (data not shown). The experimental design was a randomized block consisting of 4 replications with 3 plants per experimental unit.

RESULTS AND DISCUSSION

Container Leachate Volume. Container leachate volume was reduced in containers with fewer and smaller drainage holes than the industry standard with seven drainage holes at 1.9 cm (¾ inch) diameter (Fig. 1). About 4% less leachate was collected when the number of drainage holes 1.9 cm (¾ inches) in diameter were reduced from seven holes per container (standard container) to one hole. The volume of leachate was 41% less (312 ml to 182 ml) when the diameter of the drainage holes was reduced from 1.9 cm (¾ inch) to 0.5 cm (⅜ inch). The greatest reduction of container leachate occurred when the standard container was compared to containers with one, 0.5-cm (⅜ inch) diameter drainage hole. Fifty-five percent less leachate was collected from containers with one drainage hole.

Nitrate-N. The amount of nitrate-N (mg) was reduced in leachate from containers with fewer and smaller drainage holes than the industry standard with seven drainage holes at 1.9 cm (¾ inch) diameter (Fig. 2). About 62% less nitrate-N was detected in leachate when the number of drainage holes in containers with 1.9 cm diameter (¾ inch) were reduced to one drainage hole 1.9 cm (¾ inch). Nitrate-N was 86% less (3.1 mg compared to 0.4 mg) when the diameter of the drainage holes was reduced from 1.9 cm (¾ inch) to 0.5 cm (⅜ inch). About 93% less nitrate-N was leached from the container with one drainage hole 0.5 cm (⅜ inch) diameter compared to the industry standard.

Plant Growth. Plant growth of 'Hopi' crapemyrtle, 'Lynwood' forsythia, and 'The Honorable Jean Marie de Montague' rhododendron was similar among all plants of each species. The modification of container drainage holes had no effect on the flowering of 'Hopi' crapemyrtle. All plants flowered equally well during the experiment.

In conclusion, these results indicate that modifying the container with fewer and smaller drainage holes reduces container leachate volume and leachable nitrate-N, thus improving water quality.

Needle Evergreen Alternatives

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Leyland cypress, ×*Cupressocyparis leylandii*, continues as the unchallenged leader for screening and hedging in the southeast. Diseases, specifically *Seridium* and *Botryosphaeria* species, have been associated with branch dieback. Few monocultures survive over time, therefore our Georgia Plant Introduction Program has been accessioning and evaluating needle evergreen taxa as possible alternatives. To date, *Chamaecyparis thyoides*, *Thuja plicata*, *Calocedrus decurrens*, *Taxus chinensis*, *Cryptomeria japonica*, and *Cephalotaxus* species have shown promise.

Plants are grown under greenhouse conditions, outside in containers, and in field plots to more holistically evaluate suitability for the nursery and landscape industries. Significant commercial application resides with *C. thyoides* and *T. plicata* clones.

Chamaecyparis thyoides – Atlantic white cedar

- Over 50 clones under evaluation.
- Roots readily from cuttings, especially in November-March.
- Easy to grow in containers.
- Great range of foliage colors and growth habits.
- Drops needles in second year.
- May turn off-color in winter.
- Best clones to date – Webb #2 ('Rachel'), 'Okefenokee', 'Blue Sport', 'Webb Gold'.

Thuja plicata – Western arborvitae

- Twenty-seven clones collected.
- Roots readily after cold weather.
- Easy to grow in containers.
- May discolor in winter.
- Not as fast growing as Leyland cypress.
- Best clones to date with rather incomplete evaluation information include: 'Hoyt', 'Spring Grove' (same as 'Green Giant').

Calocedrus decurrens – California incense cedar

- Grows in Georgia, Oklahoma (Stillwater), Cincinnati, Boston, yet not commonly used.
- Now have 7 clones with an easy-to-root clone from Longwood Gardens.
- Best rooting with 5000 ppm K-NAA.
- Not terrifically happy in containers.
- Good dark green foliage year-round.
- Appears to require well drained soil slightly on dry side.

Taxus chinensis – Chinese yew

- J.C. Raulston promoted the species and featured a handsome specimen by the shade house at Raleigh.
- More heat tolerant than any *Taxus* with perhaps the exception of *T. floridana.*
- Easily rooted from December-February cuttings with 5000 ppm K-IBA.
- Does well in container culture.

Cryptomeria japonica – Japanese cryptomeria

- Widely hailed as a Leyland cypress alternative.
- Considerable tip blight (*Pestalotia* spp.?) on container-grown, overhead-watered plants; even field producers have had problems.
- Several good clones in our plant introduction program that are clean and hold good green winter color.
- 'Gyokuryu', 'Taisho Tama', and 'Winter Mint' show promise.

Cephalotaxus species – plum-yew

- Forty-five clones collected during Dr. Zhang's (now at University of Maine) Ph.D. work at Georgia.
- Too slow growing to compete with Leyland cypress.
- Several outstanding shrub types as well as upright-growing forms hold dark green needle in winter.
- More growers producing it as a standard item.

×*Cupressocyparis* taxa

- Twenty-three described in new edition (5th) of *Manual of Woody Landscape Plants.*
- Nuances of each are unknown.
- Principal cultivars in southeastern nursery production are 'Haggerston Grey' and 'Leighton Green'.
- ×*Cupressocyparis ovensii* is the fastest growing of the 17 clones we have assessed.
- Leylands will not disappear so we might as well learn all that is possible about culture, diseases, and growth characteristics.

Exotic Plants for the Plains

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Xanthoceras sorbifolia — popcorn shrub

- Can also be found growing as a small tree.
- More a large shrub than a small tree [2.7 to 6.1 m (9 to 20 ft)].
- Clean, attractive, compound foliage and attractive white flowers.
- Salt sensitive and can be easily overwatered — can be difficult to grow.
- Can deteriorate in pots — grow bag or field candidate for production.
- Easy to propagate from seed, even without pretreatment and can be rooted from cuttings.
- Hardy in Zones 4-7.
- Needs production work and marketing program to familiarize customers.
- Plant material source: Heritage Seedlings, Inc., 4199 75th Avenue SE, Salem, Oregon 97301- 9242; phone 800-727-8744.

Tetradium daniellii (*Euodia daniellii*) — Korean evodia

- Small tree 7.6 to 9.1 m (25 to 30 ft).
- Pest-free, lustrous, compound foliage.
- White flowers in July-August.
- Reddish-black capsules (open to reveal brown-black seeds) that persists into late fall.
- No fall color.
- Bark smooth and gray with maturity — striking.
- Adaptable to variable soil pH.
- Seeds germinate within 2 to 3 weeks without special pretreatment.
- Cold tender when young.
- Small, poorly known tree — potential street tree.
- Grow in Zones 4 to 8.
- Plant material source: (for *T. daniellii* [syn. *T. hupehensis*]): Lawyer Nursery, Inc., 950 Highway 200 West Plains, Montana 59859-9706; phone: 406-826-3881, trees@lawyernsy.com.
- Oklahoma source: Sunshine Nursery, Route 1, Box 4030, Clinton, Oklahoma 73601-9352; phone: 580-323-6259 sunshine.farm@mailexcite.com

Irrigation Water Retention and Recycling at Greenleaf Nursery Company

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INTRODUCTION

Greenleaf Nursery Company was founded in 1946 by Harold and Rebecca Nickel as a retail nursery in Muskogee, Oklahoma. In 1958, a wholesale production nursery was started in Park Hill, Oklahoma. Since that time, the retail nursery has been closed and the wholesale production has grown. Currently, Greenleaf Nursery Company consists of four wholesale divisions: the Oklahoma Division (500 acres in production), the Texas Division (300 acres in production), the Hidden Lake Division (150 acres in production), and the North Carolina Division (32 acres in production). The Oklahoma, Texas, and North Carolina Divisions are 98% containerized nursery production and 2% field production. The Hidden Lake Division is 100% field production.

Since 1989, the Oklahoma State Department of Agriculture (OSDA) has been monitoring nutrients and pesticides in runoff from ornamental nurseries in the Illinois River Basin (an Oklahoma designated Scenic River) to establish baselines for nursery effluents (von Broembsen, 1998). The voluntary compliance agreements between the nurseries and OSDA have been described previously (Andrews, 1995). In 1989, Greenleaf Nursery Company began a comprehensive pollution prevention program, with the cornerstone being the construction of an irrigation water retention and recycling system.

IRRIGATION WATER RETENTION AND RECYCLING SYSTEM

Construction on Greenleaf Nursery Company's irrigation water retention and recycling system started in 1992 and will be completed in late 1998. The entire system consists of eight retention basins with a total storage capacity of 70 million gal of water. There are 16 km (10 miles) of 25- and 30-cm (10- and 12-inch) pipelines tying the system together. The system was built by an in-house staff at a total cost of approximately $2 million. By phasing in the construction of this system, it has allowed adjustments to be made and spread the capital outlay over a number of years.

The propagation area water comes directly from the nursery water supply (Lake Tenkiller) and the water is chlorinated prior to storage and use. The production area of the nursery has been divided into areas where fresh and recycled water will be used. From in-house studies, approximately 45% of all water applied will be recaptured in the retention basins.

PLANT PATHOGEN MANAGEMENT IN RECYCLED WATER

A primary concern with recycling irrigation water is the potential that water-borne plant pathogens will be recycled back onto crops resulting in an increase in plant diseases. If this occurs, then the nursery would be forced to decontaminate recycled water.

In 1997, Oklahoma State University began sampling irrigation water on the nursery on a monthly basis to monitor pre-recycling levels of *Phytophthora* spp., a deadly water-borne plant pathogen. Samples were taken from the irrigation water source (Lake Tenkiller), runoff from production blocks, and water in retention basins. In 1998, this study continued. Additional sampling sites were added to monitor pathogen levels in recycled water being applied to plants.

Results of this study indicate that water-borne plant pathogens are present in the retention and recycling system, but there have been no increases in plant diseases. Crops that are highly susceptible to water-borne plant pathogens (dogwood, rhododendron, and yews) have been grouped together on the fresh water side of the nursery to prevent disease outbreaks. The large storage capacity of this system allows water to settle and be held for varying lengths of time. This allows the water-borne plant pathogens to settle out and/or be subjected to biological and physical degradation. At this time, the nursery is relying on these management strategies to minimize plant pathogen movement and preclude the necessity for decontamination of recycled water.

CONCLUSION

The Oklahoma Division of Greenleaf Nursery Company has been growing "Predictable Quality" containerized nursery plants for 40 years on the bluffs above Lake Tenkiller, one of Oklahoma's most heavily used recreational lakes. In 1989, a comprehensive pollution prevention program was started at this location to protect the local environment and natural resources.

As a result of the irrigation water retention and recycling system, conversion to slow-release fertilizer and a state-of-the-art integrated pest management program, Greenleaf Nursery Company received the U.S. Environmental Protection Agency's Environmental Excellence and Pollution Prevention Awards.

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von Broembsen, S.L. 1998. Capturing and recycling irrigation water to protect water supplies, pp. 27-29. In: M. Schnelle (ed.). Water quality handbook for nurseries. Oklahoma Cooperative Extension Bulletin E-951, Sstillwater, Oklahoma.

Starting a Nursery Business

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INTRODUCTION

I would like to share with you some things to consider when starting a small container nursery.

COMMITMENT

I believe that you need to evaluate your personal and monetary assets.

Nursery Experience. A degree in horticulture would be a wonderful asset. Next, the ideal situation would be to work for a progressive nursery producing similar crops which you would intend to grow. There is no substitute for on the job training. A minimum of 5-years experience is highly desirable.

Business Experience. General business skills are a must in any business. You will have to present a business plan or "Pro forma" to the bank to obtain financing. The plan will also have to contain a cash flow chart. A good CPA will help develop a professional "Pro forma" for you to present to your lending institution.

Capital Investment. This includes expenditures for:

- Land.
- Soil mixer system.
- Front-end loader.
- Graded growing beds for producing containerized plants.
- Irrigation system.
- Sprayer system.
- Break area for employees with facilities.
- Small office.

Next you must decide if you are willing to make the personal commitment to have a successful growing operation. For the first few years, you may have to accept a lower standard of living. You may have to postpone having your dream house for a few years. You will find yourself working weekends and holidays. The initial sacrifices you make in the beginning will be rewarded many fold down the road.

LOCATION

After everything else is in order, you will have to find suitable land for your nursery. Choosing the right property can save you many dollars in the future. We will now discuss some important factors to consider in purchasing property.

- Availability of water should be your first consideration. You will need great quantities of good quality water.
- The land should be affordable for your intended use. If possible, try to get an option on adjacent land for future expansion.
- Locate as close as possible to a good expanding market area for selling your product.

- Make sure the roads and bridges are in good condition leading to your location. The road system must be able to handle an 18-wheel loaded truck.
- Soil type and topography are important factors to consider for your location. Good topography can save you many dollars in reducing grading costs. Try to find land with good natural drainage. Remember, it costs major dollars to drain water up hill.
- Make sure adequate three phase electrical power is available. Large pumps and motors require three phase power.
- Try to locate between urban and rural areas with a good labor supply. Good luck on finding people willing to get their hands dirty!

If you make wise decisions going into business, you will reap the rewards much sooner.

Effects of Dolomitic Limestone and Micronutrients

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INTRODUCTION AND LITERATURE REVIEW

More than a dozen research studies have been conducted over the last 25 years related to addition of dolomitic limestone to pine-bark-based potting mixes. Many of the studies also investigated the effects and interactions between dolomitic limestone and minor element supplements. Results from these studies have been non conclusive, since amending potting substrates with dolomitic limestone and micronutrients has increased growth, decreased growth, and had no effect on growth of ornamental crops. Chrustic and Wright (1983) found that incorporation of dolomitic limestone decreased 'Helleri' holly and 'Rosebud' azalea growth and increased juniper growth only at 2.0 kg m^{-3} (3.3 lb yd^{-3}). They concluded that lime addition increased pH leading to increased NH_4 adsorption in the pine bark. They also concluded that if Ca and Mg supplies were adequate in container solution, substrate pH had little effect on plant growth. The duration of the study was 8 weeks. Whitcomb (1983, 1990) stated that container media pH between 4.0 and 7.0 had little effect on availability of micronutrients, except when high concentrations of Ca, Mg, Na, or bicarbonates influenced micronutrient nutrition.

Sartain and Ingram (1984) grew 'Andorra Compacta' juniper and *Rhododendron sinsii* 'Redwing' for 6 months in three potting substrates and two lime rates. They reported growth of azaleas was reduced by the high rate of lime 4.1 kg m^{-3} (7.1 lb yd^{-3}) but juniper growth was unaffected. Starr and Wright (1984), in a 7-month winter-greenhouse study grew cuttings of *Ilex crenata* 'Helleri' fertilized with one of four rates of dolomitic limestone including 0, 1.9, 3.7, and 7.5 kg m^{-3} (0, 3.4, 6.8, and 13.6 lb yd^{-3}). They found that addition of dolomitic limestone increased the concentrations of Ca and Mg in container solution, but unamended bark supplied both elements in quantities sufficient for growth. Leda and Wright (1997), studying effects of particle size of dolomitic lime, grew *Buxus sempervirens* 'Suffruticosa' liners for 2 years in a pine bark and peat moss medium. The finer particles of dolomitic limestone were more effective in adjusting pH. In more recent work, Amy Wright et al. (1997) conducted a lime and micronutrient study where nine species of landscape trees were grown for 19 weeks in a pine bark only substrate (Wright et al., 1997). Results showed that adding micronutrients increased height of some species, while adding lime either had no effect or suppressed height. Adding micronutrients without lime increased concentrations of Ca, Mg, Fe, Mn, Zn, and Cu whereas these concentrations were diminished with addition of lime except for Mg. They concluded that an increase in pH may have reduced elemental concentrations when lime was added. While micronutrients were necessary for optimal growth, lime did not increase growth of any species and some species had suppressed growth with addition of lime.

In a study conducted at Auburn University, addition of dolomitic limestone to a pine bark and peat moss (3 : 1, v/v) potting medium increased the size of *Nandina*, *Hosta*, chrysanthemums (*Dendranthema*), and 'Green Luster' and 'Burfordii' holly

after 360 days, but had no effect on *Rhododendron formosum* or October Glory® red maple (Cooper et al., 1997). However, quality of red maple, dwarf nandina, and hosta declined with increasing amounts of lime when micronutrients were not added. A second study was conducted for 330 days, either 2.8 or 5.5 kg m^{-3} (5 or 10 lb yd^{-3}) of a fine ground or pelletized dolomitic limestone were applied (Murphree et al., 1997). Application of 2.8 or 5.5 kg m^{-3} (5 or 10 lb yd^{-3}) to 'Fashion' azalea lead to decreased growth compared to the no lime control and the finely ground dolomitic limestone formulation decreased growth more than the pelletized formulation. However, 'Soft Touch' holly growth was unaffected by rate or lime formulation. In a study in Georgia, growth of *Buddleja davidii* 'Royal Red' was optimized at 2.2 kg m^{-3} (4.0 lb yd^{-3}) of dolomitic limestone, although plants grown with 4.8 kg m^{-3} (8.0 lb yd^{-3}) had greatest shoot lengths (Gilliam et al., 1998). Plants grown without dolomitic limestone had Ca and Mg levels below recommended concentrations for normal growth.

Differing results may be due to differences in duration that have ranged from a few weeks (Sartain and Ingram, 1984; Star and Wright, 1984; and Wright et al., 1997) to 2 years (Cooper et al., 1997; Leda and Wright, 1991; and Murphree et al., 1997). Most studies have been summarized with recommendations that irrigation water pH, bicarbonate levels, nutrient content and substrate potting components be considered as dolomitic lime application rates are determined for any specific nursery. In short, no one "recipe" is necessarily appropriate for every nursery and the choice to apply dolomitic limestone and the rate should be nursery specific.

EFFECTS OF LIME PRODUCTS AND RATES ON MICRONUTRIENT PRODUCTS EXPERIMENT

Several standard nursery crops such as *Juniperus conferta* 'Blue Pacific', *Abelia* 'Edward Goucher', *Myrica cerifera* (southern wax myrtle), *Ternstroemia gumnanthera* (syn. *Cleyera*), *Nandina domestica* dwarf form, and some azalea cultivars have shown considerable chlorosis by mid to late growing season. Problems related to irrigation water quality, dolomitic lime rates, and minor element supplements were suspected, after foliar, leachate, and/or soil analyses did not provide explanations for the chlorotic appearances of the plants.

To study relationships between micronutrient packages and dolomitic limestone products, we initiated a study on 22 May 1996 (Bilderback and Warren, 1998). The study was terminated 420 days later on 16 July 1997. Plants were harvested and analyzed after 92, 194, and 420 days. The main plots were two dolomitic limestone products [pulverized (James River Limestone, Buchanan, Virginia) and ground (Rockydale Quarries Corp., Roanoke, Virginia)] incorporated at rates of 0, 2.8, 5.5, and 8.3 kg m^{-3} (0, 5, 10, and 15 lb yd^{-3}) at potting. Greater than 75% of the pulverized limestone passed through a 100 mesh screen whereas < 45% of the ground limestone passed through a 100 mesh screen. James River and Rockydale dolomitic limestone were selected for study since these two lime products are used frequently in nurseries as potting amendments. Subplots in the study consisted of micronutrient packages (MicroMax and Step); a fertilizer containing micronutrients (Osmocote Plus 15N-9P-11K), and no micronutrients. Each subplot consisted of three containers for a total of 12 plants per treatment. MicroMax 0.8 kg m^{-3} (1.5 lb yd^{-3}), STEP 0.7 kg m^{-3} (1.25 lb yd^{-3}) and Osmocote Plus (equivalent to 4 g N per container) were incorporated at potting. Substrates containing MicroMax, STEP, and no micronu-

trients were incorporated with Osmocote High N Southern Blend 23N-4P-8K at 4 g N per container at potting. Irrigation volume of 800 ml was applied daily before dawn via pressure compensated spray stakes (Wade Rain Acu-Spray Stick, Wade Manufacturing Co., Fresno, Calif.) at a rate of 0.7 cm min^{-1} (0.3 inches min^{-1}). Osmocote Southern Blend and Osmocote Plus were surface applied on 31 March 1997 at the same rate. We also included a control with no dolomitic limestone and no minor element amendment and another treatment where Ca was supplied by gypsum and Mg was supplied by Crop Mag 36, a product produced by Martin Marietta. Our intent in this study was not to pick a winner, but to learn more about how lime products and rates and micronutrient packages interacted and affected plant growth and nutritional chemistry.

RESULTS AND DISCUSSION

Results from all portions of the plants measured (tops, roots, and total dry weight) gave the same response in respect to limestone products, limestone rates, micronutrients, time, and their respective interactions.

Micronutrient Results. The response of juniper growth to micronutrients changed during the experiment (Fig. 1). At 92 days of production the top, root, and total juniper dry weight were unaffected by micronutrients regardless of limestone product and limestone rate. Junipers grown with no micronutrients were similar in weight to those grown with MicroMax, OsPlus, and STEP. At 194 days, dry weights of juniper grown without micronutrients (none) were less (smaller plants) than junipers grown with MicroMax, OsPlus, and STEP. By 420 days, total dry weight of junipers grown with MicroMax, OsPlus, and STEP were 133% to 151% greater than junipers grown without micronutrients. Thus, results here agree with previous reports that micronutrients enhance growth and may explain where the debate over the use of micronutrients originates. A short-term study (i.e., 92 days) would have concluded that incorporating micronutrients is not necessary for maximizing growth whereas, results at 194 and 420 days of production illustrated the value of incorporating micronutrients. In addition, top, root, and total dry weight of junipers grown without micronutrients (none) were significantly smaller than junipers grown with MicroMax, OsPlus, and STEP regardless of the limestone product (Fig. 2).

Limestone Products and Rates. Differences among the micronutrient products were affected by limestone product (Fig. 3). MicroMax, OsPlus, and STEP produced similar dry weights when grown with ground limestone (Rockydale). Even though micronutrients were added with OsPlus at potting (22 May 1996) and reapplied with OsPlus on 31 March 1997 whereas, MicroMax and STEP were only incorporated at potting, the growth was similar. This illustrates that MicroMax and STEP can provide adequate micronutrients for 420 days of production.

Junipers grown with ground limestone (Rockydale) increased quadratically with increasing rate of limestone incorporation with maximum dry weight occurring at 2.8 kg m^{-3} (5 lb yd^{-3}) (Fig. 4). Total dry weight of junipers grown with 5.5 and 8.3 kg m^{-3} (10 and 15 lb yd^{-3}), decreased 20% and 42%, respectively. In contrast, total dry weight of junipers grown with pulverized limestone (James River) decreased linearly with increasing rate of limestone incorporation. Maximum dry weight occurred with no limestone added 0 kg m^{-3} (0 lb yd^{-3}). Dry weight of junipers grown with pulverized limestone decreased 28%, 29%, and 36% for 2.8, 5.5, 8.3 kg m^{-3} (5,

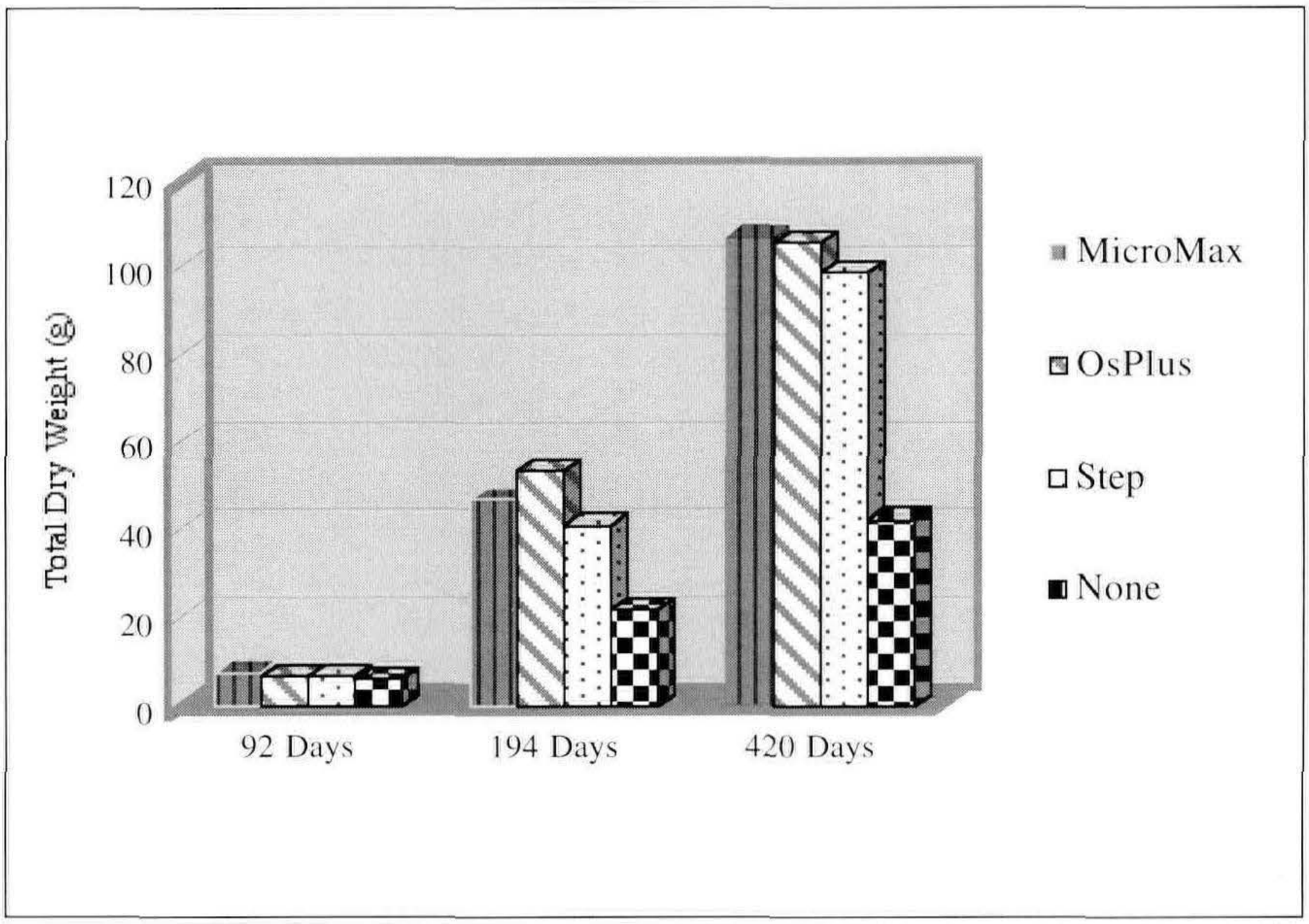

Figure 1. Micronutrient effects on growth of 'Blue Pacific' juniper at 92, 194, and 420 days of production.

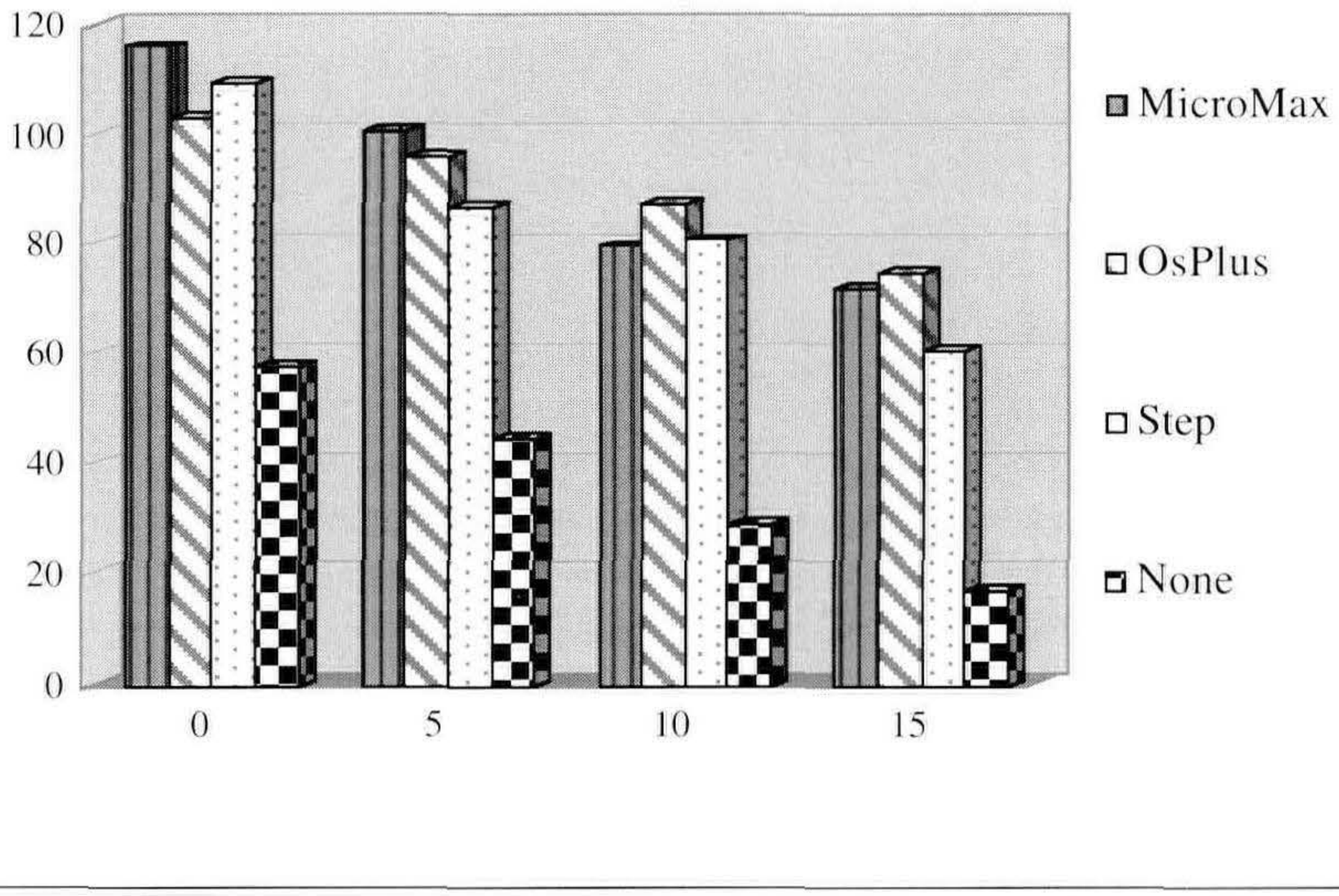

Figure 2. Growth of 'Blue Pacific' juniper as affected by micronutrients and increasing rates of dolomitic limestone.

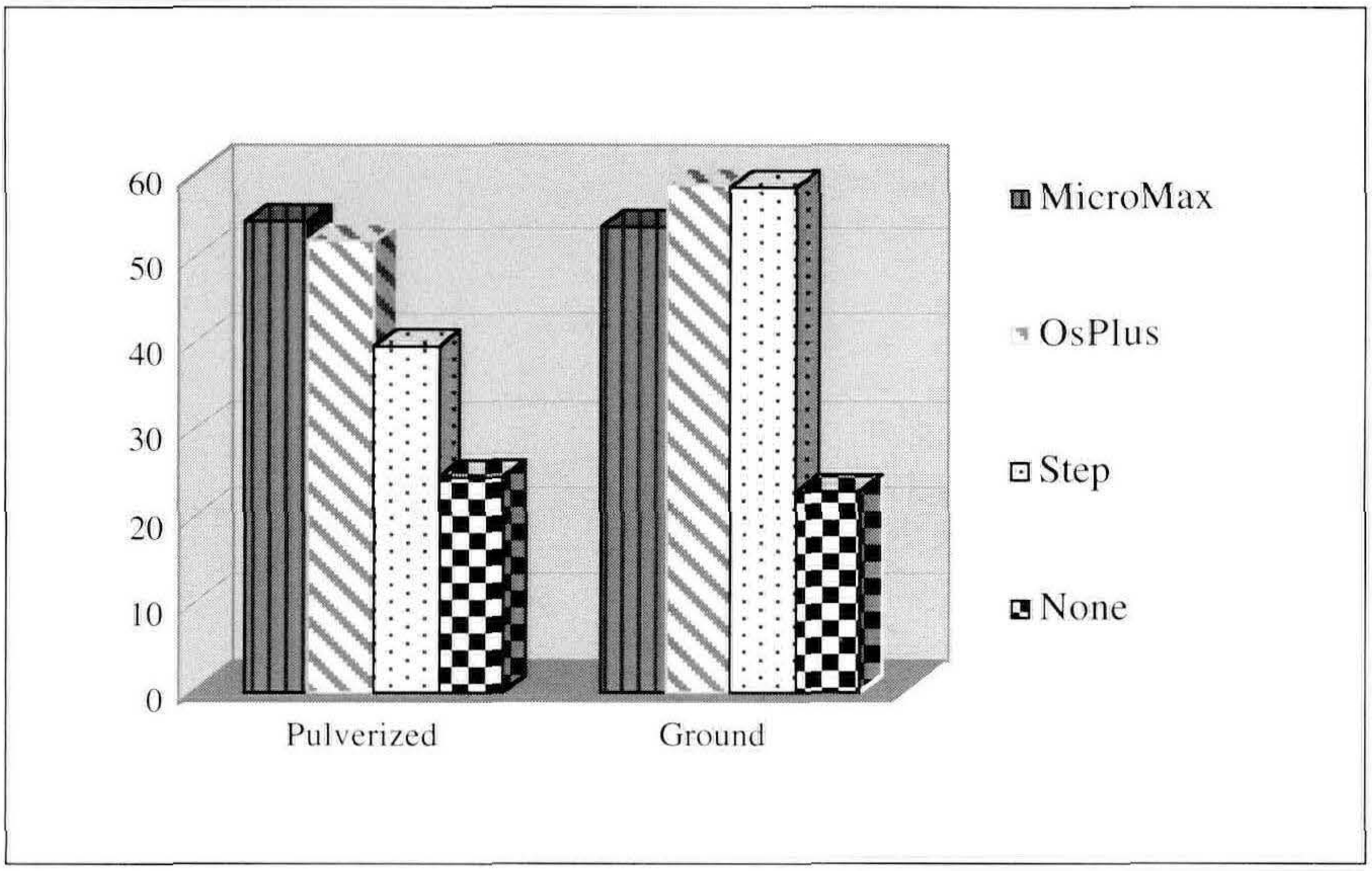

Figure 3. Effect of pulverized and ground limestone on micronutrient products and the growth of 'Blue Pacific' juniper.

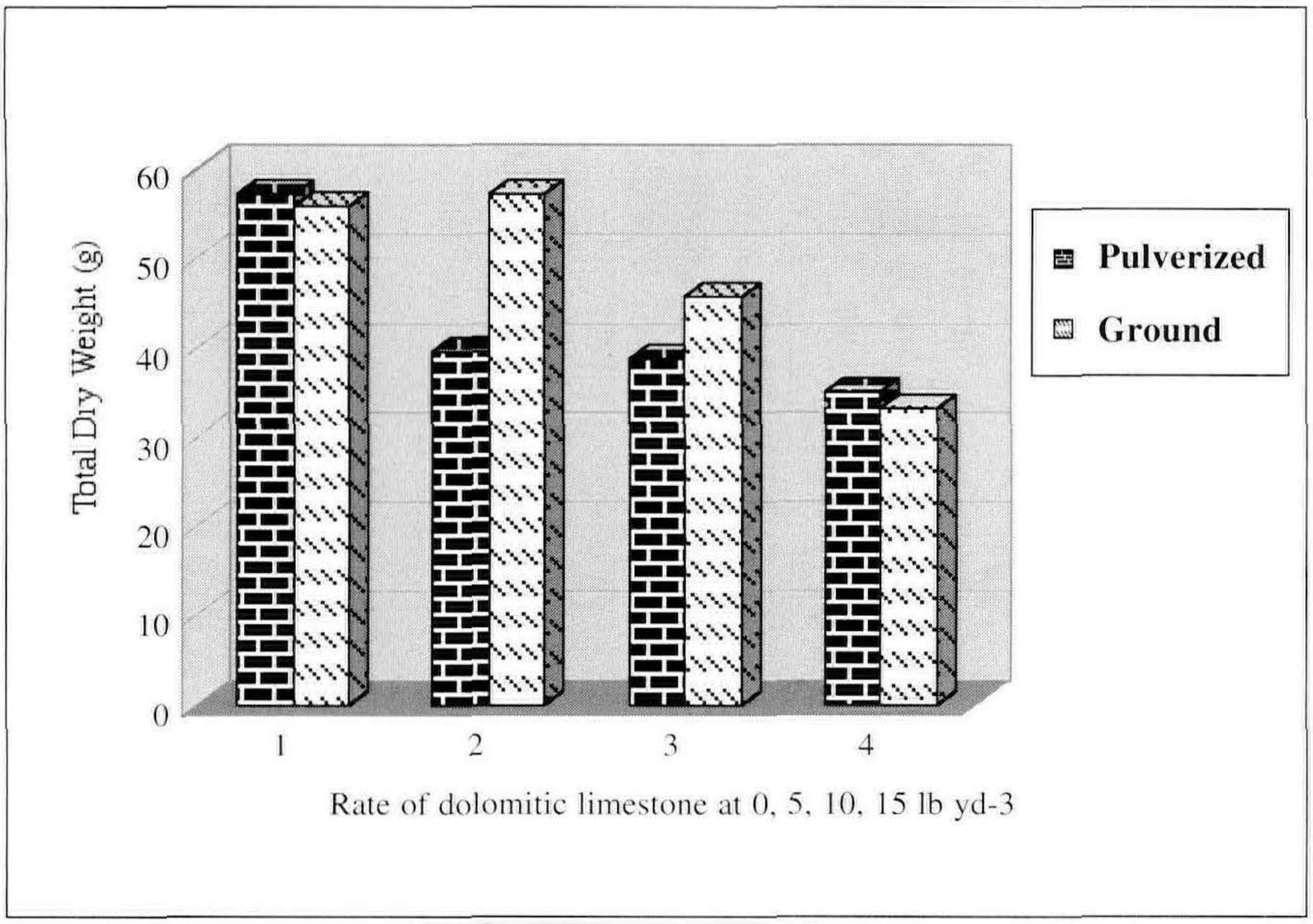

Figure 4. Growth of 'Blue Pacific' juniper as affected by rate of pulverized and ground limestone.

10, and 15 lb yd^{-3}), respectively. Junipers grown with ground limestone (Rockydale) were significantly heavier compared to pulverized limestone (James River) at 5.5 and 8.3 kg m^{-3} (5 and 10 lb yd^{-3}).

Unfortunately, limestone is currently used as a generic term, i.e., that all limestones are created equal and thus are used interchangeably. These results agree with results reported by Murphree et al. (1997) and illustrate that the particle size of the limestone affects the growth of the plant. These data suggest that the current recommendations for limestone need to also consider recommendations for micronutrient products, and mesh size of the limestone products.

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Southern Magnolia Propagation and Production

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INTRODUCTION

Rooting southern magnolia (*Magnolia grandiflora*) has proven difficult for most propagators and relatively easy for a few. Important factors are humidity and heat [100% relative humidity and propagation temperature of 38C (100F)]. However, the key is proper watering by a very attentive propagator. At GreenForest Nursery, we propagate 'Little Gem', 'Red Robbins', 'D.D. Blanchard', 'Claudia Wanamaker', 'Green Giant', and have recently added 'Bracken's Brown Beauty'.

Seasonal Timing for Optimal Rooting. Optimum time for rooting *M. grandiflora* cuttings seems to be late summer to early fall in southern Mississippi. Late enough in summer for cuttings to harden-off (no new leaf emergence), and early enough in the fall to maintain a high enough temperature in the greenhouse for the promotion of callus and root initiation.

Sticking cuttings in mid-summer (July in southern Mississippi) has also led to successful rooting. Advantages of propagating in mid-summer include having an earlier start, which means much better root development before fall, and continued root liner production during the winter, thus allowing for spring sales of liners. A disadvantage of propagating in mid-summer includes the selection of cutting wood, since many of the cuttings are too tender. Controlling heat during summertime in the propagation house can also be challenging. While venting the propagation greenhouse helps reduce the higher temperature load, it adversely lowers the higher relative humidity required for rooting.

Another acceptable propagation period is during early spring (late February to early March in southern Mississippi). Cuttings should be taken from the previous fall's new growth. Cuttings should be callused, with root initiation begun as greenhouse temperatures rise to 38C (100F) in the spring. Our biggest disadvantage in spring propagation is that we are very busy shipping and doing other nursery activities.

Collection and Preparation of Cuttings. Cuttings are taken as early in the morning as possible. They are taken to a cool area and kept damp. The preferred cutting wood is small in diameter [0.6 cm (¼ inch)] with a green outer layer that is beginning to lose its pubescence. Leaves are removed from the cuttings so that only two mature leaves remain. The cuttings are cut to a length of 12.7 cm (5 inches), submersed in a fungicide mixture of 1.5 kg Alliette per 832 liters of water (1.5 lb 100 gal^{-1}), and left until removed for preparation. Cuttings are wounded on two sides, about 5.1 to 7.6 cm (2 to 3 inches) along the cutting base with a potato peeler. The cuttings are then given a 5-sec quick-dip of auxin. We prefer K-IBA at 2500 ppm, however, since this is not commercially available, we use Dip 'N Grow, which is diluted down to the same concentration. From there the cuttings are taken directly to the greenhouse and stuck 7.6 cm (3 inches) deep one in each liner pot.

Propagation Medium. The medium we use is a fine grade of locally available pine bark mixed with approximately 5% sand. This mix has a 26% water holding capacity and is very well drained. The pH generally runs around 5 and no amendments are added.

Greenhouses. Greenhouses are 7.9 × 29.2 m (26 × 96 ft) quonset-style frames covered with 4-mil white poly or clear poly sprayed with Kool Ray for a 50% reduction of light. The floor area is shaped into a crown using the natural soil. A 7.6- to 10-cm (3- to 4-inch) layer of a sandy gravel mix is then placed in the greenhouse for drainage. The sand is then covered with a black ground-cover cloth.

Irrigation. Spray heads used are from Senninger Irrigation, Inc. We use the Super Spray bodies with #6 gold nozzle and a convex spray pad. The most important aspects of irrigation are good coverage, water particle size, and timing. Good coverage is achieved by correctly sizing pipe, water volume, and water pressure with the spray heads of choice. Particle size is reduced by the right spray head or mist nozzle and high water pressure. Timing of water is, in my opinion, the most important factor in rooting magnolias. This is accomplished by having the correct person for the job. Our basic strategy is beginning with a 1-sec on and 1-min off cycle, while we are sticking the cuttings. Thereafter, we will increase the off time by 1 min until 5 min is reached. From this point variations in water cycles are determined by moisture content on the leaves, stems, in the medium, and of course by daily weather patterns. The trick seems to be 100% relative humidity, or as close to 100%. This requires keeping the foliage and stems damp, while only keeping media slightly moist with good air porosity. In 1 week, there is a slight separation of cambium area to pith wood. Callusing can be seen in about 2 weeks. At this time, the off interval of the time clock will be increased gradually to promote white healthy callus growth. This schedule is maintained for an additional 6 to 8 weeks. When rooting begins, a process of drenching and drying-out is initiated utilizing liquid solutions of 20N-20P-20K fertilizer. At the point roots are becoming visible, cuttings are slightly stressed by altering the irrigation and fertilizer levels. This partial stress seems to stimulate root initiation. After the majority of cuttings have some root initiation, light amounts of a granular 3-month formulation of slow-release fertilizer is applied. As rooting continues more light applications of the granular fertilizer are applied until soluble salts range around 1 dS m^{-1}. Once this is accomplished, typical growing methods of proper temperature and watering is maintained for further root development.

Container Production. *Magnolia grandiflora* is easily produced once a few unique cultural requirements are reached in the growing program. GreenForest Nursery produces 56-, 95-, and 170-liter (15-, 25-, 45-gal) containerized *M. grandiflora.* Fifteen- and 25-gal pots are filled with medium and set can to can under overhead irrigation. When quart liners are ready (usually early June), holes are dibbled in each pot and slow-release fertilizer is placed in the bottom of each hole (50 g per container). After planting, trees are held in this area between 12 and 16 months. During this time, tip pruning and staking are done for uniform branching and a central leader. Each cultivar has different requirements. For example, the blooming habits of 'Little Gem' and 'Claudia Wanamaker' require diligent pruning for a central leader, while 'D.D. Blanchard' has to be watched for excessive central leader

growth with no branching. When spacing is required for the final growth before sales, drip irrigation is preferred to overhead irrigation with pot-in-pot being our favored production system. The 56-liter (15-gal) containerized plants are spaced on a 0.9 m × 1.2 m (3 ft × 4 ft) design, 95-liter (25-gal) containers are spaced on 1.4 m × 1.4 m (4.5 ft × 4.5 ft) centers, both with four rows per bed. Larger 179-liter (45-gal) plants are spaced on 1.5 m × 1.8 m (5 ft × 6 ft) centers with two rows per bed. During the final growth stage, specimen trees of 'Little Gem' and other cultivars are produced by properly watering, fertilizing, tip pruning, and disbudding the containerized plants.

Other cultural requirements, somewhat unique to *M. grandiflora*, are the control of stem borers with pesticide applications of Lindane, while Turcam is used to control soft scale.

Granular applications of Dursban are placed in a ring against the base of the tree trunk in late February to control magnolia root crown borer. This seems to deter the entrance of the magnolia root crown borer in March or April.

SUMMARY

There are no magic tricks to the rooting of *M. grandiflora* cultivars. Finding the right person that understands its unique mist irrigation requirements, and who will be attentive enough to observe and react to changing propagation conditions is of the utmost importance.

Multiple Uses of Spin Out® in the Nursery and Landscape

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INTRODUCTION

The benefits of using copper salts in a latex carrier to control root development in containers has been well documented in the literature and has gained widespread use in forestry and nursery crop production with the introduction of pretreated containers in the 1990s. Using copper to control root growth in containers to eliminate root spiraling first began in forest seedling production in the 1960s and has increased to where greater than 90% of lodgeple pines produced in British Columbia are grown in copper-treated containers. Horticultural research at Ohio State University demonstrated the benefits of controlling roots in container-grown red oaks (*Quercus rubra*). This caught the attention of Griffin Corporation, which is a major producer of copper fungicides. In 1994, Griffin introduced Spin Out® root growth regulator, which is the first EPA registered product for controlling plant root growth in containers.

USE OF SPIN OUT® IN CONTAINER PRODUCTION

Spin Out® was specifically formulated as a stable, ready-to-use product to be applied to the inner surfaces of plant containers to control undesirable root growth and produce plants with high root regeneration potential. The active ingredient in Spin Out is copper hydroxide. Copper hydroxide has been used for over 30 years for disease control on crops throughout the world and is considered the best source of copper for copper-based fungicides/bactericides. Spin Out has been formulated to adhere to plastic nursery containers where the copper coating remains in place to control root growth only along the container wall. It is easily applied to the inner surfaces of new and used containers using conventional spray paint equipment. It was also formulated to reduce the problems of copper-induced iron chlorosis, which can occur with mixtures of household latex paint and copper carbonate. When root tips reach the sides of the container, the Spin Out coating inhibits root elongation and deflection and stimulates root branching. As the plant produces new roots, they in turn will be pruned, resulting in a very fibrous root system. Spin Out prevents the "cage root" condition where roots are only present on the outside of the root ball. In a typical black nursery container, 80% of the roots are within 1 inch of the container wall. Instead, the roots are able to utilize all the available potting medium. An improvement in root distribution can lead to an improvement in the nutrient status and health of the plant which will encourage more rapid growth during upcanning or transplanting. An increase in flowering has been demonstrated with lantana grown in Spin Out -treated containers during greenhouse production. With the absence of circled and matted roots, no mechanical root pruning is required at transplanting resulting in fewer sites where root diseases can enter the plant. Also, heat stress associated with black nursery containers is reduced in Spin Out -treated containers. Using Spin Out allows the root system to be more evenly distributed

through the soil, thereby reducing the mass of roots which come in contact with the edge of the container that are most vulnerable to temperature extremes. Spin Out also makes removal of plants from containers easier since the roots do not adhere to the plastic or styrofoam. This benefit is referred to as the "Teflon effect".

Most of the research with Spin Out has been on ornamental trees, shrubs, and herbaceous annuals and perennials grown in containers ranging in size from 1 to 100 gal (3.8 to 379 liters). Initially, Spin Out was developed and marketed as a user-applied coating where growers applied the product to containers at the nursery. Growers found the product very effective but were resistant to the time and inconvenience of application. This led to Griffin forming a partnership with the Lerio Corp., a container manufacturer, in 1996, to supply pretreated pots and propagation trays to the market. Pretreated propagation trays are produced by a patent pending process where flat polystyrene sheet is coated with Spin Out and then formed into a tray. This represents a significant reduction in the cost and time to produce treated trays and the coating rate is specific to cell size. A full line of pretreated plastic trays with a range of cell sizes and depths are available from Lerio. Plants rooted from cuttings stuck in Spin Out-treated cell trays can develop more roots from the stem. This results in more uniform root distribution around the stem and more stable plants as they increase in size.

In developing countries where rigid containers are too expensive, Griffin has developed polybags pretreated with Spin Out. Treated polybags are being tested on numerous forestry, nursery, and orchard crops in several countries as a cost-effective way to solve root and survival problems associated with polybag culture.

Spin Out can be incorporated into fiber pots made from recycled paper. Fiber pots have been used for nursery plant production for many years, but are limited to regions with cool climates like the Pacific Northwest and the Northeast. In the Southeastern United States, fiber pots cannot be used for plant production because they decompose within 2 to 3 months and become too soft to transport. When Spin Out is incorporated into fiber pots, it extends the life of the pots for up to 2 years by slowing down the decomposition. One of the primary advantages of fiber pots in hot climates is they are porous and provide a cooler root environment compared to standard black plastic nursery pots. Plants sensitive to high root temperatures, like conifers and herbaceous perennials, are more easily grown in fiber pots. Spin Out also prevents root growth into the fiber, making it easier to remove the pot for transplanting.

USE OF SPIN OUT IN GEOTEXTILE FABRICS

The development of Spin Out has lead to many other uses for root and pest management in nurseries, greenhouses, and in the landscape. Griffin has teamed up with Texel, Inc. of Quebec, Canada, to provide geotextile fabrics pretreated with Spin Out. Spin Out-treated groundcover fabric prevents weed establishment in decorative mulches for up to 5 years. For weed control in containers, Spin Out-treated nonwoven fabric is cut into circles or discs (Geodiscs™) and placed on the tops of pots to control weeds as an alternative to herbicides. When weed seeds germinate, the roots are pruned, preventing weed establishment and the seedling dies. Water is able to pass through the fabric since coated fabrics remain porous. Controlled-release fertilizers can be placed either under the disc or on top. The placement of Geodiscs™ is important. For best performance use single plants placed

in the center of the container where the medium is a least 1.3 cm (0.5 inch) below the rim of the pot. Geodiscs™ can be used on container-grown fruit trees and shrubs where herbicides cannot be used.

Spin Out-treated geotextile fabrics can be used to replace air pruning under plastic propagation trays where the coating prunes the roots as they emerge from the drain holes. Treated fabrics can also be used to cover capillary sandbeds (a type of subirrigation) to control roots growing from the drainage holes of containers, as well as weeds, liverworts, and several types of algae. In England, the use of sandbeds was declining when herbicides used to control root growth into the sand were discontinued due to groundwater issues. The commercial introduction of two pretreated fabrics, Supercover Plus™ (Fargro Ltd, England) and Tex-R® fabric (Texel Inc., Quebec, Canada), have saved the use of sandbeds. Research in England has demonstrated that treated fabrics will control zoospores of *Phytophthora cryptogea* and reduce the spread of disease from infected to noninfected plants on a sandbed. Other research in Oregon, Hawaii, and Canada has demonstrated that slugs and snails are repelled by the Spin Out coating on fabrics. It may be possible to keep plants free of slugs and snails by placing containers on treated fabric or by coating the surface under containers.

Spin Out-treated fabric (Tex-R) can be used between the socket and growing pots for pot-in-pot production to control rooting-out. Problems occur with pot-in-pot when roots grow out of the drain holes of the growing pot into the socket pot and then into the surrounding soil, thus preventing the plant from being hand harvested. Spin Out-treated fabric provides a physical and chemical barrier to reduce escaped roots.

Spin Out can be used to control undesirable root growth on root control barriers used in the landscape around pavement, foundations, curbing, and retaining walls (hardscape). Undesirable root growth is a major problem and expense in the urban environment where arborists maintain a healthy urban forest. Texel has developed a fabric root barrier as an alternative to Biobarrier® (trifluralin-impregnated fabric produced by Reemay, Inc.) to divert roots under sidewalks and other hardscape. Fabric barriers have an advantage over rigid barrier as they allow for the movement of water. The Spin Out coating on the fabric barrier modifies the root system as it develops and prevents large roots from deflecting along the barrier, growing down and then under the base of the barrier. By modifying the root system adjacent to the barrier, the life of the barrier is extended and the root system is more effectively redirected under the hardscape.

In Japan, paper sheets are treated with Spin Out and placed under the soil in flats used to grow rice and onion seedlings for transplanting. This treatment eliminates the root mat on the bottom of seed flats and decreases the time to separate the small plants. The decrease in root damage at transplanting has resulted in yield improvements up to 10%. Spin Out is also registered for use as a tree wound and pruning paint.

PROBLEMS WITH COPPER-INDUCED CHLOROSIS

The most significant problem encountered when growing in treated containers is copper-induced iron chlorosis. This condition is most common in cell trays where there is a high container surface area to low soil volume ratio. Iron (deficiency) chlorosis results from low availability of active ferrous (Fe^{+2}) ions in newly forming

Table 1. Reduction in top growth observed in plants propagated in Spin Out-treated cell trays.

Tissue Culture	Propagation method	
	Cuttings	Seed
Leucanthemum (Shasta Daisy)	*Heuchera* 'Mt. St. Helens'	*Asparagus densiflorus*
Ficus benjamina	*Murraya paniculata*	*Schefflera arboricola*
Musa acuminata 'Dwarf Cavendish'	*Viburnum odoratissimum*	
Anthurium	*Viburnum suspensum*	
Syngonium	*Viburnum tinus*	
Deffenbachia	*Cissus rhombifolia*	
Globba winitti	*Hypoestes phyllostachya* 'Splash'	
Liriope muscari		
Spathiphyllum		
Guzmania		
Philodendron 'Black Cardinal'		
Maranta leuconeura var. *erythroneura*		

plant organs. Because copper competes with iron for uptake at the root tip, it reduces the relative availability of iron at any fertilizer rate. Hence, copper can exacerbate an existing iron deficiency or bring on an impending one sooner. This condition is easily corrected by applying supplemental iron fertilizer.

Spin Out has been tested on over 300 species of plants with very few occurrences of phytotoxicity. Plants that have been identified as sensitive to copper root pruning are listed in Table 1.

SUMMARY

In summary, Spin Out was developed as a ready-to-use copper coating to help nursery growers control root growth in containers, but has been found to provide many other benefits depending on the substrate it is applied to and the problem the grower wants to solve. Providing pretreated pots, propagation trays, fabric, and paper has made Spin Out very versatile and easy for the grower to use to solve root problems in the nursery and landscape.

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Innovations at Lancaster Farms — AKA 30 Years of Trial and Error

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INTRODUCTION

When asked to present a paper on innovations at Lancaster Farms, I said to myself "no sweat". All I would have to do is take a few pictures, show several slides at the meeting, and write a short paper. However, when we really think about the subject — it is much more than a gadget!

For a multitude of reasons we seek out innovative approaches to our problems. The old saying that "need is the mother of invention" is indeed true, and is the principle reason for innovation in most nurseries.

The entire concept of innovation is more that just simply a "gizmo," but is a mind-set, a philosophy if you will.

This concept revolves around the opposite or converse of innovation, which is stagnation. I don't remember where I came upon the following list, so I can't give the originator the proper credit, but it has served as a valuable tool and guide for over 25 years when we think "innovation."

EIGHT WAYS TO STAGNATION

- We tried it one time a number of years ago.
- Never "done it" that way before.
- We are just not ready for that.
- We are doing O.K. without it up to now.
- We don't have the time to try it now.
- It will cost too much.
- That's not our responsibility.
- I know it just won't work.

I am not suggesting that every idea we have will come to fruition, but what I am trying to relate is that we have to be open to new and exciting concepts about how we accomplish tasks on the nursery. Some ideas just don't work, and other concepts are obviously beyond our individual financial means. But we are all guilty at times of making daily decisions that fall into the category of "ways to stagnation".

Actually, I really don't like the word "decision". I like to think that when we come upon a problem or challenging situation that we develop a solution, rather than make a simple decision. Real solutions go far deeper than a simple decision. They are lasting and serve as true building blocks that can be used over and over again. When a solution is found, the decision process is almost automatic.

I have never been to a Casino and don't plan to visit one — so I am not talking about gambling. A systematic and well organized analysis of a problem eliminates a great deal of the "gamble" and leads to a more realistic solution.

An old saying goes something like this "you better not be the first one with an idea, but if you are the last then it will be too late". I am sure this adage is true. However, I have never put much stock in it. What I have discovered over and over again is that

when we seem to be stepping into uncharted waters, we later discover that other nurseries were taking similar steps.

We travel. We ask questions. We learn from other nursery friends, and we always try to seek and share. Each of these efforts makes us realize that no one operates in a vacuum, and the stimulation to be innovative is **contagious**.

INNOVATIONS THAT HAVE WORKED FOR US

These following examples illustrate some of the problems that we have faced and the solutions we have helped develop over the past 30 years. Although all are in common practice now, I can assure you that when we were busy developing these solutions, they were quite different and innovative compared to practices being utilized.

Problem: How to grow Japanese holly or an azalea in #3 containers without having to shift up from #1 containers.

Solution: Transplant plants in 7.6-cm (3-inch) liner pots directly into a #3 container. This sounds really simple now, but 27 years ago it was crazy to think that you could go directly to a large container without going through the #1 can step-up method.

Problem: Finding time to pot cuttings rooted in trays.

Solution: Direct sticking of cuttings. Simple task now but a major project in 1971-72 (Meadows, 1981). This eventually evolved into direct rooting of dormant cuttings, which is our current practice on many items (Parkerson, 1983).

Problem: Sore legs and feet standing at a trade show booth all day long.

Solution: Tip from a friend. Purchase a pair of Echo shoes.

Problem: Irrigation layout, design, and operation.

Solution: Prior to PVC and poly pipe we were almost forced to limit our nozzle spacing to increments 6.4 m (21 ft), which was the standard length of galvanized pile. Today, it is so easy to cut and glue pipe, that it is hard to visualize what it was like in the 1960s. Hand valves have given way to solenoid valves controlled by precision time clocks.

Problem: Winter protection of plants grown in open beds.

Solution: Developed a system for laying white 4-mil plastic directly on top of the plants. The plastic is held in place using shade cloth, nails, earth anchors, and rope. We also designed a device to re-roll the plastic and shade cloth in the spring (Parkerson, 1985).

Problem: Not enough water to support nursery expansion.

Solution: My partner Bill Daughtry developed the concept of "pulse-cyclic irrigation" utilized in the greenhouse industry into a practical system for nursery production (Daughrty, 1990).

Problem: Waterborne pathogens in re-cycled retention basin irrigation water.

Solution: Chlorine gas is routinely added to our irrigation water and helps control motile spores of *Pythium* and *Phytophthora* (Daughtry 1983, 1989).

Problem: Production of "field-grown quality plants" in containers.

Solution: Pot-in-pot production (Parkerson, 1990). We continue to refine containers, watering practices, root manipulation, etc.

Problem: What to do with excess or damaged plant inventory.
Solution: Grind discarded plants using a tub grinder. The ground-up material is reused in potting mixes and sold as soil amendment for landscape beds.
Problem: Record keeping.
Solution: Computers. We started in 1979 with one of the first Radio Shack computers sold on the East Coast. The computer terminal is now our time clock, fuel control, truck scheduler, checkbook, typewriter, etc. Features, such as the spell check of a word processor, help make us more productive and efficient.

NOT ALL IDEAS TURN INTO INNOVATIONS

I have not mentioned the big pile of 13 innovations that were a complete waste of our time, money, and effort. If we are going to be innovative in our business approach then we must recognize and accept disappointments — but never accept defeat! Mr. J.C. Penney once said "if you are correct 51% of the time than you will be a success." I strive for more that 51%, but the concept is sound. If you want innovation then you must not be afraid of some setbacks — this is all part of trying to be innovative.

WHAT'S AHEAD? WHERE WILL THE INNOVATION TRAIN LEAD US IN THE FUTURE?

One day we will have robot-like gadgets running around moving, spacing, grading, loading, labeling, spraying, collecting cuttings, and many other task. Global positioning systems (GPS) will aid in plant location, pesticide application, deliveries, etc. Powerful computers with artificial intelligence, and trading on the World Wide Web will be reality.

What an exciting time! I so look forward to what lies ahead.

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Aging, Rejuvenation, and Propagation in Trees

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DEVELOPMENTAL ISSUES: PLANTS VERSUS ANIMALS

Plants and animals are structured along very different lines. Animals are considered determinate and entire in their development, while plants are considered indeterminate and open. Animals are organized around tissue and organ systems and develop at the cellular level, while plants are structured around meristematic zones and develop at an organismal level (Kaplan and Hagemann, 1991). The higher degree of morphological plasticity found in plants relative to animals is a manifestation of their more flexible developmental processes (Arber, 1950).

The challenge facing plant propagators is twofold: first to distinguish the variable, yet synergistic, roles that genetics, environment, and development play in shaping the form of the tree (Halle et al., 1978); and second, to use this knowledge to produce high quality, true-to-type plants for the market place.

AGING IN PLANTS

Plants age from the base to the top and from the inner to the outer. From the chronological perspective, the cotyledonary node is the oldest part of any seed plant but, paradoxically, it is ontogenetically the most "juvenile". In contrast, the flower meristems at the periphery of the tree are chronologically the youngest part of the plant but ontogenetically the most "mature". Researchers have resolved this apparent paradox by describing three different types of aging in plants (Fortaniers and Jonkers, 1976):

1) Chronological Age. The amount of time that has elapsed in the course of the life span of the whole plant or a portion of the plant. In clonally reproducing species such as quaking aspen, *Populus tremuloides*, or creosote bush, *Larrea divaricata*, chronological age can either refer to the age the entire organism, measured in thousands of years, or the age of a given stem, measured in hundreds of years.

2) Ontogenetic Age. This refers to the process of a plant passing through different "phases" of development. At any point in time, different sectors of a tree can be in different growth phases. The control of the ontogenetical aging process is localized in the meristematic tissues of the plant body. The generalized characteristics of the various phases of tree growth are summarized in Table 1.

3) Physiological Age. This refers to the general condition of the entire plant body. In the case of mature trees, it covers the suite of traits circumscribed by the term senescent. Such traits include the loss of growth vigor in the root and/or shoot systems; stress-related decline and general deterioration ("die-back"); or the breakdown of the internal regulatory system that normally controls and coordinates the development of form (Romberger, 1976). In general, the control of the physiological aging process is localized in the differentiated tissues of the plant body.

Rejuvenation. Rejuvenation is the opposite of aging. As such it can either be ontogenetical or physiological, the former being much more difficult to accomplish than the latter.

EXAMPLES OF ONTOGENETICAL AGING IN PLANT PROPAGATION

Numerous cultivars of various tree species have been created by selectively propagating a specific portion of the plant that is in a particular ontogenetic phase. Such cultivars are not genetic mutants per se, but epigenetic selections whose distinctive characteristics are the result of variation in gene expression rather than in gene composition (Brand and Lineberger, 1992; Greenwood, 1993). For propagators, the source location of the propagation material on the parent tree is of crucial importance because it can strongly affect the form of the final product (Hackett, 1983; Warren 1991). Some well-known examples of epigenetic cultivars maintained by selective propagation include:

1) Thornless selections of *Gleditsia triacanthos* ('Elegantissima' syn. 'Inermis') and *Citrus* sp. which are propagated from sexually mature portions of the tree. Seed-raised honeylocust and citrus always have thorns on their trunks.
2) 'Prostrata'-type cultivars among various conifer genera, including *Abies, Araucaria*, and *Taxus*, are propagated from lateral branches. They are essentially stuck in the mature growth phase and maintain a horizontal orientation for many years, a phenomenon technically known as topophysis (Olesen, 1978; Del Tredici, 1991).
3) The vase-shaped, spreading cultivars of various nut-producing species, including pecan (*Carya illinoinensis*), walnut (*Juglans*), and ginkgo (*Ginkgo biloba*), represent the mature growth phase of the tree. When grown from seed, these same species have a juvenile form dominated by a strong central leader (Del Tredici, 1991).
4) Shrub-form cultivars of *Hedera helix* with entire leaves and flowers represent the mature, difficult-to-rooting phase of growth. In its juvenile phase, English ivy has lobed leaves and readily produces adventitious roots.
5) Many dwarf conifers with "immature" foliage and congested growth are stuck in the seedling or juvenile growth phase. Examples include the dwarf Alberta spruce, *Picea glauca* 'Conica', and the so-called "Retinospora" cultivars in the genus *Chamaecyparis*. Among angiosperms, broadleaf evergreen *Eucalyptus* and *Acacia* species provide examples of trees which sometimes retain juvenile foliage for many years (Borchert, 1976).

REJUVENATION OF ONTOGENETICAL AGING

In nature, one commonly finds ontogenetic rejuvenation in trees that produce suckers from the basal portion of their trunk. Such suckering is usually an adaptation to some form of periodic disturbance or environmental stress. Following Groff and Kaplan (1988), the author has identified four basic types of "in vivo" rejuvenation in woody plants: (1) root suckering species such as *Ailanthus* and *Populus* (Del Tredici, 1995), (2) stoloniferous species with specialized underground stems (many shrubs in the Rosaceae are in this category), (3) species with decum-

Table 1. Phases of ontogenetical development in temperate trees.

Phase name	Morphological characteristics	Physiological characteristics	Propagation implications
Seedling	Cotyledons fully functional Heteroblastic leaf development Vigorous tap-root development Anthocyanins in shoot tips	Maximum developmental plasticity Indeterminate growth flushes Polarity of shoot and root systems established	Strong adventitious root formation Propagules vertical Propagules thorny
Juvenile	Large, dimorphic leaves Thorns on stems Anthocyanins in shoot tips Long-shoots dominate crown Prolonged leaf retention	Strong apical control of shoot system Leader shoot strongly vertical Recurrent growth flushes Sylleptic branching	Strong to moderate adventitious root formation Propagules vertical Propagules thorny
Mature	Small, uniform leaves Thornless stems Flower and fruit production Short-shoots dominate crown	Strong apical dominance Horizontal (plagiotropic) orientation of lateral branches Single annual growth flush Root growth horizontal	Moderate to weak adventitious root formation Propagules diagonal and heavily branched Propagules thornless
Senescent[1]	Burl & sprout formation on trunk Sucker growth from root crown Greatly reduced extension growth Crown and/or root die-back	Loss of apical control Reiteration on all parts of tree Sectoring of vascular system (strip-bark development)	Weak adventitious root formation Propagules diagonal and heavily branched
Rejuvenation	Large, dimorphic leaves Thorns on stems Anthocyanins in shoot tips Leaf retention Adventitious root formation	Indeterminate growth Growth strongly vertical Sylleptic branching	Strong to moderate adventitious root formation Propagules vertical Propagules thorny

[1]More a physiological than an ontogenetical phase.

bent lateral branches that produce adventitious roots when they come in contact with the soil (referred to as layering), and (4) basal suckering species that produce vigorous shoots and adventitious roots from the root collar or lignotuber (*Sequoia sempervirens, G. biloba*, *Eucalyptus*, etc.). In the case of this last group, the root collar buds typically originate from meristems located in the axils of the cotyledons. These are the oldest buds on the tree and yet when they sprout 50 to 100 years after their initiation, the shoots they produce are considered fully juvenile (Del Tredici, 1992).

Shoot cuttings taken from a tree in the mature phase of growth often show partial rejuvenation when artificially propagated by grafting or rooting, particularly if the scions or cuttings originated from vigorous trunk sprouts or basal suckers (Brand and Lineberger, 1992; Cameron and Sani, 1994). Plant propagators learned long ago that such juvenile shoots have a much greater capacity to produce adventitious roots than mature shoots from the same tree and they have developed a variety of pruning techniques, including stooling, hedging, and pollarding stock plants, specifically designed to stimulate the production of vertically oriented, easy-to-root propagation material (Libby and Hood, 1976; Hackett, 1988). In the author's opinion, however, it is an oversimplification to define all adventitious roots as a manifestation of juvenility in the shoot system that produces them. While the statement is true for cuttings propagated under controlled conditions, it is not necessarily true for mature trees in nature, where adventitious root production appears to be as much the cause of shoot rejuvenation as the result of it.

Using modern, in vitro tissue culture techniques, researchers have been able to come much closer to achieving full ontogenetic rejuvenation of mature growth phase tissue than is possible with traditional techniques (Brand and Lineberger, 1992; Huang et al., 1992). However, even under optimal in vitro conditions, measurable differences in maturation state between cuttings taken from the base as opposed to the top of a tree can persist indefinitely (Bon et al., 1994; Greenwood, 1995). Indeed, most available research indicates that the rejuvenation effects associated with sexual reproduction — including apomixis — are qualitatively distinct from those associated with vegetative reproduction. It is for this reason that the seedling phase is separated from the juvenile phase in Table 1.

PHYSIOLOGICAL AGING AND ITS REJUVENATION PHYSIOLOGICAL AGING AND ITS REJUVENATION

In nature one finds the longest-lived trees growing in the most stressful environments. The bristle cone pine (*Pinus longaeva*), which grows at high elevations in California's White Mountains and reaches ages over 4000 years, is a famous example of the apparent paradox that "adversity promotes longevity" (Schulman, 1954). A less well known, but equally remarkable case is the eastern arborvitae, *Thuja occidentalis,* which grows on the steep, limestone cliffs of the Niagara Escarpment in Ontario, Canada. Under extremely exposed conditions, individual arborvitae stems can reach ages over 1200 years, considerably longer than the 300 to 400 years they last on more favorable sites (Larson et al., 1993). As a general rule, the longest-lived individuals within any given tree species are inevitably the slowest growing.

In an extensive survey of the longevity of North American tree species, Loehle (1988) found that the longest-lived species among both gymnosperm and an-

giosperm genera were those that directed the greatest proportion of their carbohydrate budget into chemical and structural defenses as opposed to vegetative growth. This same trade-off scenario seems to operate within a given species and provides a plausible explanation for why trees growing under extreme, continuous stress live longer than their counterparts growing under more favorable conditions..

For trees in cultivation, intensive pruning is often considered a mechanism for reversing the negative effects of physiological aging. The Asian art of bonsai is a well-known example of such rejuvenation induced by pruning. The techniques used in bonsai, particularly the root pruning, seem to produce a suspension of the physiological aging process that persists as long as the pruning regimen is maintained (Del Tredici, 1989). Pollarding and coppicing are tree pruning techniques of European origin that, when applied to appropriate species (e.g., *Corylus, Platanus, Tilia*, and *Ulmus*), promote greater longevity that one sees in unpruned trees of the same taxa (Rackham, 1976).

By analogy with trees growing on the tops of mountains, one might consider the intensive pruning of cultivated trees to be a form of environmental stress that causes the tree to invest more heavily in chemical defenses than it normally would. In general, pruning seems to bring about a measure of physiological rejuvenation by: (1) inducing the growth of ontogenetically younger meristems, (2) shortening the internal transport path of water and nutrients, or (3) reestablishing the balance between shoot and root activity when the latter is limited in some way (Bochert, 1976; Fortanier and Jonkers, 1976).

As a final point, one should ask the question, can the root systems of old trees undergo rejuvenation the way that shoot systems can? The practical experience of bonsai masters, as well as companies that specialize in transplanting large trees certainly suggests that root systems can be rejuvenated, but there is no obvious morphological evidence of it the way there is with shoot systems.

CONCLUSION

Many of the practices employed in commercial plant propagation are firmly intertwined with the confusing and poorly understood concepts of juvenility and maturity. Much of this confusion can be clarified with the realization that the ontogenetical and physiological aging processes operate independently of each other and that trees, unlike people, can be simultaneously embryonic and senile.

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Commercial Propagation of Southern Native Woody Ornamentals

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Colonial Williamsburg, Virginia, was one of the earliest and most refined communities of our young country. Williamsburg was carefully planned and beautiful homes and commercial buildings were planted with gardens and landscaping. The majority of the plants used in gardens were native shrubs. Only occasionally would a non-native appear, perhaps roses or fruit trees which found their way from Europe. Another famous colonial site was George Washington's estate in Mount Vernon, Virginia. George Washington, Father of our Country, was also a famous horticulturist who established extensive plant collections and well designed gardens. Once again, the major source of available garden plants was native species.
As our country grew both westerly and southerly, most of our gardens were decorated with native shrubs and trees. Gardening focused on food production.

In the Southern U.S., these trends continued until early in the 20th Century because of the lack of industrialization, the complications of the Civil War, and the agriculturally based economies. The early 1900s saw everything change and so did the preference of ornamental plants by Southern citizens. Those who could afford the luxury began to plant non-native *Camellia japonica* and evergreen azaleas throughout developing cities like Charleston, South Carolina; Mobile, Alabama; Baton Rouge, Louisiana; and other similar cities. After World War II, the South experienced the housing boom and urbanization much like cities throughout the U.S. Landscaping became more commonplace and a commercial nursery industry began rapid growth.

Production and use of mostly non-native species from Asia dominated the trend during this era, which lasted until the early 1990s. Nurseries and landscapes were dominated with *Ilex crenata*, *I. cornuta*, evergreen azaleas, *Ligustrum*, *Pittosporum*, and a few other non-native species. Only a few natives were commercially important. *Ilex vomitoria* 'Dwarf' (syn. 'Nana') , a dwarf form of the native yaupon holly was an exception to the rule and was one of the few native species produced.

The Southern U.S. is blessed with a wide diversity of native trees and shrubs. Southern species are now a very exciting and important sector of our commercial production and landscapes. The advantages of producing and planting native species is obvious, i.e. adaptation to local climatic conditions and resistance to pests.

We produce about 40 native species and nearly 700,000 native plants per year. Granted, a large number of *I. vomitoria* dwarf clones constitute a significant part of the total production. Other native species produced are very important to Southern landscapes and Southern nurseries. Some of the more important species are detailed below. Propagation information for many others can be seen in Table 1.

Gelesemium carolina, Carolina jasmine, is a vine flowering in spring that grows throughout the Southeastern woods. In cultivation it is beautiful. Recently, *Gelesemium rankanii* is getting commercial attention because it flowers in the fall and spring. We have discovered a natural hybrid, which will flower 2 weeks later in the spring than does Carolina jasmine. This new hybrid is named 'Butterscotch'.

Table 1. A summary of propagation techniques of southeastern native species.

Scientific	Common	Cultivar	Propagation information
Acer saccharum subsp. *floridanum*	southern sugar maple	'Magnolia Springs'	IBA 6250 ppm and NAA 2500 ppm, early summer-late spring
Agarista populifolia (syn. *Leucothia populifolia*)	Ocala leucothia		4-in cuttings, scar 1 side, IBA 3125 ppm, semi-mature wood
Betula nigra	river birch	Legacy™ river birch	Hard new growth, stick in May and June, quick rooting, IBA 1875 ppm
Bignonia capreolata	crossvine	'Tangerine Beauty'	2-node cuttings, IBA 2500, mid-summer
		Shalimar Red™ crossvine	" "
Callicarpa americana	beauty berry		hard new growth, cut tips one at a time, mid-summer, IBA 1875 ppm
Calycanthus floridus	sweet shrub		IBA 1875, early summer, 3-inch cuttings
Chionanthus virginicus	Grancy grey beard		Cut when it's raining, don't let it get dry, hard new growth, scar 1 side, April is best , IBA 1875 ppm
Cliftonia monophylla	black ti-ti		IBA 1800, mid-summer, 3-inch cuttings, we normally white flowering
Clethera alnifolia		'Pink Spire'	Treat like a native azalea, put in around July, KIBA 5000, propagate May through July

Scientific	Common	Cultivar	Propagation information
Clethera alnifolia		'Ruby Spice'	
		'Hokie Pink'	
		'Hummingbird'	*see above
Gelsemium hybrid		'Butterscotch'	4-inch cuttings, get rid of tender tips (1 at a time), dip in IBA 1250 ppm
Gelsemium rankinii	Rankinii jasmine		*see above
Gelsemium sempervirens	Carolina jasmine	Lemon Drop™ Carolina jasmine	*see above
	Carolina compacta		
Hydrangea arborescence		'Annabelle'	One-node cuttings, trim leaf tips, late May early June, IBA 1250 ppm
Hydrangea quercifolia	oakleaf hydrangea	Dayspring™ oakleaf hydrangea	KIBA 3000 ppm, stiff new growth, 4-inch cuttings, trim leaf tips
		'Alice'	" "
		Snowflake™ oakleaf hydrangea	" ", keep isolated from other types *of hydrangea*
Ilex cassine var. *myrtifolia*	cassine holly		IBA 2500, semi mature cuttings, July-September
Ilex glabra	gallberry holly	'Compacta'	IBA 1875, 4 in cuttings, mid-summer
		'Densa'	
		'Shamrock'	

Table 1. A summary of propagation techniques of southeastern native species.

Scientific	Common	Cultivar	Propagation information
Ilex vomitoria	yaupon holly	'Kathy Ann'	Cuttings should be branched to soil
		'Hightower'	" ", 4-in cuttings, scar on 1 side, stick in late summer and fall
		'Ocracoke'	" "
		weeping cultivar	" ", very unpredictable, difficult
		'Shadow'	*see Kathy Ann Batson
Ilex vomitoria	dwarf yaupon holly	'Schilling's Dwarf'	IBA 1875, October-May, no dip July-September, dip after 1st frost, cuttings should be branched to soil and stuck, shallow, branched cuttings, lower branch at soil level
		Bordeaux™ yaupon holly	" "
Illicium floridanum	Florida anise	'Head's Compact'	KIBA 5000, mid summer
Illicium parviflorum	star anise		KIBA 5000, mid summer
Itea virginica	sweet spire	'Henry's Garnet'	4-in cuttings, IBA 1875, late spring to early summer
		'Longspire'	" "
		'Saturnalia'	" "
Juniperus virginiana	eastern red cedar	'Brodie'	IBA 3750 ppm and NAA 1500 ppm, winter cuttings, brown wood for the cuttings

Scientific	Common	Cultivar	Propagation information
Leucothoe axillaris	coast leucothoe		4-inch cuttings, scar one side at a time, IBA 3125 ppm quick rooting 4in cuttings, scar one side at a time, IBA 3125, stick in high peat moss soil mix IBA 10000 and NAA 500 on very hard cuttings
Lonicera sempervirens	trumpet honeysuckle	'Canary'	One-node cuttings, mature new growth, thick cuttings, KIBA 5000
		'John Clayton'	
		'Allan Bush'	
Magnolia grandiflora	southern magnolia	'Little Gem'	Leave cuttings with 3 leaves, cut ½ of leaf off, cut below leaf node, IBA 20000, no pubescent hair on scarred end, don't over water or stress, each variety is slightly different, graft 1 inch or smaller root stock in January with cleft graft, cover with styrofoam cup; add soil to seal, seed germination: clean fresh seed, stratify for 2 to 3 months and plant
		D.D. Blanchard™ southern magnolia	" "
		'Southern Lights'	" "
		Green Back™ southern magnolia	" "

Table 1. A summary of propagation techniques of southeastern native species.

Scientific	Common	Cultivar	Propagation information
Magnolia virginiana	sweet bay	'Santa Rosa'	IBA 20,000 ppm, new mature cutting in late spring and early summer
Myrica cerifera	southern wax myrtle		Seed germination: clean fresh seed by rubbing off wax coating with abrasive Surface, stratify for 2 months and plant; by cutting, semi-mature cuttings, IBA 1875 ppm
Prunus caroliniana	cherry laurel	Cherry Ruffle™ cherry laurel	Winter cuttings, reddish cast on stem, scar on one side, KIBA 15000 ppm
Quercus shumardii	Shumard oak		Seed: use tree pot, plant fresh seed in greenhouse in the fall
Quercus virginana	southern live oak		Seeds: pick up and plant seeds ASAP before worm eats acorn, fresh seed-fall plant in greenhouse using tree pot
Rhapidophyllum hystrix	needle palm		Feb. and March, cut flowers from male plants and transfer to flowering female trees, lay cut male flower on female flower and let pollen fall on the female to pollinate, harvest mature seed in December, seed germination: plant and wait 2 years for germination, some reports say to break hard seed coat and germination is faster

Scientific	Common	Cultivar	Propagation information
Rhododendron austrinum	florida swamp	Select Yellow #1	Soft new growth, KIBA 5000 ppm, stuck in May until mid June
		Select Yellow #2	
		'Sunrise'	
Rhododendron canescens		'Varnador's Pink'	*see above
Rubus allegheniensis	blackberry	Navaho™ sow-teat blackberry	Node cuttings, one grows in ground, IBA 1250, cut in summer Harvest or purchase seeds fresh, clean from burr and plant immediately, watch for worms and grubs during the cleaning process and eliminate if present, some will clone
Viburnum obovatum	Walter's viburnum		IBA 2500 ppm, new Spring growth, not real or blackhaw virburnum limber
Vitis rotundifolia	muscadine grape		KIBA 3000 ppm, 2 node cuttings
Wisteria frutescens		'Amethyst Falls'	KIBA 3000 ppm, in early summer through late spring, 3 to 5 inches

Another new clone of Carolina jasmine is a ground cover, mounding, non-vining form, which we will name 'Lemon Drop'.

The oakleaf hydrangea, *Hydrangea quercifolia,* has recently become very popular. Two cultivars were produced very early, Snowflake™ oakleaf hydrangea and 'Snow Queen'. Recently, other selections have been made. Our selection, 'Dayspring', is now adapted to heat and humidity. It has outstanding purple-maroon fall color. Dr. Michael Dirr's 'Alice' is robust and easy to produce.

Magnolia grandiflora, the most famous Southern tree species in the last few years, has exploded with commercial opportunities. The challenge of being a successful producer of southern magnolia is the challenge of propagation. Each successful propagator has a different technique. Some of our best cultivars are 'D.D. Blanchard™ southern magnolia, and 'Little Gem'. One to look for in the future is 'Teddy Bear', a very columnar, compact brown-black clone with dark-green leaves.

Production of native species is now a major factor in Southern nurseries and Southern landscapes. Many species are being recognized beyond the native ranges because of their beauty and hardiness and they are finding niches in the Midwest, Northeast, Europe, and occasionally in other horticultural markets around the world.

Question and Answer Period: Thursday Morning General Session I

Bruce Briggs: What effect, if any, did the recent hurricanes have on southern nurseries?

Jim Berry: It could have been a hair-raising experience, but it wasn't for me. One of our nurseries is on the shore of Mobile Bay. Hurricane Frederick emptied the Bay in 1979, but Hurricane George filled the Bay up and we had lots of rain, lots of high tide, and we had quite a few plants go under water. It was slightly salty. When it receded we checked the EC and we did leaching. Some of the azaleas were affected, but by next spring we think they will be alright. We had minimal plant damage.

Mary Irish: Can pollarding actually shorten the life of a tree?

Peter Del Tredici: Pollarding and coppicing were developed as agricultural systems in Europe to promote the continuous yield of firewood. Pollarding is essentially coppicing at a higher level so that grazing animals cannot destroy the new developing wood. If it's done right by starting the technique at a young age, it can increase the life span of the tree. Problems arise when mature trees are pollarded.

Elizabeth Davison: Do you see any gradation or gradient in juvenility in root systems? Are suckers from roots closer to the trunk more juvenile than suckers that emerge 10 ft from the trunk?

Peter Del Tredici: There is work that has addressed this question. I believe the same general rule applies below ground as above ground. The further out you go on the root system the less juvenile it is.

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The Benefits from Protecting New Plant Introductions

Evelyn Weidner
Weidners' Gardens, 695 Normandy Road, Encinitas, California 92024

Open any wholesale plant catalog today or take a close look at the label that is attached to the plant and you will almost surely see those little letters next to the plant name (Pat., PPAF, or the small symbols ®,™) that indicate the name is trademarked.

The next thing you will often see is "Propagation Prohibited"; you might even see "Propagation Strictly Prohibited". Perhaps propagation is permitted under license only. Whatever you see, it means that the breeder or his assignee has gone to the time, trouble, and expense of protecting his rights to that particular plant cultivar.

Why is this done? What has caused the sudden proliferation of all these plant patents and trademarks? Who gets the money? How many entities have their hand in the pot? And of course, the final question, how many of you out there will abide by the rules and how many of you will be illegally propagating on the side?

There are a number of factors that have fueled both the proliferation of plant patents and new and exciting cultivars.

BENEFITS

Money. The royalties paid per plant are relatively small, but with the potential in a global marketplace, those pennies add up into big dollars. Without a means of both recouping the costs of breeding and eventually making a profit, there is very little incentive to the breeder.

Demand. Competition within our industry is relentless. To survive, those large companies that supply major crops must introduce newer, better, newer, and even better cultivars in an endless stream.

Public Popularity. The buying public has responded with enthusiasm, especially to the new blooming, cutting-grown "spring crops". What the public wants, the industry will try to provide.

Scientific Advances. High-tech techniques allow breeding breakthroughs that in past years were simply not possible.

Professional Marketing. More and more originators and their licensees have awakened to the fact that "marketing and advertising pay off". This is something other major product producers have known for years. We are just playing catch-up.

It is helpful to understand what plant material can or cannot be protected by plant patent. Who gets the fees involved and what do they do to earn those fees? Here it is in very simple terms. Look up the government's web site (www.uspto.gov) for more information.

If you find a new and wonderful plant, growing in nature — you can grow it, you can sell it, but you cannot get a patent on it!!

If you find a new and wonderful plant, growing in a garden or in a pot — that plant you can patent (if it fits all the rest of the criteria).

If you propagate and grow lots of that same first wild plant and one of those plants sports or mutates into a smashing, variegated beauty: that plant you can patent.

Table 1. Some of the costs of introducing and patenting new plants

Finder/breeder	Foreign agent administrator	Licensed grower/propagator	Finished plant grower
Owns patent on plant	Collects royalties, finds licensees, pays patent fees	Grows the liners, markets, distributes, trade shows	Grows on to sell to retail
$0.03 to $0.10	$0.02 to $0.05	Nothing to $0.04	$0.00

If you cross two plants and make a hybrid new plant—that new plant you can patent.

Be prepared to spend money, evaluate, and test hundreds and hundreds of plants. Understand that you may need to work years.

Then you might take some homely wild *Alstroemeria* and end up with a major florist cut flower plant.

All of these types of new cultivars are eligible for patent protection.

We are in the business of bringing beautiful, useful, and successful plant material to the gardening public. We increase our sales of plant material by being enthusiastic participants in the quest for new and exciting plants. It's our responsibility as individuals and industry leaders to pay those patent royalties so that we will continue to see ever better plant material. Nature isn't going to do all the work by herself! The scourge of illegal propagation, copy-cat or stolen (re-baptized) plants, and bringing out plants without thorough growing trials all work directly against the goals that we as members of I.P.P.S. stand for.

The Problems!

Along with all the good that has come from this proliferation of new plants has come intense pressures that have led to a number of problems. Our patent laws in both the United States and Europe have many loopholes that need to be addressed. Recent high tech developments have made many of the old rules obsolete. There is a good article addressing this issue by Paul Ecke Jr. in GPL Greenhouse Product News magazine's September and October issues. The "softening of breeder ethics" is a matter that affects us all. GPL Greenhouse Product News can be reached at www.greenhouseproductnews.com or email at gpntim@aol.com electronically.

The costs of developing and patenting new plants vary (Table 1). The fees vary according to how agreements are made. The royalties can be anywhere from $0.03 to $0.10, or even $1.00 to $1.50 on certain plants. Some royalties are based on a percentage of the wholesale finished plant price.

Patents are good for 20 years.

Question and Answer Period: Thursday AM General Session II

Andrew Davis: How is it determined when a "new" plant warrants patenting? What are the current costs for coming up for a genetic fingerprint of a plant?

Evelyn Weidner: A new plant whose protection is being applied for has to be grown alongside other plants. It has to show significant differences in at least one and up to seven to eight different ways. I don't know what the cost is for determining the genetic fingerprint of a plant.

Eunice Messner: What right does the United States have to patent the neem tree that is native to India?

Evelyn Weidner: I don't think they have the right to do that. This is one of the problems we face since we work under two systems of plant patent rules, the U.S. and European. There are many loopholes.

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NEW PLANTS

PRESENTERS:

Lynne Caton, Briggs Nursery, Inc. Olympia, Washington
Helleborus Royal Heritage™ hellebore
Daphne ×*burkwoodii* 'Briggs Moonlight'
Rhododendron 'Northern Starburst' PP#10388
Rhododendron 'Arneson Pink'
Rhododendron 'Lemon Lights'

Dennis M. Connor, Monrovia Nursery, 18331 E. Foothill Blvd, P.O. Box 1385, Azusa, California 91702-1385
Abelia ×*grandiflora* 'Sunrise', Sunrise™ variegated abelia PPAF
Carissa macrocarpa 'Tomlinson'
Citrus 'Cocktail'
Coprosma repens 'Pink Splendor'
Miscanthus sinensis 'Kirk Alexander'
Pennisetum setaceum 'Moudry'
Calamagrostis acutiflora 'Overdam'
Miscanthus sinensis 'Purpureus'

Kathy Echols, Midhill Farms, 197 Midhill Road, Martinez, California 94553
Salvia muirii

Dennis Perry, Perry's Panorama, P.O.Box 540, Somis, California 93066-0540
Protea (*P. susanae* × *P. magnifica*) 'Susara'
Protea cynaroides 'Mini King'
Leucadendron (*L. salignum* × *L. laureolum*) 'Jester' (syn. 'Rewa Gold')
Telopia (*T. speciosissima* × *T. oreades*) 'Shady Lady'
Banksia ericifolia 'Giant Candles'
Erica cerinthoides 'Hairy Heath'

Peter Del Tredici, Director of Living Collections, Arnold Arboretum-Harvard University, 125 Arborway, Jamaica Plain, Massachusetts 02130
Parthenocissus tricuspidata 'Fenway Park'
Zelkova serrata 'Green Veil'

Glen Williams, Fullerton Arboretum, California State University, Fullerton, P.O. Box 6850, Fullerton, California 92834-6850
Lysiloma watsonii
Ipomoea carnea subsp. *fistulosa*

Abelia ×*grandiflora* 'Sunrise' Sunrise™ variegated abelia PPAF

Zones: 6-10.
Category: Shrub.
Origin: A chance sport found September 1992 on a single branch of an *Abelia* ×*grandiflora* growing at Taylor's Nursery, Inc. Raleigh, NC.
Size: 3 to 5 ft tall and 4 to 6 ft wide.

Habit: Compact growth habit, slightly slower grower than *Abelia* ×*grandiflora* 'Edward Goucher'.
Foliage: Spring coloration is bright gold surrounding dark-green center. Summer color is cream surrounding dark green. The variegation holds year round in full sun to heavy shade (heavy shade produces a lighter variegation) bright orange and red fall color.
Flowers: White flowers appear throughout summer and fall.
Uses: Mass planting, foundation, or containers.
Culture: Grow in a warm, sunny situation in any fertile soil. Provide shelter from cold winds. In cold areas, grow against a south- or west-facing wall. 'Sunrise' holds up better in full sun, tolerating a medium to heavy shade.
Pest & Diseases: None known.
Propagation: Cutting grown.
Family: Caprifoliaceae.
Notes: The North Carolina State University Arboretum has been an important friend to our industry by introducing many new plants for commercial production. 'Sunrise' abelia will have a patent royalty of $.30 per unit sold, with all proceeds from its sale going to support the work at the NCSU Arboretum.

***Banksia ericifolia* 'Giant Candles'**
This is a superior selection of *B. ericifolia*, for the terminal bloom characteristic and adaptability to soils and climate. Clay loam and neutral pH are not usually a problem and this is a rare selection that holds its flowers up to the sky.

***Calamagrostis acutiflora* 'Overdam'**
USDA Cold Hardiness Zones 5-9 AHS Heat Zones 9-1. Semi-evergreen grass with mounding, slowly spreading foliage 2 to 3 ft tall. The broad foliage emerges striped with a soft yellow variegation, becoming white with maturing and taking on pink tones by late summer. Flower spikes are purple, becoming pinkish gray, and appear 3 to 4 ft above the foliage in early summer. Can be planted as a single specimen or in mass throughout the landscape in a formal garden, perennial border, or naturalistic setting around a pond. The pink tones of the flowers and foliage combine well with *Loropetalum* 'Sizzling Pink' and *Imperata cylindrica* 'Rubra'. Plant in full sun to partial shade.

***Carissa macrocarpa* 'Tomlinson'**
USDA Cold Hardiness Zones 10-11 Tomlinson Natal Plum, AHS Heat Zones 12-1. Dwarf, compact evergreen shrub is slow growing to 2 to 2½ ft tall by 3 ft wide. This cultivar does not have the large thorns along the branches characteristic of *C. macrocarpa*. Lustrous, leathery oval-shaped foliage is mahogany-tinted. Large, white five-petaled star-shaped flowers appear throughout the year followed by wine-colored fruit and flowers, green and ripe fruit often appear together. A superb choice as a tub plant or for foundation plantings. Fruit is edible, should be picked when red and has a flavor that can be described as similar to cranberry. The fruit can be eaten out of the hand, in salads, or used to make jelly, sauce or pie.

***Citrus* 'Cocktail'**
USDA Cold Hardiness Zones 9-10 AHS Heat Zones 12-1. A hybrid between pummelo and mandarin from the University of California at Riverside. Evergreen tree 20 to 25 ft tall and wide. Fruit ripens in December and has a greenish-orange exterior and light orange interior. The juice is very sweet and has a unique flavor with a hint of grapefruit. The fruit has many seeds and is prized for its sweet juice, but can be eaten like a pummelo by individually peeling the segments. Grow in full sun. Soil should be kept moist but fast drainage is a must. Can be used as a specimen or container plant.

***Coprosma repens* 'Pink Splendor'**
Cold Hardiness Zones: 9-10. Heat Hardiness Zones: 12-4. Evergreen shrub with bright-yellow variegated margins on very glossy green leaves ¾ inches long and ½ inch wide. New foliage emerges light green, and develops a rosy pink cast when mature, hence the name. Leaves curl upwards at the tip and sometimes at the sides providing interesting texture to the plant. Grows best in full sun with regular water, though it can tolerate partial shade. Landscape habit of 6 ft high and wide makes it ideal as a low hedge or container plant. Bright variegation adds color to perennial displays, especially when combined with bright yellow, red, and orange blooming lantanas, daylilies, yarrows, and cannas — spectacular with *Canna* Tropicanna™ canna

***Daphne* ×*burkwoodii* 'Briggs Moonlight'**
This extraordinary new cultivar was discovered at Briggs Nursery among a batch of *D.* ×*burkwoodii* 'Somerset' cuttings. Creamy-yellow leaves with narrow margins of dark-green make the plant literally shine in any application. 'Moonlight' is remarkably adaptable to any garden site other than the extremes of heat or shade. Prefers a well-drained site. Fragrant flowers. 4 ft × 4 ft. COPF. Plant Breeders Rights applied for in Europe.

***Erica cerinthoides* 'Hairy Heath'**
This is a long blooming, winter through spring, hardy *Erica*. Moist, acid soils are best, with summer drought tolerance. Prune and mulch this small shrub.

***Helleborus* Royal Heritage™ hellebore**
Briggs Nursery's 1999 Plant of the Year. The Royal Heritage™ hellebore is a collection of *Helleborus* ×*hybridus* developed over the last 15 years by the noted plantsman John Elsley of Wayside Gardens. Progeny for its strain was obtained from excellent parentage initially acquired from the esteemed European hybridizer, the late Helen Ballard. Parent stock includes excellent forms of *H.* ×*torquatus* (known for its dark colors), *H.* ×*olympicus,* and *H.* ×*orientalis*. As a result of long and careful selection, the strain exhibits hybrid vigor, a long flowering period and fantastic evergreen foliage of superior form, texture, and color. We have found the mix to show approximately 70% rich dark red with the remaining percentage a mix of pure white, velvety black, and a variety of spots and stripes on pink blossoms. This seed strain is trademarked by John Elsley.

Ipomoea carnea* subsp. *fistulosa
Pink bush morning glory was again brought to Fullerton Arboretum as seed from the southern end of the Sonoran Desert. (The plant is from seed collected in Mexico by one of our long-time supporters. This is the name we have keyed the plant to, but

most of the references are old, so I can only hope it has not had recent name changes.) The seed source is probably not native to the area, but normally found farther south. With good drainage (especially in winter) our plants have taken light frost (~30F) without any problem other than losing lower leaves (it kept right on flowering though). Our plants have only been in the ground for 4 years so they may eventually grow larger than the 8 ft they are now. Once the seedlings began to bloom they have not stopped.

The seedlings took about 8 months to begin flowering, but cuttings frequently start blooming again in 4-inch pots. We grow them in 1-gal containers and with a light pinch, if needed to promote bushiness, they can be ready for sale in as little as 8 weeks (10 to 12 weeks in winter). We produce *I. carnea* subsp. *fistulosa* from cuttings (now that the seedlings have grown) because we get blooming plants more quickly. With bottom heat, cuttings will root in 10 to 14 days in perlite, and during the summer, can be transplanted from the initial 4-inch pot to 1-gal containers in another 2 weeks. Or, the rooted cuttings can be planted directly into 1-gal containers with no problem.

Leucadendron 'Jester'

Many new sports of 'Safari Sunset' have been tested and some of the best are becoming available. These selections show the same great adaptability to soils as 'Safari', but with striking variegated foliage. Vigor is reduced prior to full establishment, but heavy pruning is suggested after establishment.

Lysiloma watsonii

Lysiloma watsonii grows naturally in the southern Sonoran Desert at elevations from 1000 to 3500 ft. (This introduction is from seed collected in Mexico by one of our long-time supporters. The name we have keyed the plant to is from old references, so I can only hope they have not had recent name changes.) Although the references indicate it will grow from 25 to 45 ft tall, the plants on the grounds at the Fullerton Arboretum are only 8 to 10 ft tall after 20 years.

Feather tree is one of the common names given to this lovely tree which we market at our plant sale as a good hot climate or hot area replacement for the Japanese maple which looks so poor after a summer in full sun. The feather tree loves the heat and sun, indeed as young plants they do not seem to like more than 20% shade, and they love the heat. This may explain why they do not get larger at our arboretum; it may not be hot enough in the summer. They do lose their leaves, usually fairly late in the year, about Thanksgiving or later. The feather tree is very drought tolerant (one plant on the grounds has had no additional water for at least the last 15 years) but they seem to look better with deep infrequent watering once established. Our plants had no problem in the freeze of 1989-90 when the temperatures went down into the high teens (18F) for more than 8 h, but since they are from low winter rainfall areas feather trees do not like to stay wet in winter; good drainage is important.

Lysiloma watsonii is easily grown from seed, which needs to be scarified, and placed on a heating mat (>80F). The seed germinates in 7 to 14 days and once it does, the seedlings need to be moved to very good light (morning sun then 40% afternoon shade is what we use) or they will not develop strong stems. After germinating we transplant into 3-inch pots using a sandy mix (basically a cactus mix) with Osmocote 14N-14P-14K at the label rate. Once the seedlings have developed a good root system we transplant them into 1-gal pots with our standard potting mix for sale or

later into 5-gal pots if they are to be used on the grounds. Usually it takes about 6 months to get a salable size 1-gal plant, and about 14 months to have a nice 5-gal plant.

We have not had any luck rooting cuttings of *L. watsonii* taken at several different times of the year.

***Miscanthus sinensis* 'Kirk Alexander'**

USDA Hardiness Zones 6-9 AHS Heat Zones 8-1. Deciduous grass with ½ inch wide, horizontally variegated arching foliage to 48 inches tall and wide. A dwarf form of *M. sinensis* 'Zebrinus' with striking bright gold horizontal bands of variegation. Flowers are pinkish copper and appear above the foliage in September. Foliage turns brown with the first frost. Attractive as a specimen or dramatic garden accent when in groups, especially when planted alongside water. The variegation is particularly effective when backlit by early morning or late afternoon light. Prefers full sun or partial shade and moist, fertile soil and can tolerate shallow water.

***Miscanthus sinensis* 'Purpureus'**

USDA Cold Hardiness Zones 7-8 AHS Heat Zones 8-1. Deciduous grass with blazing orange-red fall color which becomes a burnt reddish-brown in late fall through winter. Compact, upright clumps 3 to 4 ft tall of very narrow medium green foliage ¼ to ½ inches wide. Produces silvery plumes in July and August which appear 1 to 2 ft above the foliage. A beautiful focal point in the garden; use in perennial borders, in combination with grasses of different textures and colors, and in containers.

***Parthenocissus tricuspidata* 'Fenway Park'**

This unique cultivar of Boston ivy (*Parthenocissus tricuspidata*) produces yellow-green foliage. The plant originated as a bud-sport mutation on a specimen that was growing on a west-facing wall of an apartment complex in the vicinity of Fenway Park, Boston, Massachusetts. Arnold Arboretum staff member Peter Del Tredici discovered the plant in August 1988 while on his way to a Red Sox baseball game with his son. The evening sun was setting and the top portion of a mostly green plant seemed to glow in the fading twilight. Upon closer examination, it was discovered that the upper part of the vine was producing bright yellow leaves. With the cooperation of the superintendent of the building, cuttings of the mutant portion were collected and subsequently propagated in the greenhouses of the Arnold Arboretum. The outstanding characteristic of 'Fenway Park' is the color of its leaves during the growing season, which, depending upon the amount of light they receive, are various shades of yellow to chartreuse. When grown in full sun, leaf coloration comes close to Royal Horticultural Society (RHS) yellow-green 151A to C; in shade, it is a uniform lime green (RHS 154D). The coloration of the leaves of 'Fenway Park' is stable throughout the growing season. In the fall they turn brilliant shades of orange, scarlet, and yellow. In full sun, the distal portion of many of the large leaves may lose their chlorophyll altogether, making their tips susceptible to sun-scald during hot, dry summers. For this reason, the plant is best grown on a north- or west-facing wall. 'Fenway Park' is hardy within USDA hardiness Zones 4 through 9, and is useful as a climbing vine to brighten up walls, fences, or buildings, that are located in dark, shady places.

***Pennisetum setaceum* 'Moudry'**
USDA Cold Hardiness Zones 6-9; AHS Heat Zones 9-2. Produces flowers that are nearly black when mature, but emerge brown in late summer. Flowers are 6 to 8 inches long and appear 10 to 18 inches above the foliage. Black flowers contrast against the green foliage and combine well with *Coreopsis*, *Salvia,* and *Rudbeckia* 'Goldstrum'. Deciduous grass with dark green, glossy leaves ½ to ¾ inches wide. Forms a dense, upright, mounded clump 18 to 26 inches tall and wide. Foliage becomes yellow to yellowish-orange in fall, maturing to a straw color by winter. Can re-seed in an irrigated garden situation, but will not naturalize in arid western gardens.

***Protea cynaroides* 'Mini King'**
Many new color selections of smaller flowered 'King Protea' are becoming available. Darker pinks and red are the most sought after colors. These selections are from acidic quick draining soil regions, but their smaller size make for a great patio tub or retail potted plant. The foliage is green, attractive and great with a companion plant.

***Protea* 'Susara'**
A vigorous hybrid with clean foliage and pink flowers on long stems in winter-spring. It is adaptable to soils that are neutral in pH and loam in texture, as well as those soils with an acid pH and free-draining nature. High yield for the cut flower grower, tolerant for the home gardener, and with a great flower made from a superior selection. Prune 'Susara' vigorously and mulch the soils.

***Rhododendron* 'Arneson Pink'**
A stunning new hybrid from Ivan and Robertha Arneson. Strong pink semi-double blooms with wavy margins cover the dense shrub in May. Bud hardiness of at least -15F plus strong mildew resistance make this an outstanding choice. Becomes 3 ft by 4 ft in 15 years.

***Rhododendron* 'Lemon Lights'**
The latest introduction from the breeding program at the University of Minnesota features an abundance of bright lemon-yellow flowers with a vivid orange-yellow blotch on the upper petal. Good mildew resistance. Lightly scented. 5 ft by 4½ ft in 15 years. Plant and bud are hardy to at least -40F. Blooms late May.

***Rhododendron* 'Northern Starburst' PP#10388**
This outstanding new release is a result of years of research in the development of polyploid rhododendrons. 'Northern Starburst' is a tetraploid form of P.J.M. Compact. Significantly larger flowers of greater substance, stronger stems, and larger thicker foliage are of exceptional quality. The leaves are apple-green in summer, changing to a very deep purple-black in winter, dusted with brown. The flower color is bright lavender pink. It has the same reliable cold hardiness (-30F) as its counterpart.

Salvia muirii
The plant I have chosen to speak about is *Salvia muirii*. I teach a new plant introduction class at a Community College in northern California. In looking at new plants I realized that *Salvia muirii* has many of the characteristics which make a plant highly desirable for the home garden. One of the most significant advantages it has over other sages is that it is very small and compact. As the trend to smaller

lot sizes occurs in many parts of the world, the public demands smaller plants for the little space they have. This salvia is from South Africa and is new to the trade. It is a small compact shrub to 2 ft tall and 3 ft wide. The plant's growth habit is that of a stiff little shrub with a distinctive odor reminding you of a drugstore. The leaves are small and dark green. It blooms April through October with nice blue blooms with a white bee-landing patch. Cultural requirements are good drainage, sun to part shade, and regular water. It is hardy to 20F or maybe less in short cold blasts. *Salvia muirii* is an easy plant to maintain and requires only deadheading at the end of the flowering season. It is named for Dr. John Muir a botanist in England who discovered and described it. It should make an excellent garden plant. *Salvia muirii* is available at two growers in California. One is San Marcos Growers in Santa Barbara and the other is Rosendale Nursery in Watsonville.

Telopia 'Shady Lady'

The breeding work in *Telopia* is beginning to show great results. Shady Lady is a selection that has shown better garden habits, reduced size, soil tolerance, and yet maintains the spectacular flower of *T. speciosissima*. Pruning is advised to keep the plant vigorous and cool acid soils are best.

Zelkova serrata 'Green Veil'

Zelkova 'Green Veil' was introduced into cultivation in North America by Brookside Gardens of Wheaton, Maryland. It was obtained as grafted plants from the Shibamichi Nursery Company of Japan in 1978. 'Green Veil' forms a somewhat narrow tree, up to 60 ft in height, with a gracefully pendant habit of growth. The distinguishing feature of this cultivar is that the trunk and second order lateral branches are strongly ascending, while the smaller branchlets are strongly drooping. This contrasting orientation produces a dramatic effect in the landscape. The rate of growth of 'Green Veil' is more or less typical for the species, averaging between 1 and 2 ft in height per year. At the Arnold Arboretum in Boston, an 18-year-old plant is 36 ft tall by 20 ft wide, while a similar-aged specimen at Brookside Gardens in Maryland is 32 ft tall by 15 ft wide. 'Green Veil' is a striking specimen plant in most landscape situations. Because of its narrow growth habit and broad ecological tolerance, it has potential as a street tree.

Control of Soilborne Pathogens in Containerized Ornamentals

Donald J. Merhaut
Monrovia Nursery Company, 18331 East Foothill Blvd., Azusa, California 91702-1385

The propagation and production of woody ornamental plants often involves the use of containers during part or all of the production life of the plants. Containers inevitably restrict the development of the root systems and expose the rhizosphere to environmental stresses that would normally not be encountered if the plants were grown in the ground. Secondly, the manipulation of shoot and root growth that sometimes occurs during plant production presents additional internal physiological stresses to the plant. All of these stresses weaken plants and make them more susceptible to attack by various pathogens and pests. Therefore, containerized plants must be treated differently so these stresses can be minimized or eliminated, thus reducing the likelihood of diseases.

The following is a general synopsis of plant growth and development and the challenges faced by growing plants in containers, with a strong emphasis on understanding whole plant growth, development, and physiology. This review is organized into three topics: (1) the basic physiology of plants and how different cultural practices affect the major metabolic pathways; (2) pathogens encountered in nursery production; and (3) cultural control practices that can minimize plant stress and reduce the incidence of pathogens and pests.

PHYSIOLOGICAL PROCESSES OF SHOOTS AND ROOTS

Decisions on container sizes, planting media, and cultural practices are often based on the immediate aesthetic quality of the plants. Although these qualities are essential for plant display and sale, the short- and long-term impact of cultural practices on the physiological processes (photosynthesis, respiration, transpiration, and nutrient/water uptake) should be carefully considered. It is the proper functioning of these metabolic pathways which ultimately determines the long-term health and survival of plants.

In general, container-grown plants are usually subjected to restricted and/or manipulated root and shoot growth. Root growth is challenged, not only by the size of the container, but also by the physical, chemical, and biological characteristics of the planting medium. Normal shoot growth is altered directly by pruning, spacing, and synthetic growth regulators, and indirectly by factors affecting normal root growth. Understanding the different physiological processes which occur in the roots and shoots will aide in making sound cultural decisions to ensure optimum health and survival of plants.

DISEASES AND PATHOGENS OF ROOT SYSTEMS

There are several types of diseases that can have a significant impact on the proper functioning of root systems. Some of the major diseases include: root dieback, roothair senescence, galls, root-knot nematodes, lesions, and vascular plugging. These diseases impact the functionality of roots in several ways. Some diseases

destroy the root tips and root hairs, directly reducing the ability of the roots to take up water and nutrients. Others, such as galls formed by nematodes or other pathogens, reduce the number and efficiency of roots. Finally, the ability of the root system to transport water and nutrients to the shoots can be impaired by vascular plugging, galls, and lesions caused by mechanical damage, fungi, bacteria, and viruses. There are many pathogens responsible for root senescence. Some of the major pathogens include: *Agrobacterium*, *Cylindrocladium*, *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia*, *Sclerotinia*, and *Verticillium*. While some of the organisms are very pathogenic, attacking even healthy plants, most pathogen-related root diseases can be reduced or prevented by growing healthy plants in nonstressed environments.

PLANT HEALTH PRACTICES

Producing disease-free plants can be achieved by keeping plants healthy throughout production, eliminating the source of pathogens, and providing an environment that is not favorable to the growth and spread of pathogens. Horticultural practices can be divided into four primary categories: water management, sanitation practices, nutrient management, and cultural practices.

Water Management. There are three factors to consider regarding water management: water quality, irrigation timing, and irrigation methods.

Water Quality. Water quality can influence plant health indirectly by the presence/absence of pathogens in the water and directly by the amount and type of fertilizer in the water. Pathogen contamination of water should be tested regularly. If pathogens are a problem, proper purification procedures should be implemented such as filtration and/or chemical treatments. Nutrient concentrations should also be monitored regularly. The proper nutrient concentration of water is dependent on the fertilization program of the nursery, the time of year being considered, the crop in question, and the climatic conditions. If the nursery relies more on mineral additions into the planting media, less fertilizer is required in the water. Fertilizer requirements are usually higher during the spring and summer, when plants are actively growing.

Irrigation Timing. Similar to water quality, time of irrigation directly and indirectly impacts plant health. Containerized plants should never be in a state of drought stress. Although, many xerophytic plants, in their native habitat, are adapted to long periods without water, these same plant species will often senesce if exposed to even short periods of drought. This is associated with the restricted root system and lush vegetative growth that often occur with containerized plants. Time of day for irrigation may also be critical to plant health. Many plants, which are susceptible to foliar diseases, will benefit from watering in the morning rather than in the evening, so that plant foliage can dry out before dark. Otherwise, the extended period of leaf wetness may allow certain pathogen spores to germinate and infect the plant.

Irrigation Methods. Overhead watering verses drip irrigation or similar ground irrigation methods will influence plant health and disease incidence. Plants susceptible to foliar pathogens usually benefit from drip irrigation. However, if plants are susceptible to heat stress and root systems are incapable of providing sufficient water, overhead irrigation can cool canopies and therefore prevent heat stress.

Sanitation Practices. Proper sanitation practices will reduce the incidence of pathogen infestations, minimizing the likelihood of introducing pests into the nursery, and/or providing a favorable environment for a pest/pathogen to grow and reproduce.

Plants and Materials. Plants used for propagation and production should be free of any pests or pathogens. Infected plants must be properly discarded if they cannot be properly cleaned. Also, plant material, if rooted, should have a well developed uniform root system. Any rooted plants or seedlings that have roots wrapped around the main stem should be thrown away, since these roots will girdle the main stem when the plant is older. In addition to plant quality, planting media and the water sources also should be free of pest and pathogens.

Propagation and Production. All regions of propagation and production should be clean. Any plant debris or areas of standing water will harbor pests and pathogens. Weeds should also be removed since they may play host to various insects and lower pathogens. A well established Integrated Pest Management Program (IPM) will directly and indirectly control the spread and establishment of many pests and diseases since many fungal and viral diseases are spread by insect feeding.

Nutrient Management. Plants grown with a sound nutritional program are stronger and more resistant to pests and pathogens. When designing a fertilization program, consideration should be given to fertilizer rates, fertilizer source, plant type, and time of year. If plants are over fertilized, not only is there a greater risk for nutrient toxicity, but there is also a potential risk to contamination of the environment. Secondly, it is critical that the fertilization program is balanced with regard to all the essential elements. Over fertilization with one element can often lead to nutrient deficiencies of other elements, such as over fertilization with magnesium inducing a calcium deficiency. In a similar manner, plants do not produce the same growth with all fertilizers, even though the fertilizer nutrient content may be the same. For example, nitrogen can be supplied from ammonium or nitrate sources. However, different growth will often result from these two nitrogen sources. There are also seasonal differences for plant nutrient requirements. In general, most plants, especially woody temperate species, require and take up more fertilizer during the spring and summer months. By autumn, the nutrient requirements of plants as well as their ability to take up nutrients are drastically reduced.

Cultural Practices. Several processes in the growth and production of plants will increase plant health and reduce the incidence of pest and pathogen infestations.

Bed Structure. Containerized plants should not be in direct contact with the ground, since this greatly increases the risk of pathogen movement from the ground to the container and from one container to another container. Containers can be elevated off of the ground with benches, gravel, etc. The use of gravel or benches will also reduce the spread of pest and pathogens caused by water splashing from the muddy ground. In addition to bed structure, container spacing can reduce plant stress. In the summer, plants that are "container-tight" will experience less root dieback caused by high container temperatures.

Planting Practices. When planting young liners into larger containers, careful consideration should be given to planting depth, since some plants are very susceptible to root rot caused by planting too deeply. Proper watering schedules are also important until new plants are established.

Plant Maintenance. As discussed earlier, proper pruning decisions must take into consideration the environmental conditions and all of the major physiological processes that are occurring in the whole plant. Similar considerations must be made when staking and tying plants. Placing stakes into containers will damage root systems. If possible, stakes should be placed in containers before the plants. Tying plants to stakes should be done carefully. Sufficient room should be left between the stake and the stem to allow expansion of the stem. If crops are long-term, ties should be replaced to prevent stem girdling.

CONCLUSIONS

The propagation and production of plants in containers exposes plants to many stresses that are not normally encountered in nature. This makes container-grown plants more susceptible to many diseases. Therefore, it is imperative that plant health is maintained by providing optimum water and nutrients and providing a stress-free environment. Secondly, the sources of plant pests and pathogens should be eliminated to reduce the likelihood of infection. Environmental conditions should also be adjusted to make conditions less favorable for pest and pathogen establishment. Finally, when making any horticultural decisions, the effects of cultural practices on whole-plant physiological processes should be taken into consideration.

Growing Mycorrhizal Native Plant Species

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INTRODUCTION

Since its establishment in 1986, Bitterroot Restoration, Inc. (BRI) headquartered in Corvallis, Montana has been doing ecological restoration on severely disturbed lands. The focus of much of our work has been on arid, semi-arid, and sensitive, high-elevation areas, as well as sites severely disturbed by mining and pollution. Many mining companies, the National Park Service, the Environmental Protection Agencies, other federal and state agencies, and the private sector in the western United States of America work with us because we offer comprehensive restoration services and provide site specific native plants for our restoration projects. During the past several years, we have been trying to incorporate root-associated microorganisms into our restoration processes. Today, I will share with you our philosophy and approach to the restoration process, and our successful mycorrhizal program.

OUR PHILOSOPHY AND APPROACH

We at BRI believe that site specific native plants and their associated rhizosphere microorganisms must be utilized for successful restoration on environmentally sensitive and severely disturbed sites. Native plant species, through millions of years of natural selection, have adapted to their indigenous environments. Rhizosphere microorganisms are not only part of the ecosystems, but also critical to both establishment and long-term survival of plants in a sustainable plant community. Planting a site with shrubs and trees is not always enough; an ecological approach must be used.

A general approach to building a restoration plan follows these steps:

1) Gather baseline information. This would include comprehensive information obtained from an undisturbed reference plant community. On the disturbed site, information would be collected including: species composition, soil data, microorganisms, succession stage, habitat, and conditions limiting vegetation survival and growth. This initial site visit and analysis is very important.
2) Establish a site-specific restoration plan by carefully selecting the major components of vegetation and closely associated microorganisms, soil amendments, and a time line leading to the installation.
3) Collect plant propagules and microorganism inocula.
4) Propagate plants, isolate and culture microorganisms, and inoculate plants with microorganisms.
5) Harden-off plants and induce dormancy.
6) Amend soil.
7) Install plants on the sites and ameliorate micro-site conditions.
8) Modify and update original restoration plan with monitoring.

WHY MYCORRHIZAE ARE IMPORTANT?

First, mycorrhizal fungi are naturally occurring components of soil ecosystems. Seventy percent or more of the species of angiosperms, and most or all species of gymnosperms are mycorrhizal (Harley, 1991). Because mycorrhizal fungi may not exist on severely disturbed sites, we need to restore both vegetation cover and rhizosphere microorganisms in the soil.

Second, mycorrhizal fungi increase the uptake and translocation of water and nutrients for plants by significantly increasing the soil volume that the roots can effectively explore. The range of maximum values of mycorrhizal fungal mycelium length to root length are <1 to 592 m cm^{-1} of root (Sylvia, 1986). This means that the mycelia length increases effective root length by up to 59,200 fold. I am sure some of you are very familiar with Read's incredible picture of a small seedling with mycorrhizal hyphae (Read, 1991). One can imagine, from this picture, how the mycorrhizal fungi increase the root absorption area in the soil.

Third, mycorrhizal fungi reduce plant transplanting shock by increasing plant drought tolerance (Pigott, 1982; and Walker et al., 1989). This is extremely important for initial plant survival on arid and severely disturbed sites. The number one issue facing restorationists with these sites is plant survival. Incorporating mycorrhizal fungi into plant production process can dramatically increase plant survival after installation. One should realize that while mycorrhizae may not significantly increase plant growth in the nurseries, they are critical to plant survival and successful revegetation on harsh and severely disturbed sites (Evans, 1997).

Last, mycorrhizal fungi alleviate the toxicity of heavy metals to plants (Denny and Wilkins, 1987; and Jones and Hutchinson, 1986). Heavy metals in soil at mining sites, and Super-Fund sites are toxic, even to native plants. However, mycorrhizal fungi can help plants resist heavy metal toxicity through sequestering these metals in the fungal hyphae. Inoculation of these plants greatly increases a plant's initial survival and long-term growth on these sites. Additional benefits include disease suppression and improvement in soil structure.

OUR MYCORRHIZAL PROGRAM

Mycorrhizal fungi are classified according to the type of relationship they have with root cells and by their culturing requirements. The major groups of mycorrhizae are ectomycorrhizae, endomycorrhizae, and ectendomycorrhizae.

The plants we grow at BRI that form ectomycorrhizae include the genera: *Abies, Alnus, Betula, Picea, Pinus, Populus, Quercus,* and *Salix.* The hyphae of these ectomycorrhizal fungi do not penetrate root cells. They grow between and outside the root cells and form a layer called the Hartig net. Ectomycorrhizae are usually very distinct and easily recognized by their visible structures (Castellano and Molina, 1989). This type of mycorrhizal fungi can be cultured with artificial semisolid or liquid media. At BRI, we use either fruiting bodies collected from specific sites, or commercially available spores to inoculate all our ectomycorrhizal plants in greenhouse 6 to 10 weeks after sowing of seeds. Before planting, mycorrhizal colonization rates are assessed. We have been very successful in colonizing all our ectomycorrhizal plants.

However, most of the native plant species we grow at BRI are endomycorrhizal species. Endomycorrhizal fungal hyphae penetrate into root cells and occasionally form structures called vesicles and arbuscles. They are also referred to as vesicular-

arbuscular mycorrhizae (VAM). This type of mycorrhizal structure is not easily visible. One has to rely on chemical staining and de-staining methods to examine them microscopically (Rajapakse and Miller 1992). Culturing this type of fungi in semisolid or liquid media is not possible. They must be cultured directly with host plants. Characteristically, mycorrhizal fungi spread very slowly in the soil as they can only be carried by root growth or distributed by soil disturbances. Consistent with the restoration plan, we collect native plant roots and soils from restoration sites, isolate the target mycorrhizal fungal spores in the laboratory, increase the mass with host plants in our research greenhouse, and inoculate target plants with these fungi. After monitoring the plants to ensure that we achieve at least 30% success rate of colonization to total root mass for each seed lot, we inform our clients of the status of the plants. If the colonization percentage of a seed lot is less than 30%, we reinoculate. We have grown most endomycorrhizal native plants successfully including the genera: *Amelanchier, Chrysothamnus, Juniperus, Prunus, Purshia, Rhus, Ribes, Rubus,* and *Rosa*.

Ectendomycorrhizae have characteristics of both ectomycorrhizae and endomycorrhizae. These mycorrhizal fungi penetrate into root cells as well as grow outside of roots as ectomycorrhizal fungi. Native plant species we have grown with this type of mycorrhizal association are in the genera *Arctostaphylos* and *Vaccinium*. *Arctostaphylos* is sometimes referred to as *arbutoid*, and *Vaccinium* as *Ericoid* (Smith and Read, 1997). For the genus *Arctostaphylos*, we have grown native plants with site-specific inoculant cultured in our research greenhouse, as well as commercial ectomycorrhizal sources. We have been particularly successful colonizing *Arctostaphylos uva-ursi*. For *Vaccinium* species, our approach and method are consistent. However, it has been very difficult to stain and observe the mycorrhizal fungi in the laboratory. Future work needs to be done to improve and verify our results.

In summary, we have successfully grown many mycorrhizal plant species native to the western United States. We continue to research and develop techniques for mycorrhizal fungal collection, isolation, culturing, inoculation, and colonization analysis. We have incorporated our mycorrhizal program into our normal propagation routine and have seen positive results of mycorrhizal inoculation in the field. Our future goal is to incorporate not only mycorrhizal fungi, but also other beneficial microorganisms into our plant propagation and restoration work.

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Propagation of Indigenous and Endemic Ornamental Hawaiian Plants

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Hawaii's nurseries have been stimulated to begin production of indigenous plants as a result of a state policy requiring the use of these plants in public landscapes. While many native plants can be grown from seed, vegetative propagation of ornamentally attractive selections is necessary to maintain these ornamental qualities. In this paper, propagation practices are described for *Hibiscus arnottianus, H. clayi, H. brackenridgei, Gossypium tomentosum, Sida fallax, Wikstroemia uva-ursi, Heliotropium anomalum, Osteomeles anthyllidifolia, Vitex rotundifolia, Artemisia australis, A. mauiensis, Erythrina sandwicensis, Metrosideros polymorpha, Pittosporum spp.,* and *Psydrax odorata*.

INTRODUCTION

With the passage of Act 73 (relating to the use of native plants in landscaping) in 1992 by the Hawaii State Legislature, landscape contractors who bid on public projects were required, where feasible, to use Hawaii's indigenous species in the landscape. Wording in the Act included the purpose, "to encourage the propagation of Hawaii's indigenous species of land plants." This measure was enacted to prevent the decline of Hawaii's unique native flora by encouraging its use in the landscaping of public buildings, facilities, and housing projects developed by the State.

Since there has not previously been a major market for Hawaiian native plants, nurseries have had to speculate a bit and build up stock for the landscape industry to evaluate. Recently, private and public developers have begun to incorporate native plants into their landscaping. A number of suitable ornamental plant materials have already been identified (Bornhorst, 1996; Bornhorst and Rauch, 1994; Weissich, 1994), but some are difficult to propagate and stock plant material is lacking for others.

This paper summarizes some of the successful propagation systems developed at the University of Hawaii as well as at various botanical gardens and by native plant enthusiasts. Some of the information is research-based; some is anecdotal.

MATERIALS AND METHODS

Cutting propagation research carried out at the University of Hawaii is usually conducted under intermittent mist with a cycle of 6 to 8 sec "on" time every 5 or 6 min (depending on the timer used) under 30% saran shade and ambient outdoor temperatures, in media of equal parts coarse perlite and vermiculite or No. 2 vermiculite alone. The rooting compounds used have been either commercial talc dust preparations such as the Hormex or Hormodin series, liquid preparations from Dip-N-Grow or Woods Rooting Compound (both with 2 : 1 IBA to NAA ratios), or 30% alcoholic solutions prepared from crystalline IBA. When citing the work of others,

every effort has been made to determine what propagation methodology was used, but most of the reports have failed to describe the conditions of propagation.

ORNAMENTAL HAWAIIAN PLANT MATERIALS

Hibiscus arnottianus var. *punaluuensis* (koki'o ke'oke'o) is a fragrant, perpetually white-flowered hibiscus native to a small mountainous valley on the island of Oahu. It can grow into a small tree of about 30 ft. in height, but is often found in our landscapes as a hedge or accent plant. It can be grown readily from seed, but terminal and sub-terminal cuttings root readily following treatment with 4000 to 7500 ppm IBA : NAA (2 : 1 ratio) (Tokumaru, 1997), and Hormex #3 has also been used successfully (Bornhorst, 1996). Grafting and air layering are also reported as feasible technqiues (Rauch et al., 1995).

Other native hibiscus species with ornamental potential are *H. clayi, H. kokio* subsp. *saintjohnianus,* and *H. brackenridgei. Hibiscus clayi* is native to the island of Kauai. It forms an upright growing shrub or small tree with solitary dark red flowers and makes a handsome specimen or accent plant. *Hibiscus kokio* subsp. *saintjohnianus* is another Kauai native with orange flowers that can occur as a shrub or small tree. It makes a colorful landscape plant in a sunny location. Both of these natives can be grown from freshly collected seed with no difficulty. Cutting propagation is enhanced by the use of auxins such as 4000 to 6000 ppm IBA : NAA (2 : 1 ratio) on terminal cuttings under intermittent mist. About 8 weeks is required for rooting.

Until recently, *H. brackenridgei*, Hawaii's State Flower, was on the endangered species list and it was illegal to own plants without a permit under State law. Act 381 was passed in 1997 to remove that prohibition if the plant came from cultivated sources and not from the wild. Thus, arboreta and botanical gardens are licensed to propagate and sell from their established plants. *Hibiscus brackenridgei* is a somewhat short-lived (5 to 6 years in the wild) sprawling shrub or small tree found on all of the main islands of Hawaii (Bornhorst, 1996). It produces large, clear yellow flowers in the spring months and does not flower during much of the rest of the year. It can be grown from seed or cuttings. Cuttings require auxin treatment and the 4000 to 6000 ppm concentration range of IBA : NAA (2 : 1 ratio) seems to work well.

Another member of the Malvaceae with ornamental potential is the Hawaiian cotton or ma'o, *Gossypium tomentosum*. The plant habit ranges from sprawling shrubs to sculpted mounds to prostrate groundcovers. The foliage is silvery green and palmately lobed. The yellow flowers are 2 to 3 inches in diameter and produced year around. It can be used as a background or filler plant, as a specimen plant, shaped into a hedge, or grown in a container. Terminal cuttings, both soft and semihardwood, rooted in 3 to 4 weeks under mist following treatment with 2000 ppm IBA in either liquid or talc dust formulation. Seed propagation is also used, but the growth habits of resulting plants are not as uniform as from vegetative means. Following removal of the short brown fibers from the seed, a 24-h presoak in water or scarification enhances germination (Rauch et al., 1993a). The 'ilima, *Sida fallax,* is a malvaceous, low-growing woody shrub with a range of leaf textures and growth habits, bearing yellow to orange flowers year around. Hundreds of the small flowers are strung into leis that represent the island of Oahu. Cultivated forms have been selected for prolific flowering as well as for prostrate, upright, and mounding growth habits. Coastal-derived plants are suitable for hot, dry locations, while the upland

types are more upright and better adapted to irrigated landscape situations (Rauch et al., 1993b). 'Ilima can be propagated from seed or cuttings (Rauch et al, 1993b), but extremely wet intermittent mist conditions cause leaf drop and poor take in rooting of cuttings. The methods used for ma'o should work for 'ilima.

One of the more widely planted natives is 'akia, *Wikstroemia uva-ursi,* used as a foundation planting, ground cover, or mass-planted in beds or borders. It has good tolerance to coastal conditions. It is generally a prostrate or sprawling shrub, with grayish-green ranked foliage and dense branching. The flowers are tubular and yellow-green. The single-seeded fruits are about 3/8 inches in diameter and orange to bright red in color. Propagation by seed is common and easily done, but seed is sparse in some years. Propagation by cuttings was regarded as difficult, but research has shown that recently matured terminals about 5 to 6 inches (12 to 15 cm) long can be rooted in high percentage with wounding and rooting compounds (Matsuda and Criley, 1980; McEwen, 1995). The wound was made by a quarter-inch long incision through the bark at 2 or 3 sites at the base of the cutting or by pulling off some lower leaves with a strip of bark. IBA at 3000 ppm and Dip-N-Grow at 1 : 9 and 1 : 4 dilutions produced 80% to 100% rooting within 6 weeks. The talc dust formulation of IBA at 3000 ppm was not as satisfactory as the liquid.

Another coastal plant material, hinahina, *Heliotropium anomalum* var. *argenteum,* finds use as a groundcover for beach exposures and well-drained sites. Its rosettes of silvery blue-green foliage contrast well with taller, dark green vegetation or with the dark hues of rock walls (Crivellone, 1991). While it requires regular watering in cultivation, it also requires good drainage. Soft, herbaceous cuttings of hinahina root in 3 weeks under intermittent mist without the use of rooting hormones and neither the root quality nor percent rooting were improved if IBA strengths of 500 to 2000 ppm were used (Crivellone and Rauch, 1991).

Indigenous to Hawaii, the Cook Islands and Tonga and up into the Ryukyu Islands near Japan, 'ulei, *Osteomeles anthyllidifolia*, is one of the few members of the rose family that is found naturally on all of the main Hawaiian islands. 'Ulei's habitat ranges from open fields and shrublands, dry to mesic forests, to disturbed areas where it will compete well with alien weeds. The dark-green glossy foliage is odd pinnately compound and fine to coarse in texture. This plant can mound up to 10 ft (3 m) in height, but is most often a sprawler-spreader. It takes pruning well and finds use as mass plantings, ground covers, rock wall, bank covers, and low hedges. The hard seeds require about 2 months to germinate and seedling growth is slow. Since fine-textured and compact forms may be selected from seedlings, vegetative propagation may have some advantages. Recently matured terminal cuttings rooted with only 67% success after 8 weeks following treatment with 6000 ppm IBA (the highest concentration tested).

Pohinahina, *Vitex rotundifolia*, is another indigenous plant found along sandy beaches and rocky shores. It is a sprawling shrub with round, grey-green/silver leaves and purple-blue flowers. While it is often wind-pruned to only a couple feet in height, in cultivation it will mound up to about 4 ft. It can be maintained as a groundcover, as a natural or pruned hedge, foundation plant, bank cover, in rock gardens, and at the tops of retaining walls. As the seeds are difficult to extract from the fruits, the whole fruits can be planted after soaking in water for 48 h to soften them. Germination is slow, about 3 to 6 months (Koob, 1998b). Cuttings are faster. Nonflowering terminals about 4 inches long will root in 3 to 4 weeks under mist

following treatment with IBA (Hormex series 3, 8, and 16 have all improved root quality over no hormone treatment). Seedlings and rooted cuttings should be pinched after transplanting to encourage branching.

Continuing in the silver-foliaged plants, ahinahina, *Artemisia mauiensis* and its close relative *A. australis*, are attractive ornamentals related to sagebrush and wormwood. Small shrubs with finely divided foliage, they do well in full sun and well drained sites. They are wind-tolerant, and respond well to pruning to shape them. *Artemisia mauiensis* is found at 6000 to 7500 ft elevations on the lee side of Mt. Haleakala, while *A. australis* is found on windward coasts. Propagation from seed is possible if fresh seed is used, but it is very fine and does not store for a long time. Sow on a fine-textured potting medium kept moist during germination then transplant seedlings after the second of third set of true leaves appear. *Artemisia australis* roots easily from cuttings, although weak hormone solutions speed root formation, but *A. mauiensis* requires medium strength rooting hormones. Tip cuttings 3 to 4 inches long are used and a high humidity environment yields better results than intermittent mist. Rooting takes 4 to 8 weeks, after which they can be transplanted (Koob, 1998a).

There are many species of *Erythrina* worldwide, and one of them, *E. sandwicensis*, is found in the dry, leeward lowlands of nearly all the Hawaiian Islands. They are tolerant to drought, salt air and wind, and are thus suitable for dry areas and coastal sites (Rauch and Hensley, 1993). Known as wiliwili, these are small trees (to about 30 ft tall) of moderate to fast growth rate. The pea-like flowers are borne in late summer and range in color from red-orange to salmon, white, yellowish, and chartreuse. The easy-to-germinate seeds (5 days) are borne in small twisted pods (wiliwili means twisted). Germination is enhanced by scarification or an overnight soak in warm water. They can also be grown from tip cuttings and air layers. Rooting hormone treatment probably enhances the speed of rooting, but published information is not available.

The ʻohiʻa lehua, *Metrosideros polymorpha*, is found all the way from sea level to high elevations, from wet coastal areas exposed to salt spray to bogs nestled high in the mountains, and on new lava flows. There are many forms (hence, the species name polymorpha) ranging from prostrate ground hugger to shrubs to trees of 100 ft (30 m) height. The elliptical, leathery, sometimes tomentose, foliage is borne densely along the stems. Their landscape use is as accent plant, specimen, container or foundation plants, but good drainage is a necessity despite their need for regular watering. The flowers consist mostly of brilliantly colored stamens and pistils in reds, oranges, yellow, and occasional pinks. White flowers are mentioned in descriptions of these plants, but there are no white forms in cultivation. Some forms are easy to root and others quite difficult. Since many of the ornamental forms are relatively easy to root, these forms should be the ones propagated for the nursery and landscape trades. Seed is fine and may be sown on the surface of a moist medium where it will germinate in about 10 days. Transplanting is done after 2 or 3 true leaves have developed. Both tip cuttings from vigorous, recently matured growth and air layers root when rooting hormone solutions of 2000 to 4000 ppm IBA or IBA-NAA combinations are used. The difficult-to-root forms may benefit from higher concentrations of auxin as Tanabe and Frazier (1985) found 3% IBA in talc dusts improved both percent rooting and root quality of air-layered ohia.

The native *Pittosporum* species (*P. confertiflorum*, *P. floculosum*, and *P.hosmeri*) are dense, slow-growing, handsome broad-leaved evergreens. They are not used much because of the difficulty of obtaining plants, but they offer one of the challenges to the Hawaii nursery industry. Seed takes 6 or more months to germinate (NTBG, 1996), and it is not clear that the recommended scarification and soaking treatments are particularly helpful. Cutting propagation has, to this point, yielded low percentages of success with tip cuttings and 4000 to 6000 ppm auxin.

Another challenge to the Hawaii nursery industry is alahe'e, *Psydrax odorata* (syn. *Canthium odoratum*). A small shrub or tree found in the dry mountains and exposed coastal slopes, alahe'e produces glossy dark-green leaves on a densely branched plant. Its tiny white flowers are fragrant. Seed propagation is a preferred method of propagation, but the larvae of a tiny moth attack the seeds and fewer than 10% are viable. Germination takes 30 to 180 days and both cold storage and presoaking the seed in water for 24 h have been recommended (NTBG, 1996). At the University of Hawaii, we have had some success in rooting greenwood cuttings under high humidity. The use of 4000 ppm IBA has worked about as well as any other treatment, but rooting percentages have not been high, about 10%. We have also tried the phenylthioester of IBA at 5000 and 10000 ppm with no improvement over the lower IBA treatment.

Many Hawaiian plants with ornamental potential remain a challenge to the nursery industry. A more than 20-year-old challenge to germinate the seed of pukiawe (*Styphelia tameiameiae*) (Woolliams, 1975) has been met by Alvin Yoshinaga, a researcher at the Harold Lyon Arboretum, and by a demonstration of culturing seed aseptically by one of our graduate students, Ted Radovich. Still, neither would claim that their work is the basis for commercial propagation. We looked for evidence of an immature embryo by slicing the seed on a microtome and found that the embryo was already developed when the fruit was harvested.

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Propagating in the Desert Southwest: What We Do and Why We Do It

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INTRODUCTION

An important challenge in the American Southwest is to introduce newcomers to the exciting variety of landscape plants adapted to the desert climates. A major effort on the part of water companies is directed to reducing landscape water use. Commercial growers, botanical gardens, highway plantings, and public displays all showcase species that can be successful in landscapes with less than 10 inches of rainfall. For this reason, commercial propagation efforts focus mostly on species unique to areas of the world that have similar high light, low relative humidity, and extreme diurnal temperature ranges.

CLIMATE

The USDA hardiness zones for the North American Deserts range from Zone 8 to Zone 11. Average temperatures in the Sonoran Desert range from below freezing on winter nights to over 100F (40C) on summer days. The diurnal range in any season is normally 30F. Rainfall in the Sonoran Desert is typically about 10 inches (25.4 cm) per year, about evenly divided between summer thunderstorms and gentler winter showers. Relative humidity in the driest seasons is normally under 10%. High irradiance levels are the norm; measurements often register above 10,000 fc (2000 microeinsteins m^{-2} sec^{-1}) on a summer day.

PROPAGATING FROM SEEDS

Species native to the desert environment have evolved unique survival mechanisms. Seeds normally ripen and dry down during the hottest driest months, so these mechanisms include at least one type of seed dormancy.

Many trees commonly grown in the Southwest nursery trade are members of the Fabaceae family. Examples include the genera *Prosopis, Cercidium, Olneya, Sophora, Cercis, Acacia, Erythrina,* and *Psorothamnus.* They exhibit seed-coat dormancy that requires some scarification effort (boiling water, acid soaking, or tumbling in sand) specific to the species. Other trees from the higher elevations (*Cupressus, Juniperus*) or sometimes from the lower river beds (*Celtis, Rhus*) require moist stratification from 3 to 10 weeks, depending on the species. More often than not, both dormancy restrictions occur to some degree.

Desert shrubs in the family Fabaceae (*Senna, Calliandra, Caesalpinia, Bauhinia*) grown from seed typically have seed-coat dormancy requiring scarification (sometimes only boiling water is sufficient; other times, acid is more efficient). Seeds from most plants in dry climates are considered classic orthodox seeds: easily dried and stored for many months. Very few seeds in desert ecosystems would be considered recalcitrant (*Quercus*, from the slightly higher grasslands, being one exception).

Cacti are hybridized for improved flower color and length of bloom time; many species are grown from seed by specialty producers. Cactus seeds normally require

no special treatment and are sown in March, in a very loose soil mixture which may include pumice and rough sand. Although misting the seeds is not beneficial, germination is enhanced if ambient temperatures are 80F (27C) and the relative humidity is raised with plastic enclosures. The best cactus hybridizers have begun to propagate their crosses vegetatively (see discussion of cactus grafting below).

Wildflowers are big business in the Desert Southwest. Seeds are harvested during the driest months — April, May, June, or October and November. Drying machines are not needed. Seeds typically have at least inhibitor dormancy (benefitting from soaking) and some are sensitive to high soil temperatures. Since most of the wildflower species are winter annuals that bloom from February through April, sowing outdoors is most successful in October when soil temperatures have dropped and rain can be expected. A variety of mixes is available for revegetation, home gardens, attracting wildlife, etc. If mixes bought for use in the lower elevations include species from cooler sites, these species may fail to germinate in future years due to lack of colder winter temperatures.

CUTTINGS

The SW nursery industry has begun to offer patented and/or trademarked varieties of arid-adapted species — everything from trees to groundcovers. Since these must be propagated vegetatively, growers have correctly begun to pay more attention to the challenges of our hot dry environment.

Many woody species in the SW Deserts have two growth flushes — one from April through mid June, another after summer rains from September through October. Taking cuttings during these times often ensures better rooting success. Some of the legume trees are particularly sensitive to the succulence level or stage of growth, and have been found to root more readily if taken during April and May.

Despite the relatively warm climate, and even with a mist system, outdoor propagating set-ups result in less than optimal rooting success. The low relative humidity, high light levels, wind, and large temperature swings throughout the day do not provide the required benign environment favorable for root initiation. Even though desert trees, shrubs, and succulents have mechanisms to reduce heat load, the physiological process of root initiation seems to be most successful if the high light levels are reduced to approximately ¼ to ⅓ of ambient noon levels, depending on the season.

To raise the relative humidity in a desert climate, both plastic enclosures and reliable mist systems (with quality components) are a non-negotiable requirement. The mist must turn on at least every 8 to 10 min throughout the day and preferably a time or two during the night. It is less important to have a climate-override feature, since light and atmospheric conditions are quite consistent on a monthly basis.

Because the mist needs to run so often, the medium must be very loose. Frequently, a heavy mix is the cause of leaf drop and stem softening in cuttings of many desert species. At the University of Arizona, we use coarse vermiculite mixed 1:1 with perlite. Mesh table tops or good air circulation reduce excessive medium wetness. Deep containers drain better, too, so trays or cones should be at least 4 inches deep.

Because most arid-adapted shrub, perennial, and groundcover species are fairly woody, auxin improves rooting success. We have found at the University of Arizona

that liquid formulations often induce roots more rapidly than the same strength in powder formulation possibly due to the light mix that might fail to hold a powder near the stem base.

To counteract the wide diurnal temperature swings, bottom heating on the mist table is normally turned on near the end of October when night temperatures are dipping to the mid-50s. We try to keep soil temperatures above 80F. Often the bottom heat system is sufficient to heat the house through the night. An important point is that the system must be regulated by a thermostat, since day temps throughout the winter may still be high enough to require full cooling.

In the Desert Southwest, fans and pads must be top of the line. The good news is that because of the low RH, the evaporative cooling principle works extremely well. Most of the year it is possible to reduce the temperatures a full 80% of the wet bulb/dry bulb differential. Shade cloth is often custom made for the houses, applied in early March and removed in November. Varying grades of the shade cloth can effect a noticeable reduction in heat load, and light levels may be lowered to a workable level inside the houses. Depending on the species (and growth stage) rooting may be improved if the mist areas are shaded further.

GRAFTING CACTI

The states in the Desert Southwest are the source for cacti and succulents for a world market. Most of the landscape species are grown from seed or are propagated from stem sections or offsets. On the other hand, hybrids bred for improved flower size/color and unusual or novelty forms (crested cultivars, those lacking chlorophyll, thornless or misshapen forms) are sold to collectors or combined in cactus gardens, etc. Unusual scions are normally grafted onto a vigorous rootstock, for increased production and more rapid sales. The typical rootstock for this use is *Myrtillocactus geometrizans*, a rapidly growing species. One of the most innovative growers of unusual cacti has developed a "double cut" system where scion tips or even sections of four to five aureoles are grafted to the rooted stock. Grafts normally take in 2 weeks.

SUMMARY

An increasing number of growers are introducing arid-tolerant species that will thrive as ornamental landscape plants in the desert climates of the world. However, propagating in the American Southwest is a challenge because of the extremely dry atmosphere, the large range in daily temperatures, and the high irradiance levels. In any arid subtropical country, the challenges would be similar. An understanding of the markets, desert species' growth patterns, dormancy requirements, and controlled climate technology will all serve to increase the availability of native and locally adapted taxa.

The Best of New and Old California Native Perennials

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In this short paper, I would like to introduce or reacquaint the reader with a number of cultivars of Californian perennials and subshrubs that certainly deserve to be more widely propagated and grown. These beautiful Californians are riding the waves of interest in perennials and native plants. Most of these plants are also well matched to today's smaller gardens. This paper differs from the oral presentation in two ways: (1) Plants that were covered in the presentation and are not covered in this paper (*Lessingia filaginifolia* 'Silver Carpet', *Romneya* 'White Cloud', *Salvia spathacea* 'Pilitas', *Epilobium septentrionale* 'Select Mattole', *E. canum* 'Sierra Salmon', and *E.* 'Solidarity Pink') and (2) two older cultivars and one new selection that were not covered in detail in the presentation are included in this paper to clarify information regarding their origins (*Achillea millefolium* 'Island Pink', *Sisyrinchium bellum* 'San Simeon', and *Verbena lilacina* 'De La Mina').

***Achillea millefolium* 'Island Pink'.** 'Island Pink' was originally selected by Wayne Roderick from the top of the ridge above Prisoner's Harbor on Santa Cruz Island about 1976. The bright-green basal foliage is finely dissected and is pleasantly fragrant when crushed. The stiffly erect flowering stems rise to a height of 8 to 15 inches and carry a dense flat-topped cluster of tiny daisy-like flowers. Fresh flowers are a bright rosy-pink and age to a pale dusty pink over the course of several days. The plant is highly favored by insects, especially butterflies. Cut flowers and dried inflorescences are useful in arrangements. This plant can be propagated from seed, division, or from basal cuttings. Seed-grown plants must be rogued to maintain the desired characteristics of the cultivar.

***Artemisia californica* 'Montara'.** 'Montara' was selected, named, and introduced by Ray Walsh through his Wildwood Nursery in LaVerne in 1987. The plant was named 'Montara' since it was originally found on Montara Mountain in San Mateo County. Unlike all typical forms of California sagebrush, the habit of this plant is a dense low mound. The foliage is typical of the species: lush thread-like divisions of gray-green in the winter months and shorter nearly white during the dry season. The plant is best suited for dry landscapes and sites with well drained soils. It is easily propagated from cuttings of new vegetative shoots taken from late winter through spring.

***Aster chilensis* 'Point Saint George'.** The extreme northwest corner of coastal California in Del Norte County is the point of origin for this aggressive low-growing form of our native aster. This plant was originally collected in 1979 by Al Seneres of the East Bay Regional Parks Botanic Garden in Berkeley, though it was apparently named and introduced by Yerba Buena Nursery around 1994. 'Point Saint George' typically reaches 4 to 8 inches tall and spreads at an astonishing rate via underground runners. The spathulate dark-green shiny leaves are about 3 inches long and ½ inch wide. The flowers are a pale lavender color, have yellow centers and are freely produced on erect inflorescences that may reach 8 inches high. A light pruning at the end of the flowering season (November-December at our

garden) is suggested for best appearance. As noted above, this cultivar is particularly vigorous and should be used with caution. This plant is most readily propagated from division, and is also easily propagated from cuttings of basal shoots.

***Encelia californica* 'El Dorado'.** 'El Dorado' is easy to grow and dependable. This plant was selected from a planting at Rancho Santa Ana Botanic Garden (RSABG) by Dylan Hannon in 1996 for its bright-yellow flowers that are up to 3 inches across and was subsequently introduced by RSABG in 1998. The plant blooms profusely in spring and fall, with occasional flowers produced throughout the remainder of the year. Plants tolerate typical garden conditions, but will grow too lush if given excessive water and a rich soil. For best performance, plant this daisy in full sun. Established plants should be cut back very hard (to stubs about 4 inches long) in late fall or early winter. Expect the plant to reach 3 to 4 ft tall and to typically spread 5 to 8 ft wide. It can be grown for cut flowers. New plants are easily produced from cuttings of young vegetative growth in late winter and spring.

***Eriogonum umbellatum* 'Alturas Red'.** 'Alturas Red' is a striking 1990 introduction from Siskiyou Rare Plant Nursery and is named for its geographic point of origin: Alturas, California. The plant has unusual foliage and floral characteristics. The spathulate leaves are dark-green (often nearly black) on their upper surface and have white undersides. The 4- to 6-inch stalked inflorescence carries a number of subsidiary ½-inch umbels of red buds that open to cream-yellow flowers that age a rich rusty brown. The growth habit of this plant is a compact hemisphere up to 6 inches high and 1 to 2 ft wide. 'Alturas Red' grows best in full sun and well drained soils. As with other *E. umbellatum* cultivars, this plant is grown from semihardwood cuttings. These cuttings consist of a long, bare internode topped by a terminal whorl-like grouping of leaves. Roots emerge at various points along the bare internode. Our experience at RSABG indicates that 'Alturas Red' is much slower growing than the other cultivars of *E. umbellatum*: 'Beartooth Pass', 'Lake Tahoe', and var. *polyanthum* 'Shasta Sulphur'.

***Fragaria chiloensis* 'Aulon'.** 'Aulon' is an especially handsome male selection of our native strawberry. The plant was selected and named by Brett Hall from an Indian abalone-shell midden at Laguna Beach, Santa Cruz County and was introduced by the University of California Arboretum, Santa Cruz in 1992. The name 'Aulon' is the Costanoan Indian word for abalone. This vigorous plant spreads by stolons to create a beautiful ground cover of glossy, dark-green, three-parted leaves. The petioles and stolons are dark red. Small clusters of 1-inch-wide, yellow-centered, white-petaled flowers are produced in limited quantity. The plant is easily propagated from the numerous plantlets along the stolons or by division of established plants.

***Lepechinia calycina* 'Rocky Point'.** 'Rocky Point' was originally named and collected by Al Seneres in 1988 from Rocky Point along the Big Sur coast of Monterey County. The plant had been growing in the East Bay Regional Parks Botanic Garden for several years prior to its introduction by California Flora Nursery in Fulton in 1991. This selection of pitcher sage is particularly satisfying as a garden plant. 'Rocky Point' is a low growing (to 3 ft tall and 5 ft wide), compact plant that has especially beautiful gray, soft-hairy, fragrant foliage. The leaves are produced at short intervals along the arching stems. The plants produce terminal inflorescences of showy white flowers that have a faint blush of lavender. 'Rocky

Point' is readily grown from soft vegetative cuttings taken in late winter or early spring, prior to flowering.

***Penstemon* 'Margarita BOP'.** 'Margarita BOP' is a wonderful recent introduction from Las Pilitas Nursery in Santa Margarita. It was selected and named by Bert Wilson in 1993, who considers it to be a hybrid between *P. heterophyllus* and *P. laetus*. The plant's name commemorates its origin as a chance seedling: at the nursery, behind the house, at the Bottom Of Porch. However, the plant has produced a number of seedlings at our garden and all of these are essentially identical to the parent plant, leading this author to surmise that 'Margarita BOP' is actually a clone of *P. heterophyllus*. In any event this is, without a doubt, the most durable plant and reliable bloomer of any seed strain or vegetatively reproduced clone of *P. heterophyllus* that I have encountered. It adapts equally well to both nursery and garden conditions. Unlike many of the Californian penstemons, this plant produces an abundance of branching stems that form a short dense 6 inch × 12 inch mound of gray-green foliage. A profusion of 8-inch inflorescences appear in mid-spring, when the plants are nearly obscured by the sky-blue flowers that have rosy-pink highlights. The plant continues to produce scattered flowering stems until cold weather sets in. 'Margarita BOP' is easily propagated from young vegetative cuttings taken from winter to early summer.

***Sisyrinchium bellum* 'San Simeon' (= *Sisyrinchium macounii* 'Alba').** 'San Simeon' dates back to the early 1950s and, as such, it is one of the oldest vegetatively produced California native plant perennial cultivars that is still in cultivation. The original plant is said to have been collected by the noted California native plantswoman, Lester Rowntree, from near San Simeon in San Luis Obispo County. The plant subsequently made its way to Victor Reiter's La Rochette Nursery, where it was incorrectly identified, named, and introduced about 1956 as *S. macounii* 'Alba'. This incorrect name persists (or rather dominates) to this day, to the extent that I have never seen the plant sold with the correct name. The plants have the typical grass-like foliage and large white flowers. New plantlets are formed in the infrutescence that are easily detached and rooted.

***Verbena lilacina* 'De La Mina'.** 'De La Mina' is a 1998 introduction from Santa Barbara Botanic Garden. The plant was selected and named by Carol Bornstein, who had collected the original propagules from Canyon de la Mina on Cedros Island, Mexico. The plant has bright-green dissected foliage and fragrant lavender flowers that are produced year-round. This vigorous selection has a much denser growth habit, and darker flowers than the form(s) that is (are) currently in cultivation. It is easily propagated from soft cuttings at any time of the year.

THE SAGES:

***Salvia* 'Allen Chickering' (*S. clevelandii* × *S. leucophylla*).** 'Allen Chickering' is the oldest widely grown perennial native to California. This hybrid was originally noted in about 1937 by Allen Chickering during a walk through the original Orange County site of Rancho Santa Ana Botanic Garden with the Garden's founder, Susanna Bixby Bryant. The plant was a seedling that had grown in a planting of *S. clevelandii* that had been originally collected on the east side of Palomar Mountain in San Diego County. The original hybrid plant was never vegetatively propagated,

though seeds were later collected from the same group of plants that generated the original hybrid individual, and a new plant was chosen and renamed 'Allen Chickering' about 1949. This individual plant was vegetatively propagated for the first time in 1955. Cuttings of new vegetative shoots root readily in spring and may be taken from late winter until the plant flowers.

***Salvia* 'Bee's Bliss' (*S. clevelandii*(?) × *S. sonomensis*).** 'Bee's Bliss' occurred as a chance seedling at the University of California Botanical Garden in Berkeley, where it was noted and distributed to several nurseries by Roger Raiche in about 1988-89. In 1992, the bee covered plant in the garden of noted *Salvia* expert Betsy Clebsch inspired artist Marcia Donahue and Clebsch to name the plant. 'Bee's Bliss' combines the large showy inflorescences of *S. clevelandii*, *S. leucophylla* and their hybrids, with the prostrate growth habit of *S. sonomensis*. The ample foliage is a pale gray-green. The foliage mat of this plant may reach 6 to 8 ft wide and may reach from 6 to 18 inches tall. The flowering stems are about 1 ft in length and carry several whorl-like aggregations of lavender-blue flowers. This plant is easily propagated from new vegetative shoots in late winter or early spring. Young plants in containers (and in the ground) are often subject to seasonal attacks of powdery mildew due to excess moisture and/or shade.

***Salvia* 'Desperado' (*S. apiana* × *S. leucophylla*).** This is a big sage, the largest yet of the named native clones. 'Desperado' was selected and named by this author and the plant was introduced by RSABG in 1998. The plant has been in the living collection at RSABG for many years. The lush white leaves closely resemble those of the white sage (*S. apiana*), but in this cultivar, they often turn bright colors (yellow, orange, or pink) before dropping. An individual leaf may reach up to 5 inches long and up to 1 inch wide. The large, well branched (up to 26 branches in a single inflorescence) flower spikes carry large whorls of big lavender-pink flowers (from *S. leucophylla*). The whorl-like assemblage of calyces may reach up to 2 inches across. An established mature plant may reach 15 ft wide and, when in flower, may reach 10 ft in height. Plants perform best in full sun and well drained soils. As with most of our native sages, this should be cut back fairly hard (between one-third and two-thirds of the season's growth should be removed — do not prune back into old wood) in late fall, prior to new growth. Young plants should be regularly pinched and lightly pruned to develop a good branching structure and dense growth habit, even if this means sacrificing the flowers for the first year. Hummingbirds like this plant. Propagate this selection from cuttings taken from lush new spring growth that is freely produced prior to flowering.

***Salvia* 'Mrs. Beard' (*S. mellifera* × *S. sonomensis*).** 'Mrs. Beard' originated as a chance seedling in the garden of Helen Mar Beard some time in the 1960s. She brought the plant to the University of California Botanical Garden in Berkeley, where it was planted on a sunny east facing slope in the California section. The plant was never formally accessioned as it was not a plant of wild origin. Over the years the plant was propagated and gained limited distribution in northern California. In the late 1980s and early 1990s the plant finally gained the cultivar name 'Mrs. Beard'. This vigorous plant is a prostrate to low, mounding groundcover and may reach 6 to 18 inches in height and may spread up to 10 ft wide. Occasionally the plants will root where the prostrate stems contact the soil. The upright inflorescences are typically 8 inches tall and produce many small pale-blue

flowers in whorl-like clusters. 'Mrs. Beard' is the longest lived and best performer in the widest array of garden conditions of the *S. sonomensis* selections and hybrids. New plants are easily grown from cuttings of soft vegetative shoots from late winter through early summer.

***Salvia* 'Pozo Blue'.** 'Pozo Blue' is rather similar in appearance to 'Allen Chickering'. The principal difference that I have observed is in its vigor and performance as a garden plant. This plant was selected, named, and introduced by Bert Wilson of Las Pilitas Nursery in 1989. It appeared as a chance seedling in a pile of old potting soil. Mature flowering plants will easily exceed 6 ft in height and 8 ft wide.

***Salvia spathacea* 'Powerline Pink'.** 'Powerline Pink' is an impressive giant form of the hummingbird sage. Immense does not begin to describe the huge 3- to 5-ft inflorescences that adorn the plants in spring. Well grown, vigorous plants have a tendency to rebloom in fall. This selection was made in 1993 by Bert Wilson of Las Pilitas Nursery of Santa Margarita in San Luis Obispo County. Unlike most of the hummingbird sages, this clone prefers to grow in full sun, even tolerating our extreme summer heat in inland southern California. Half of the plant's name is a mystery to me — it was collected along a powerline right-of-way, but I see nothing pink about it. The flowers are, in fact, a beautiful deep maroon-red. The inflorescence bracts and calyces are often colored complementary dark tones. Apple-green is the color of the textured-surfaced 5- to 6-inch leaves. All vegetative parts of the plant are covered with glandular hairs and carry a pleasing fruity fragrance. Plants may be grown from cuttings of vegetative shoots or from division. In any event, propagation of this extremely desirable form has been slow.

***Salvia* 'Vicki Romo' (*S. apiana* × *S. clevelandii*).** 'Vicki Romo' was selected and named by this author from a chance seedling at RSABG and was introduced by RSABG in 1992. It was particularly appropriate to name this plant in honor of Victoria Romo, a deceased RSABG graduate student, who had been working (among many other projects) on molecular studies of native Californian *Salvia* cultivars. Her investigations conclusively determined the parentage of 'Allen Chickering', 'Aromas', 'Pozo Blue', 'Santa Cruz Dark', and 'Whirly Blue' as F1 hybrids between *S. clevelandii* and *S. leucophylla*, with the exception of 'Allen Chickering' which is an F2 hybrid. 'Vicki Romo' must be grown in full hot sun for best performance. The winter and spring foliage of this selection is gray-green, and from late spring through fall it is nearly white. The large upright inflorescences of this plant may reach 3 to 5 ft in length and are often basally branched. The violet blue flowers are carried in large whorl-like clusters. When in bloom, a mature plant may reach 6 to 8 ft in height and 4 to 6 ft wide. Propagate this plant from cuttings taken from fresh new growth in late winter and early spring.

Epilobium

Although the genus *Zauschneria* has been reduced to synonomy under the genus *Epilobium* by a number of botanists, this group of plants is both botanically and horticulturally distinct from *Epilobium* to the extent that this author feels that they should be considered a separate genus. [Botanical Editor's note: The genus *Zauschneria* is synonymous with *Epilobium canum* and *E. septentrionale*]. The plants listed below all benefit from a hard pruning to short stubs in December. For the best appearance at flowering time (late summer and fall), the plants should also

be pinched back or lightly pruned in May or June. All of these plants are readily grown from soft cuttings of young vegetative shoots taken in spring to early summer.

***Epilobium* 'Calistoga'.** 'Calistoga' was selected and named by Philip Van Soelen from material collected near Calistoga, Napa County, in 1994. This clone has the most distinctive foliage that I have ever seen in this genus — the broadly oval gray leaves are up to 2 inches long and up to 1 inch wide. The flowers are fairly typical of the genus, flaring red-orange trumpets, and are produced in few-flowered terminal clusters. At RSABG, we grow this plant with *Salvia* 'Bee's Bliss' as the foliage of these two plants closely resemble each other such that most people perceive a single plant that produces radically different flowers in spring and fall.

***Epilobium canum* 'Catalina'.** 'Catalina' was selected by Mike Evans from Middle Ranch Canyon on Santa Catalina Island in 1987. He later named it and the plant was introduced by Tree of Life Nursery in San Juan Capistrano in 1990. 'Catalina' is notable in many respects: it has beautiful, narrow, silver-gray leaves; brilliant orange-red large flowers; and a strongly upright growth habit. Plants that have not been cut back and have been allowed to lean/grow into surrounding plants may reach a height of 6 ft, whereas plants that have been cut to the ground every winter may reach heights from 1 to 3 ft tall.

***Epilobium* 'Route 66'.** 'Route 66' was selected by this author from RSABG's entry sign at the corner of Foothill Boulevard (the historic Route 66) and North College Avenue. The plant was named and introduced by Rancho Santa Ana Botanic Garden in 1996. The most notable feature of this selection is its extreme abundance of orange-red flowers that are produced over the course of 2 months from late summer to early fall. The short, broad leaves of this cultivar are green. The plant may reach a height of 1 to 2 ft and may spread 2 to 4 ft wide. As with most of the taller (over 1 ft in height) selections, 'Route 66' benefits from light pinching/pruning in May-June that will result in more intertwined branches that will serve to hold the plant upright and together when it is covered with heavy blossoms several months later.

***Epilobium* 'Summer Snow'.** 'Summer Snow' is a low-growing white-flowered plant that was selected from near Sugarloaf Mountain, southeast of Big Bear Lake in the San Bernardino Mountains by Walter Wisura in 1986. It was subsequently named by him and was introduced by Rancho Santa Ana Botanic Garden in 1989. The plant has broad green leaves and will reach a height of 6 inches and creates a mat of foliage 2 to 3 ft across. 'Summer Snow' will perform best if given some afternoon shade when grown in the hot interior.

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The New Cultivars of New Zealand Flax

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INTRODUCTION

My interest in flax had its roots in a childhood of viewing large green or bronze New Zealand flax, paired with tree ferns and *Philodendron*, planted in "modern" 1960s landscapes. In structure and form this plant had no equal yet its use had become so prevalent that the plant was on the verge of becoming overly common and boring. Fortunately, new cultivars making there way into the horticultural trade in the mid 1980s rescued New Zealand flax from this mediocrity. San Marcos Growers has had a major role in the introduction of this plant into the U.S. and I would like to share some of what we have learned about this group of plants.

The common name "flax" is applied to several different plants with a fibrous nature that are used for items such as rope and clothing. Thus, such unrelated plants as the "true" or Asian flax (*Linum usitatissimum*) are often confused with New Zealand flax (*Phormium* sp.). As the common name implies *Phormium* come from New Zealand. The name *Phormium* comes from the Greek word for basket after its usage by the Maori, the Polynesians who have inhabited New Zealand since the 13th century. The two species in the genus are variable in growth form and each can be found growing throughout the other's range. The primary differences between the two are in their form, flower color, and position of the fruit. *Phormium tenax* grows vertical in habit, has erect stems of dull red flowers, and upright three-angled fruit. *Phormium cookianum* is typically smaller, has arching foliage, radiating stems of greenish-yellow flowers, and drooping fruit that are cylindrical and often spiraled.

Phormium tenax, first introduced into the U.S.A. in San Francisco, CA in 1871, was followed in 1947 by *P. cookianum,* also first introduced in San Francisco. Eventually both plants migrated from the collector's garden into the mainstream gardening world and unfortunately took on the aforementioned banality of the overused plant. With the introduction of new cultivars in the early 1980s, with a range in color, size, and form that is nearly overwhelming, *Phormium* popularity received an immense boost. The collective name Rainbow Hybrids has been aptly applied to this group which includes such now well known cultivars as 'Maori Maiden', 'Maori Queen', 'Dazzler', 'Sunset', and 'Sundowner'. Many of these cultivars reflect their relationship to one species or the other and some exhibit characteristics that show that they are hybrids between the two.

PROPAGATION OF NEW ZEALAND FLAX

Seed propagation, while relatively easy, limits the grower to one of the species unless a certain amount of variability is tolerable. Much of what is in the nursery trade as *P. tenax* Purpureum Group (syn. 'Atropurpureum') is from seed and the resulting plants are variable in stature and color. Seed collected in late summer and fall should be sown fresh and germinates in 3 to 4 weeks. Seed propagation is one of the few ways that new cultivars are found and in fact much of the "hybridization" that occurs in New Zealand nurseries is really selection from open-pollinated seed. We are

currently evaluating plants grown from *P.* 'Dark Delight' seed that appear very uniform and have deep rich-colored foliage.

Division is by far the most common and reliable method used in propagation of the cultivars of New Zealand flax. Our divisions are taken fall through spring and placed on bottom-heated benches either in a cool greenhouse or under saran. The soil medium should be well drained and the crown of the plant exposed. The size of the division differs greatly with the different cultivars and some cultivars will have very large to small divisions. The smallest divisions are rooted into 2¼-inch rose pots and the largest into 1-gal containers. Rooting-out the liner container can take 4 weeks to 3 months depending on the cultivar, division size, and weather conditions. From the liner it will take 2 to 4 months to root out the 1-gal container and it may take another growing season to fill out the fans in the container. *Phormium* is not a fast crop and considerable nursery stock must be held back to assure an adequate supply for divisions.

Tissue-culture propagation has dramatically increased the availability of many plants, often making rare and difficult-to-reproduce plants common. This has yet to happen to the new cultivars of New Zealand flax, although several attempts have been made. Monrovia Nursery tissue cultured *P.* 'Dazzler' but lost the bold red stripes in the foliage in the process. The resulting plant, dubbed *P. tenax* 'Nanum Purpureum' (syn. 'Atropurpureum Compacta') is an outstanding small red New Zealand flax, but is not *P.* 'Dazzler'. Tissue culture may remain a viable method of propagation of nonvariegated forms of *Phormium*.

GARDENING WITH NEW ZEALAND FLAX

In an article in Fall 1994 of *Pacific Horticulture*, the author, Bob Hornback, noted that "many gardeners were disappointed by these colorful plants, discovering the hard way that the new flaxes are not as hardy or as easy to grow as the old types ... the new flax need to be better understood". The following general guidelines should aid in understanding the needs and limitations of these new hybrids.

New Zealand flax are commonly thought of as plants for full sun and in cool coastal communities, such as San Francisco; full sun does bring out their best foliage color. In inland sites the upright forms grow well in full sun but placement of the softer arching foliage cultivars should be in light shade or morning sun. Evidence of heat stress and sunburn on these cultivars is often seen as gray-brown patches on the leaf surface. The yellow variegations such as *P. cookianum* subsp. *hookeri* 'Cream Delight' seem to tolerate the greatest amount of shade but the red forms tend to loose their luster in deep shade. In Southern California, with the common occurrence of dry Santa Ana winds, some of the hybrids will need summer protection from full sun even when planted near the coast.

The hybrids are generally less cold tolerant than the species, but all seem to be root hardy to at least 15F. In the dry, cold spell that engulfed California in December, 1990, we measured the low temperature at 18F. Most of the flax in our collection went undamaged at this temperature while others had disfiguring damage to all leaves.

Irrigation practices for New Zealand flax are dependent on soil conditions and climate. Coastal plantings can be considered drought resistant, but even here the plants remain most attractive with periodic to frequent irrigation. With short fleshy roots, *Phormium* is an ideal plant for drip irrigation that focuses the water at the

crown. Overhead irrigation works equally well with the plant channeling the water to its base. Some cultivars are even tolerant of waterlogged conditions and used in ponds so long as the crown is kept above the water level.

Planting into well draining soils is a key factor to having New Zealand flax thrive. At the very least the plant should be positioned so that water does not collect around the crown. Many of the cultivars, especially the smaller ones, will languish in heavy soils and often collapse when waterlogged. As with most plants, mulching the soil surrounding a *Phormium* plant is a wise idea and an all-purpose fertilizer applied in late winter is sufficient; however, we have found that some of the red foliage types will respond favorably to annual or periodic applications of phosphorus.

There are several diseases that can be devastating to New Zealand flax but most are either not abundantly present or can be managed through cultural practices. Plants will be more prone to root rots and other disease problems in heavy soils or when the plant's crown is buried. Plants arriving from New Zealand have been diagnosed with *Fusarium*, but this pathogen has not become a continuing problem. The *Phormium* leaf spot (*Gloeosporium*), so common in New Zealand, is not often seen in the United States and seems to be restricted to yellow-variegated cultivars such as 'Yellow Wave'. *Phormium* yellow-leaf virus has not been reported in California, but is prevalent and very damaging to plants in the North Island of New Zealand.

Several insects can inflict damage on *Phormium*. A white powdery crust at the leaf base is evidence of the presence of *Phormium* mealybug (*Balanococcus diminutus*). This insect is somewhat difficult to control and can disfigure a plant and reduce its vigor. It has been a pest of New Zealand flax since its discovery in California on the University of California Berkeley campus in 1906. Until the 1960s it appears that this insect was localized in the San Francisco Bay, but has now become more widespread. It seems particularly damaging to the new cultivars. The long-tailed mealybug (*Pseudococcus longisinus*) causes accordion-like growth that, while interesting looking, is permanently disfiguring to the leaf. Pealing open the leaf reveals the insect harbored within. This pest is less serious than the *Phormium* mealybug and relatively easy to control.

Other pests of *Phormium* include snails and gophers. Snails use the plant as a home to venture out from under cover of darkness and prior to the introduction of new cultivars rarely damaged the plants. The new cultivars are disfigured and weakening by snails chewing the leaves. Selective snail baiting within the crown of the plant can aid in the eradication of this pest. Gophers can and will consume the roots and crown of New Zealand flax and protection or eradication measures should be taken when this pest is present.

Grooming is essential to keep New Zealand flax plants attractive and presentable. As older leaves fade, yellow and tatter they should be pulled from the base or cut as closely as possible. In addition, any fans that do not exhibit the decorative qualities of the cultivar should be removed. The chimera-type variegation present in the new cultivars is prone to losing or changing the variegation pattern as new fans emerge. Usually these leaves turn green or bronze colored, much like the species. It is imperative that the entire fan with this foliage reversion be removed as it will often be the more vigorous and take over the entire plant.

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An Overview of a Computerized Production Program

Martin E. Stockton
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How does a complete software package for the horticulture industry work? What are the basic components and concepts that need to be understood to purchase and implement a successful package? In this paper we will look at these basic questions and attempt to answer them by using First Step Greenhouses and Plant Partner as an example.

First Step Greenhouses is a new annual bedding plant plug operation in Southern California. We use Plant Partner software from Starcom Computer Corp. to drive our business. The software handles many different functions including order entry, production planning, inventory control, shipping, production scheduling, and material needs.

For purpose of discussion we will divide the functionality of the software into two topics, sales and production. Sales deals with orders, item pricing, inventory, order collection, and shipping. The first step is to develop a sales catalog. This is a detailed profile of each item for sale including: container used, genus, variety, color, price, plant count per container, location grown, and sales window.

After the items are defined in the sales catalog and individual customers are setup, you can enter in specific orders. Information in orders identify the customer, ship date, purchase order, and shipping method. The order also details each item on order, the quantity, and pricing. You can also enter unique messages specific to the order or to individual items in the order. Reports such as packing slips, invoices, and sales history can then be run.

A master pick list is generated by the program to aid in order collection. This report lists all orders for the day or week. It is sorted by container, variety, then by customer's order. This helps speed collection by only going to that crop once and picking what's needed for all orders. The report also contains inventory information for each item; this helps to identify any shortages and prevents wasted time looking for nonexisting items.

The inventory function enables the user to track items from time of planting or purchase through to shipping. Inventory is first entered as a planted, initial, or purchased inventory. During the course of the crop numbers are deducted for spoilage and losses due to culture. Items on orders are then deducted from inventory as a committed quantity. Mathematically this is how it works: (beginning Inventory — spoilage or loss) = on hand quantity; (on hand quantity — committed or ordered

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quantity) = available quantity. So at any one time you can run a report that details what is available at your facility. First Step Greenhouses also uses barcode labels on each unit and a handheld scanner to facilitate inventory data collection. Tracking inventory also enables the user to review his success rate with specific crops (i.e., losses in rooting) and assures you are selling inventory you have.

A production schedule can be derived two ways with Plant Partner. The user can develop a plan from projected sales or can schedule based on actual orders in the system. When scheduling from anticipated sales the user determines the total quantity of a container size needed for each sales week. This number is then divided and divided again based on percentages of each item desired. This is a form of hierarchy that flows as follows: container_genus_species or series_color. For example, starting with the total container number of X this is divided as follows; 10% of X is *Impatiens*, 50% of the *Impatiens* are Super Elfin, 4% of the Super Elfin will be white.

The other way of scheduling is based on orders in the system. The program scans all orders and calculates when the item needs to be planted based on crop times. The number is then increased to account for a given spoilage percent anticipated. You can then run reports telling what items need planting on a given week.

The production side has an equivalent to the previously described sales catalog; it is called the production library. The user inputs information critical to production of the crops in this library. Each crop has its own card containing data relevant only to that crop. Information contained includes: crop times, number of cells or plants in the container, anticipated spoilage percent, and tasks and materials needed to produce the crop. Partitioning the year into different segments creates crop times. This helps to overcome weather and production time changes created by it. For each segment of the year you can define different crop times, sell windows, spoilage percents, materials, and tasks.

Once production is scheduled, reports are available to facilitate production. Reports available include sow sheets and material usage and labor needs.

In the authors opinion it is critical to have a program that integrates both the selling and producing functions of the business. This enables a healthier tighter link between these two often divided and embattled departments of the business. One must also realize that any software package developed for our industry will not run like Microsoft Office. The user should anticipate problems or "bugs" since the software company is operating on limited funds from a limited customer base. Be prepared to have yourself or an employee be the babysitter or "guru" of the system. The initial time investment to set up a system can be significant, but the rewards are also.

Question and Answer Period: Concurrent Session I: Perennials and Plugs

Mary Helen Seeger: Is there a way to integrate sales via computer modem or the Internet?

Martin Stockton: Not that I know of, but they can probably develop a custom program to handle that. That gets back to the concept of small industry, if you want to be an innovator or fore-runner you will likely pay for it.

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Propagation of Four American Carnivorous Plant Genera: *Pinguicula, Drosera, Dionaea,* and *Sarracenia*

James L. Booman
2302 Bautista Avenue, Vista, California 92084

Carnivorous plants come from genera that have little in common. The fact that these different plants developed similar methods to digest or utilize nutrients from animals is a classic case of parallel evolution.

The single greatest threat to the survival of these plants in the wild is destruction of habitat. Fire suppression and drainage ditches in pine plantations have probably eliminated more acreage of flytrap (*Dionaea*) habitat than any other actions in the last 30 years. Urban encroachment destroys habitat as well. Poaching, while significant, is a smaller factor than irreversible loss of habitat (Boyer, 1995).

Luckily, most of these interesting plants can be propagated artificially. Although we are on the West Coast, we are at a similar latitude and have the same temperature spreads as the native areas on the East Coast of the U.S. Our abundant light seems to help us maintain a year-round program of growing these plants commercially in Southern California (Vista, CA).

Venus flytraps (*Dionaea muscipula*) are the most popular of the carnivorous plants. They propagate easily in a number of different ways. Freshly harvested seed germinates readily without special care. Scatter the shiny black seeds on the top of clean peat moss. Do not cover the seed. Water from the bottom. Most every seed will grow in 4 to 6 weeks. Detached leaves from mature plants will produce adventitious sprouts along the midrib, though this is not reliable enough for us to use it commercially. Rhizomes will extend out through drainage holes in cell trays. These can be snapped into multiple pieces, each of which will grow a new plant. Flower stalks often produce aerial bulbs. Tissue culture yields a rapid and year-round supply for us. It allows us to propagate select clones with daylength neutral growth, high color, large trap size, and persistent foliage. We plant into community flats, then into plug trays. Tissue culture media references are listed in I.P.P.S. Proceedings (vol. 35:285).

Drosera species propagate easily. We propagate *D. adelae* by cutting the thick black roots into 1-cm pieces and burying them 5 mm under clean peat. We seldom use leaf propagation; but, it works as well. Detach a leaf. Lay it on the top of clean wet peat. New plants will develop between the tentacles. We prefer seed propagation. The dust-like seed keeps for years refrigerated at 40F, and germinates within 3 weeks. We sow the seed on the top of sterile peat, and bottom water until germination is complete.

Pinguicula can be grown from seed. We prefer leaf cuttings to maintain cultivar lines. Detached leaves placed on top of clean peat will callus and produce numerous new plants at the cut edge.

Sarracenia can be propagated by tissue culture. We use this method to maintain cultivars. Our preferred method of propagation is from seed. Most species and hybrids are self-fertile. Pollinating the flowers insures good seed set, often yielding 500 seeds per pod. Cold (40F) wet stratification for 30 to 90 days breaks dormancy. Seed sown 5 mm deep in clean peat germinates in 4 to 6 weeks at 60F.

We attempt to duplicate conditions found in the wild when growing these plants.

Our soil tests conducted in 1995 corroborate those of a 1977 USDA Soil Conservation Service survey of Murville soils in New Hanover, North Carolina (Anonymous, 1977). The fine black sand soils where these plants grow in North Carolina have a pH between 4.3 and 4.5 with an E.C. of 0.1. Organic to mineral (sand) ratios run 1 lb to 7 lb on a dry weight basis. Bulk densities run about half of that of a loam soil, based on dry matter per cubic yard. Iron runs 1.8 lb cu yd^{-1} and nitrogen runs 1.6 lb cu yd^{-1} of dry matter.

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Propagating Palms from Seeds

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Optimal germination of palm seeds is attained by using mature, fresh, clean seeds; a disease-free, moist but well aerated medium; clean containers and benches; and maintaining temperatures of 30 to 35C and relative humidity of 90% to 100%.

INTRODUCTION

Although some palms can be propagated vegetatively, such as those with clumping stems, or through tissue culture, nearly all palms can be propagated by seeds. Commercial seed propagation of palms is relatively inexpensive and easy, and germination is usually rapid and high if one adheres to several principles. These principles include using only mature, fresh, clean seeds; planting in a disease-free, moist but well aerated medium; using clean containers and benches and keeping them clean; and maintaining appropriate temperature and moisture levels.

SOURCES AND HANDLING OF SEEDS

Plant only clean, fresh seeds from mature fruits. Obtain seeds from reliable, reputable suppliers or collect them yourself. Collect seeds from forms or strains of individuals with desirable characteristics, such as color, vigor, conformation, etc. Check a representative sample of seeds of unknown origin by a visual examination of the embryo. Healthy, viable embryos will mostly be moist, firm, white to yellow, and full, not shrunken from the endosperm. A float test is sometimes also used for assessing viability, but it is not always reliable.

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Palm seeds, sprouted seeds, and germinated seedlings are highly susceptible to damping-off diseases. Thus, it is preferable to collect seeds from the tree since those collected from the ground are more likely to be contaminated with diseases and/or insects or other pests. Seeds should be kept clean until planting and then planted in disease-free media and clean containers. Containers of planted seeds should be kept off the ground on clean benches and growers should follow the simple rules of general nursery sanitation to prevent contamination.

Plant only seeds from completely mature or nearly so, soft-ripe fruits. Depending on the species, fruits at maturation are usually black, red, yellow, orange, purple, or brown. Full-sized, but green or undercolored, hard fruits have seeds which might germinate at a reduced percentage and rate (Rauch and Crivellon, 1989b), or not at all (Broschat and Donselman, 1988; Carpenter, 1988b). Removing the fruit pulp prior to planting usually improves germination (Yoshii and Rauch, 1989b) although seeds of some species, such as *Dypsis lutescens* (areca palm), do not have to be cleaned if planted immediately (Broschat and Donselman, 1988). Pulp of soft, juicy fruits, often thought to contain germination inhibitors (Rauch and Crivellone, 1989a), is easily removed by mashing in a bucket or other container and then using water to decant the pulp. Some palm fruits are fibrous and are not easily removed by mashing and decanting. In such cases a commercially available, mechanical seed cleaner might be useful. Wear waterproof gloves when cleaning palm seeds since the juice of some fruits can be highly irritating to tender skin.

Most palm seeds lose viability quickly so plant them as soon as possible after collection for best results. Without proper storage palm seeds will have much reduced germination percentages and rates, even after as little time as 2 to 4 weeks. Even with proper storage, though, expect reduced germination percentages and rates with many species. Some notable exceptions and their maximum seed storage times under ideal conditions include *Dypsis lutescens* - 12 months, *Phoenix roebelenii* (pygmy date palm) — 8 months, *Roystonea regia* (royal palm) — 9 months, and *Syagrus romanzoffiana* (queen palm) — 4 months. Seeds not planted immediately should be cleaned, air dried at 80%-90% relative humidity, and stored in air-tight plastic bags at 20 to 23C (Broschat and Donselman, 1988; Carpenter and Gilman, 1988; Carpenter and Ostmark, 1989). In a few rare cases, seed storage at cooler temperatures, -10C and -20C, actually enhanced seed germination of some species, such as *Sabal causiarum* (Puerto Rican hat palm) (Carpenter, 1989). Moisture content of seeds also plays a critical role in successful storage. Depending on the species, seeds store best if moisture content is at least 7% to 14% (Carpenter, 1989; Carpenter and Gilman, 1988; Carpenter and Ostmark, 1989; Carpenter et al., 1993a).

Presoaking seeds in gibberellic acid accelerates germination of some species (Nagao et al, 1980; Nagao and Sakai, 1979; Schmidt and Rauch, 1982), but is not recommended since it can also cause excessive elongation of resulting seedlings (Broschat and Donselman, 1988). Soaking seeds for 2 to 7 days in plain water alone (changing water daily), sometimes maintained at 35 to 45C (Carpenter, 1986; 1987), is preferable and often improves germination (Broschat and Donselman, 1988; Carpenter et al., 1993a; 1993b; Schmidt and Rauch, 1982; Yoshii and Rauch, 1989a; Yoshii et al., 1989). Scarifying seeds by filing just deep enough to break the seed coat at the micropylar end enhances germination of some species (Doughty et al., 1986; Nagao et al., 1980) while removal of the embryo cap stimulates rapid germination

of *Rhapidophyllum hystrix* (needle palm) (Carpenter et al., 1993a; 1993b); however, both methods can be labor intensive and expensive. Pre-plant treatment of palm seeds with fungicides is not recommended. In most cases, fungicidal treatment is unnecessary and, in a few instances might even be detrimental. More is gained by using clean seed, media, and containers, and following the rules of sanitation.

Seeds of some palm species fail to germinate if planted immediately after harvest. Freshly harvested seeds of these species contain germination inhibitors which gradually decline after several months at low relative humidity and lower temperatures than needed for germination. This process, called after-ripening, is probably a mechanism to ensure that seeds pass through lengthy, generally unfavorable conditions without germinating until conditions favorable to germination and seedling establishment occur. For example, clean, air-dried seeds of *Butia capitata* (pindo palm) germinate best when stored at 5 to 25C for 90 to 150 days and then planted and held at 40C for 3 weeks and 30C thereafter (Carpenter, 1988b). Other palms with similar requirements include some *Attalea* spp. and *Syagrus* spp.

PLANTING MEDIA AND PLANTING

Any clean, disease-free, moist but well aerated medium is suitable for palm seed germination. Equal parts of fine peat moss and perlite have given good results although there are as many successful germination media as there are growers. Position seeds on top of a premoistened medium with their long axis horizontally aligned. Depress seeds slightly into the medium so that about half the seed is above and the other half is below the surface. Water gently but thoroughly and allow to drain for 10 to 24 h, then cover the container with a clear plastic film or other air-tight covering. Seeds planted in this manner are visible for periodic observation, have less risk of remaining too wet yet high humidity (90% to 100% R.H.) is still maintained, and need to be watered much less frequently. Seeds planted without an air-tight cover should be positioned at a depth equal to about one-half the diameter of the seed, but not to exceed 1 cm, and the medium then closely monitored for moisture. Clearly label and date all seed containers.

Temperature is probably the most critical factor affecting germination. Generally, planted seeds of most species should be maintained at 30 to 35C for optimal germination (Broschat and Donselman, 1988; Carpenter, 1988a; Yoshii and Rauch, 1989a; Yoshii et al., 1991) although seeds of a few species germinate better at slightly lower or higher temperatures. Too low or high temperatures will delay, decrease, or inhibit germination. Bottom heat systems employing a thermostat and electric cables, heating pads, hot water or steam are available for maintaining temperatures in the correct range are recommended. Alternating rather than constant temperatures sometime enhance germination (Carpenter, 1998a; 1988b; 1989; Carpenter and Gilman, 1988; Carpenter and Ostmark, 1989; Carpenter et al., 1993a). Seeds of *Coccothrinax argentata* (silver thatch palm), *Pseudophoenix sargentii*, *Rhapidophyllum hystrix*, and *Thrinax morrisii* (key thatch palm) germinate best when temperatures are alternated from 25 to 35C or 30 to 40C at 6- to 12-h intervals while seeds of *Butia capitata* germinate best when initially held at 40C for 3 weeks and 30C thereafter.

Light levels should be similar to that provided by commercial shade cloth in the 40% to 60% shade range. Growers in cooler areas might consider higher light for additional heat. Too low light will result in excessively elongated and weakened

seedlings unless sprouted seeds are removed promptly, potted up into individual containers, and placed in a growing structure with appropriate light.

GERMINATION

Fresh, clean seeds of most palm species will germinate in 1 to 12 months. Historically imprecise and highly variable germination percentage and rate are dependent on several factors, including freshness and quality of seeds, temperature, moisture, and simple natural variation within and among species. Species with seeds which normally germinate within 1 to 6 months include *Archontophoenix* spp. (king and Alexander palms), *Chamaedorea* spp. (bamboo palms), *Chamaerops humilis* (Mediterranean fan palm), *Dypsis decaryi* (triangle palm) and *D. lutescens*, *Livistona* spp. (fountain palms), *Phoenix* spp. (date palms), *Rhopalostylis* spp. (shaving brush palms), *Washingtonia* spp. (California and Mexican fan palms), *Wodyetia bifurcata* (fox tail palm), and many other wet lowland tropical genera.

Some species with seeds which normally germinate within 6 to 12 months include *Butia* spp., *Chamaedorea* spp., *Howea* spp. (kentia and sentry palms), *Syagrus* spp., *Trachycarpus* spp. (windmill palms),and other tropical genera. Species with seeds which normally germinate in 12 to 24 months included *Brahea* spp., *Ceroxylon* spp. (wax palms),and *Jubaea chilensis* (wine palm).

Seeds of many species will germinate uniformly in a single flush while others will germinate sporadically or in multiple flushes over a lengthy period, sometimes as long as a year or more. Such delayed or sporadic germination might be a mechanism to enhance survival in areas with periodically less favorable germination conditions such as irregular rainfall or a long and pronounced dry season. Long and/or long-sporadic germination is possibly associated with the after-ripening process mentioned earlier.

Seeds of most palm species germinate with the new shoot developing adjacent to the seed. However, seeds of several species, such as *Bismarckia nobilis* (Bismarck palm), *Livistona* spp., *Phoenix* spp., and *Sabal* spp. (palmetto palms), germinate with the new shoot initiating remotely from the seed along an elongated cotyledonary petiole or "sinker". In this remote germination the "sinker", from which the new shoot arises, has usually grown downward, sometimes as deep as 60 cm. Seedlings which germinate remotely on "sinkers" are especially sensitive to disturbance. Care should be taken to ensure containers are of sufficient depth to accommodate easily the downward-growing "sinker". Especially large seeds with deep "sinkers", particularly those of rare or unusually valuable species, are best planted singly in a deep container. Although this method is more expensive and requires more bench space, young seedlings have sufficient space and time to develop an extensive root system without disturbance.

HANDLING GERMINATED SEEDS AND SEEDLINGS

Sprouted seeds may be transplanted into individual pots at the one-leaf stage. Most seedlings at this stage will have either deeply bifid, v-shaped leaf blades ("rabbit ears") or elongated, undivided blades. They are more difficult to handle when smaller and their roots might be entangled if transplanting is delayed beyond the two-leaf stage.

Sprouted seeds and seedlings are especially sensitive to root disturbance and drying out during transplanting. Carefully remove seedlings from the community

container, taking care not to damage their roots or the attached seed. The seed might still be supplying nutrients to the seedling so it is best to leave it attached. Plant immediately in a clean, porous, fertile potting medium. Remove only as many seedlings from a community container as can be planted within a few minutes. Cover exposed roots of removed seedlings with potting soil or damp newspaper until planting. Work in a wind- and sun-protected location.

Planting depth is critical when transplanting into individual containers. Position seedlings so the attached seed is at the soil line or, if the seed is absent, so the root/stem junction is at the soil line. Water thoroughly and place in a growing structure where light, temperature, and relative humidity are identical or similar to that during germination. Protect from sun and wind.

Planted seedlings should be monitored carefully for water during establishment. Seedling roots need abundant oxygen for optimal growth; over-watering is one of the leading causes of seedling failure. Once established, weather conditions permitting, seedlings should be moved without delay into growing structures or open beds where light levels are optimal for that particular species as adult plants. Too low light will cause excessive stretching and elongation, resulting in weakened plants susceptible to sun burn; too high light will yellow or burn seedling leaves, resulting in stunted growth.

SUMMARY

The following general principles will give the best results when germinating palm seeds:

- Use only mature, fresh, clean seeds;
- Plant them properly in a disease-free, moist but well aerated medium;
- Use clean containers and benches and keep them clean; and
- Maintain appropriate temperatures and moisture levels.

Unfortunately, specific, optimal germination conditions have yet to be determined for most palms. Experiment and try different methods employing some of the principles discussed. Don't get discouraged, and remember there is little more satisfying than to have excellent germination on a batch of palm seeds.

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Evolution in the Propagation of Tropical Foliage Plants

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Foliage propagation over the past 10 years has become more refined and specialized and it has improved dramatically. I will share the evolution in my lifetime, and what changes Southern California growers have experienced.

In my father's facility we held our own stock on many varieties, or took cuttings from production plants in rotation. Frequently we stuck cuttings in flats and later re-potted them. Misting and the use of labor-intensive sweat tents were common practices.

Cuttings purchased from Central America often had long thin roots that had to be trimmed off. Loss rates of these purchased cuttings were high, which made direct sticking difficult. Tissue-cultured plants presented their own problems; much was promised, but little was delivered. Often the parent plants selected to tissue culture were of poor quality, sizing of tissue culture products was inconsistent, and filling grower orders was sporadic. One month you would get your order, and the next you wouldn't. This has all improved, however, because the market has demanded it.

Foliage propagation requires four key cultural elements: (1) clean stock that has been grown in such a way as to increase the odds of success; (2) heat, preferably bottom heat; (3) humidity; and (4) an open, aerated soil medium.

At Kallisto Greenhouses we use a special propagation house to meet the heat and humidity requirements of propagation. In this propagation house we have rolling benches for space utilization and bottom heating is provided by EPDM tubing with forced air heaters as back-up. The system is designed to maintain soil temperatures of 74F.

To achieve an open aerated mix we use a combination of 25% peat moss, 25% coconut fiber (coco peat), 40% perlite, and 10% cinder rock. I have observed the newer element in this mix, coco peat, to hold the water better than straight peat moss, while also adding to the overall aeration of the mix.

Relative humidity in this house is provided by a fog system regulated by an environmental control computer. Although the fog system can provide a wide range of relative humidity, there have been design problems with the system. My concept in a propagation house was to get away from labor-intensive sweat tents. Originally I maintained 90% humidity in the entire 30,000 ft^2 propagation house. While unrooted cuttings needed and liked the 90% humidity, many rooted cuttings, such as *Dracaena*, did not. Some cuttings would rot or spot and it was difficult to maintain a balance between unrooted cuttings requiring 90% plus relative humidity, and the rooted plants needing to be hardened off. In the last stages of propagation all the plants became too soft and had to be moved out very quickly. Depending on the season, I now run the house at 60% relative humidity. Plants which require additional relative humidity, are misted.

If I were to redesign the propagation house, I would compartmentalize smaller areas to accommodate the special needs of each type of crop. While this would facilitate better growing, it would add to the labor costs. Another improvement would be to minimize drafts. Also, because of the very low outside relative humidity here in the summer, when I tried to raise the relative humidity to 80% to 90% inside,

the air temperature dropped too much, cooling the propagation house down to a Fahrenheit temperature in the 70s. Although rolling benches optimize space utilization, there are added labor costs bringing plants in and out. In the future this problem will be addressed with the use of a monorail system. As we specialize in select crops, the propagation house will become even more efficient and productive.

Other changes in propagation we have made over the years have been due to the market driven need for a fatter fuller plant grown in a faster turn around production cycle. We direct stick as many cuttings as possible in the container in which they will finish. This makes a fuller plant that finishes faster, with less chance of transplant shock.

The last major change we have made is no longer relying on in-house seed production for our *Spathiphyllum*. We now buy tissue culture *Spathiphyllum* from four different vendors. The improved genetics of these tissue culture plants and the delivery of uniform plants, in sufficient numbers, have made it possible to meet the market demand.

In preparing this presentation I talked to several key San Diego growers about the changes they have seen. Although each grower handles propagation material differently in order to adapt to his greenhouse structures and production goals, they uniformly agreed a major change has been the improved quality of the Central American cutting material. The Central American growers have specialized their growing grounds or farms, by putting each crop into its own best climatic zone. Fertilization and cooling techniques have hardened cutting material for better shipping durability and air rooting has also cut loss rates for growers here. Plant material is more consistent, aiding in crop cycle timing and there is a wide range of sizes from which to choose. Some growers will buy a larger cutting closer to its finish size for a quicker turn, while others buy a smaller size, then put on more leaves here for a more polished fuller look. Overall, each element in the chain is getting better and more specialized.

Growers also agreed foliage production is becoming more like bedding plant production. It is no longer a time of one greenhouse propagating everything in-house. Besides better cutting material coming in from Central America, there are many more top quality tissue culture plants and seedling plugs available from Florida. These sources have allowed Southern California growers to shorten the growing window and the ability to concentrate on finishing the product.

Chuck Ades, of Ades & Gish Nursery, pointed out the proliferation of new varieties. At one time I was growing more than 35 varieties of *Spathiphyllum*. Today there is a flood of new *Hedera* (ivy), *Ficus benjamina*, *Dieffenbachia*, *Aglaonema*, fern, and *Calathea* all done by tissue culture. There are also new types of *Dracaena*, *Algaonema*, and *Croton* coming in from Central America. While there are so many more new plant varieties to propagate, I have found this abundance of choices has not been appreciated by customers and often has only caused confusion in the market.

In the future, new communication technology will push the need to continue to specialize and improve the quality of cutting material even further. As an example, I plan on using a digital camera to take pictures of cuttings, then transfer these photos onto my computer as e-mail attachments. I will be able to show the growers in Central America exactly what I am looking for and the problems I encounter using this Internet-based technology. Both parties will be able to communicate more easily

and more precisely. Because there are so many good products available, I doubt this will result in price increases. But, those suppliers who can respond to these clearly defined propagation needs, will get the most business.

Because of this diversification of sources for propagation material and dependency on suppliers worldwide, all growers are much more subject to fluctuations in the world economy. Because our local market will not absorb price increases, the availability of cutting material from Central America shifts when Europe or Asia will pay more relative to the value of the dollar. In closing, economic pressures have dictated that every producer of foliage crops must do a better job for the same or a lower price.

Propagation of Aquatic Plants

William Charles Uber
Van Ness Water Gardens, 2460 North Euclid Avenue, Upland, California 91784-1199

I want to thank you for inviting me to speak at this International Plant Propagators' Society meeting. Van Ness Water Gardens is a third-generation company and, in my opinion, our propagating methods have change significantly since my father and Mr. Van Ness ran the business.

Originally, we used 4-inch-terra-cotta pots to grow our plants. These eventually became too expensive so we started using tin cans that we purchased from a local school cafeteria and dipped them in large vats of hot tar to rustproof them. Plants growing in the 1-gal tin cans had to be spaced further apart than the ones growing in the 4-inch-terra-cotta pots, but the plants grew larger. The larger plants and the increased volume of the 1-gal cans increased the volume of soil and the amount of fertilizer needed to grow the plants and it increased the labor required to plant and move them around the nursery. Smaller flats were also tried, but resulted in overgrowth of algae and/or the growth of some other dominant plant that killed the plants we were trying to grow.

We've tried several novel techniques to improve the propagation of our plants. In the late 1970s we tried plant hormones that improved the growth of our plants, but their use did not compensate for their cost and added labor requirements. In the early 1980s I worked with Martin Creehan at his meristem culture laboratory in San Dimas to develop a micropropagation protocol. We found it very difficult to surface-sterilize the aquatic plants and we could never completely remove fungi that grew on them.

We propagate hardy lilies and hardy tubers today the same way they were propagated thousands of years ago by cutting their "eyes" and planting them in our special soil mix. Most of the other plants we produce are propagated by cuttings. The tropical lilies are propagated by bulbs that we bring out from storage each spring. Some tropicals have the added advantage of producing viviparous off-shoots from their leaves. We use a special "tamale" planting method for our off-shoots. This means that we use a special soil mix with the plant wrapped in newspaper. One thing we have found is that the roots of aquatic plants do not like to be isolated; it is important for them to exchange gases and nutrients in the water surrounding them.

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Question and Answer Period: Concurrent Session II — Specialty Crops

Elizabeth Davison: Do you need to control the greenhouse environment to grow the carnivorous plants?

Jim Booman: I use a fog system to increase the relative humidity and help reduce the temperature.

Dick Criley: What kinds of problems are you experiencing with tissue cultured plants?

Jim Rietkerk: When we experience problems of any kind with plants we purchase we simply stop doing business with whoever provided problem plants.

New Trends in Natural Ventilation

Gary Baze
Conley's Greenhouse Manufacturing, 4344 E. Mission Blvd., Pomona, California 91766

There is no question that natural ventilation is the current "buzz word" of the day. If you had the privilege of attending this years Ohio Floral Industry trade show you would have witnessed more versions of "natural ventilation" than you may have known existed. While the issue of natural ventilation may seem new to some, it has, in fact, been a standard within our industry almost from the beginning.

In order to gain a proper perspective as to where the trends are going it is sometimes helpful to see where we've been. For the purposes of this discussion, we should start at the beginning of our industry. Please remember that the first greenhouse businesses were inherently smaller "Mom and Pop" operations. Smaller operations were the norm of the day primarily due to the more regionally based sales area and the demand for plant products. These greenhouses typically were much smaller in size than what we see today and, therefore, much easier to manage. These early structures typically incorporated small ridge vents as the primary means of ventilation. The ridge vents were opened and closed with a manual chain and pulley system.

As advances in transportation expanded the grower's sales area and the general public took more of an interest in plant products, the standard grocers found themselves requiring ever-increasing space in order to keep up with the demand for plant material. Unfortunately, the standard style of ventilation was not able to maintain the same environmental control due not only to the inadequate sizing of the vents, but also to ever increasing demands on the grower. Since there was no reliable thermostatically controlled motor available to open or close the vents, the grower found it almost impossible to manage the vent position as required.

It was during this period that mechanical ventilation found its way into the greenhouse industry. Compared to the alternative, mechanical ventilation was a Godsend in that it allowed the grower to introduce an adequate supply of fresh air to the plants on demand.

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While the use of exhaust fans represented the best form of ventilation available at the time, it came with its own set of drawbacks. Some of these included:

- The full volume of fresh air was generally introduced through one vent at the opposite wall to the fans. The plant medium closest to this inlet vent almost always got a shock from a blast of either cold damp or hot dry air.
- Growers became locked into using houses that were limited in length due to the fact that air traveling through the house picked up heat creating temperature differentials from one end of the house to the other.
- Growers who grew hanging baskets experienced warmer temperatures in the upper sections of their greenhouses (where they really needed cooler temperatures) due to the natural effects of warm air rising.
- There was a cost involved in operating exhaust fans (both the day in and day out consumption of electricity as well as ongoing maintenance required to keep these fans in good operating order).

Our desire to implement passive ventilation makes sense for many reasons including:

- The air outside is free.
- Plants, by their very nature, grow best in an outside environment.
- Natural ventilation travels vertically with the normal flow of air movement.

The problem always comes down to the fact that naturally ventilated greenhouses can not always be counted on to maintain the desired environmental conditions. I got my start in this industry working with high-pressure fog cooling systems where adequate ventilation wasn't an option, but rather a necessity for the successful cooling of the environment. In those days I can remember individuals asking my advice as to how large they should build their vent so as to create the most efficient natural ventilated design. To illustrate how naive our thinking was then, and how far we've come in just the past few years, the norm called for 10% of the total square footage of greenhouse to be vented. Based on these recommendations, a 30 ft × 96 ft long greenhouse would only require a 3 ft-wide ridge vent.

To my own defense, I can honestly say that the advice I tried to give growers was that one could not, short of removing the roof off the greenhouse, have enough vent opening to facilitate adequate natural ventilation. Of course, at the time we did not possess the proper tools or experience to remove the roof from a structure though we saw the need.

In just the past few years, while our industry has wrestled with the most efficient means of implementing natural ventilation, the methods most commonly employed to ventilate included:

- Rack and pinon ridge vents
- Rack and pinion gutter vents
- Rack and pinion side or end wall vents

With such limited vent sizes and placement, the performances achieved in naturally ventilated houses was dependent on many external factors including:

- Outside temperature
- Outside relative humidity

- Light intensity
- Wind direction
- Wind speed

It most cases, we find growers incorporating natural ventilation, orientating their roof vents in such a way as to allow the air to pass over the vent as opposed to blowing directly into the vent opening. This theory has, in my opinion, proven correct, as the air passing over the top of the vent tends to create a venture siphoning effect assisting to draw air out of the structure. However, if the environment outside were still, the rate of ventilation would typically suffer. These problems were more prevalent in more humid environments such as the Southeast regions of the U.S.

Some of the newest trends we are seeing emerge in naturally ventilated greenhouse operations include:

1) Creating higher under gutter heights within the structure.
   - Even 10 years ago we can say that standard under gutter heights rarely exceeded 8 to 10 ft.
   - Today 10 ft is about as low an under gutter height we see with 12 and 14 ft fast becoming the norm.
   - The advantage to creating more height in your greenhouse environment has to do with putting more distance (volume of air) between the plant and the top of the roof.
2) The introduction of faster and more reliable environmental control packages (computers).
   - Manufacturers are designing their controls specifically for naturally ventilated houses.
   - Controls are now available which will open a vent in multiple stages.
   - Controls are available to operate roof vents under a separate zone of control from sidewall vents.
   - Controls are now available with light and humidity sensors which give the grower more flexibility in what perimeters they use to control their environment.
   - Controls are easier to understand and operate.
3) The introduction of larger roll-up style roof vents both in the roof and roll-up vents on side walls and end walls
   - Rack and pinion roof vents are expensive and, in some instances, not able to open very wide.
   - Roll-up vents typically create larger openings than their rack and pinion counterparts.
   - Roll-up roof vents typically reduce the amount of "dead air space" created in the uppermost part of a greenhouse.
   - Roll-up side wall curtains are available in much taller designs and are effectively utilized even for colder localities.
4) The implementation of stress-reducing environmental controls systems. Internal retractable shade systems: shading vs. heat retention
   - External retractable shade systems
   - High-efficiency fog systems
   - Hot venter heating and infrared heating systems

5) The introduction of open-roof greenhouses.

- Several styles available
  - Flat profile accordion-type retractable systems
  - Gable profile accordion-type retractable systems
  - Sawtooth profile accordion-type retractable systems
  - Arched-roof roll-up style systems
  - Rack and pinion style systems
- Open-roof greenhouses are not for everyone
  - Consider fuel costs
  - Consider regional snow loads
  - Consider available ventilation in all styles of weather
  - Consider direct sunlight
  - Consider insect screening
  - Consider ventilation requirements

Given the tools available to us today, I believe we will see more and more growers implement natural ventilation into their operation. The type of crops grown dictates the degree and style of natural ventilation which should be incorporated. In most cases, bedding plant growers should probably be considering fully open roof greenhouses while tropical plant growers may not require this degree of ventilation.

Regardless of the style of ventilation which best suits your needs, natural ventilation offers a viable means of obtaining your goal.

Identification and Control of Fungal Diseases in Landscape Ornamentals

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The first step toward disease control is recognition of the disease presence and identification of the causal agent. Once the causal agent or pathogen is identified, a control strategy can then be developed. However, I agree with Westcott (1971) who states that "plant pathologists can tell you what a disease is but seldom what to do about it except to remove the diseased parts...". Sadly, many fungal diseases once recognized have few control options; thus many disease strategies are preventative in nature. Plant autopsies are common in the disease diagnosis business. The logic is, that if we can figure out what killed or injured our plants, perhaps we can prevent the occurrence in the future. Thus the bulk of this presentation will focus on recognition of landscape diseases common to Southern California gardens. Where a good control strategy is known it will be mentioned.

Plant disease was defined by the late Professor H.H. Whetzel as follows; "Disease in plants is an injurious physiological process, caused by the continued irritation of a primary causal factor, exhibited through abnormal cellular activity and expressed in characteristic pathological conditions called symptoms." The causal factor can be either a living organism (biotic cause) or an environmental condition (abiotic cause). Injury due to environmental causes differs from disease in being only a transient irritation of a causal factor. Diseases by their nature are chronic, ongoing, and take time to develop (Agrios, 1997).

For diagnostic purposes it is important to distinguish between symptoms (plant responses) and signs (parts of the causal agent). Common symptoms are wilting; yellowing, browning or death (necrosis) of plant parts; cankers (sunken lesions on plant stems); stunting; spots; etc. Signs include mycelium (collective term for fungal threads or hyphae), spores, and fungal fruiting bodies such as mushrooms, pycnidia, perethecia, etc. Based on the observation of symptoms and signs, a presumptive diagnosis can be made. However, a final diagnosis may require culture of the causal agent and identification of its spores in vitro. Sometimes, sporulation of fungi can be induced by placing the specimen in a moist chamber to allow development of fruiting bodies.

Diseases occur on all plant parts which accounts for the many different disease categories which have been devised by plant pathologists to describe plant abnormalities. The following categories are not inclusive of all kinds of disease problems but typify the majority of diseases that can occur in Southern California landscapes.

ROOT ROTS

Root rots occur on virtually all landscape plants, monocotyledons and dicotyledons, gymnosperms and angiosperms, mosses, ferns, etc. There are very few plants that are immune. The majority of the root rots are caused by fungi in the Oomycetes class of fungi. *Phytophthora cinnamomi* Rands is the cause of many root rot diseases of angiosperms, and conifers, but not of many monocotyledonous (grass) plants (Erwin

and Ribeiro, 1995). Many flowering trees are susceptible especially camphor, oak, Monterey pine, avocado, and camellia. There are over 50 recognized species of *Phytophthora* worldwide that attack many kinds of plants. California native plants such as *Fremontodendron californicum* (Tor.) Cov. are often susceptible to *P. cinnamomi* when grown in gardens.

Monocots are not exempt from root rots and are in fact plagued by them. *Pythium* spp. are frequent destroyers of bentgrass golf greens and other turf grasses. *Pythium* spp. are also closely related to *Phytophthora* spp. yet have a different host range. They are more commonly found on nonwoody hosts.

The Oomycota, including *Pythium* and *Phytophthora,* are unique fungi which are dependant on an aquatic environment for proliferation of their swimming zoospores. Reduction or prevention of over-wet conditions will help to reduce disease losses. The acylalanine fungicides (Subdue® or Ridomil®) and the phosphonate fungicide Aliette® can provide good control of water molds.

Another pathogen-causing root rot to many plants is *Armillaria mellea* (Vahl:Fr) P. Kumm. This is a mushroom-forming member of the Basidiomycetes group that causes root rot and wood decay in a number of plants. Interestingly, *A. mellea* also attacks bamboo, *Agave* spp., *Crassula* spp., *Begonia*, palm and a number other nonwoody plants. There are no fungicidal controls. Drying out affected tissues is often a recommended practice as the fungus proliferates in moist conditions; however, it is not always an effective control once the pathogen has taken hold of its host. There are no fungicidal controls available for *Armillaria* root rot.

Root rots are also very destructive to seedlings of many plants. *Rhizoctonia solani* Kühn is a basidiomycete fungus that often causes damping off of seedlings. It has no spores but does survive in soil with hardened masses of hyphae called sclerotia. *Rhizoctonia* diseases are often diseases of nursery stock and can be controlled by soil pasteurization and sanitation.

CANKER DISEASES

Cankers are necrotic spots on stems of woody plants. They enlarge in size and the necrotic tissues as they coalesce kill the stem they are formed on. This leads to symptoms of wilt, yellowing, flagging, and dieback. The most common canker disease in Southern California is cypress canker caused by *Seiridium cardinale* (W. Wagener) Sutton & I.Gibson. It occurs on many ornamental cypress plants but ×*Cupressocyparis leylandii* (A.B. Jacks. & Dallim.) Dallim. & A.B. Jacks. is the most susceptible cultivated cypress I have seen in southern California. This disease is such a problem in landscapes that nurseries should refrain from growing and selling Leyland cypress.

WILT DISEASES

Wilt diseases are most often caused by species of *Verticillium* and *Fusarium*. *Verticillium albo-atrum* Reinke & Berthier is sometimes found in Brazilian pepper causing characteristic vascular discoloration of the xylem of newly formed wood. *Fusarium oxysporum* Schlechtend.:Fr. causes the wilt disease of palms in the *Phoenix* genus. This is a common and devastating disease in California spread by humans and their pruning equipment. A most famous wilt disease is Dutch elm disease, but this is not common to Southern California.

FOLIAR DISEASES

Leaf diseases are commonly caused by a variety of fungi which infect the epidermis of ornamental plants. These fungi are encouraged by moisture especially leaf wetness (except for powdery mildews). There are a number of anthracnose fungi, leaf spot fungi, and blight fungi that occur on many kinds of ornamental plants. In many cases, changing from sprinkler irrigation to drip irrigation will prevent these diseases which spread in droplets of splashed water. *Entomosporium mespili* (DC) Sacc is a fungus that commonly infects the foliage of plants in the rose family. It can completely defoliate Indian hawthorne when cultivated under sprinkler irrigation Many fungi cause anthracnose diseases (diseases of foliage and small twigs) of elm, sycamore, pear, and oak. Symptoms of affected foliage typically follow the veins on infected leaves. *Apiognomonia veneta* (Sacc. & Speg.) Hohn. and *A. errabunda* (Roberge) Hohn. commonly infect California sycamore and coast live oak in southern California landscapes. Although not serious enough to warrant control measures (McCain, 1988), anthracnose fungi can cause dramatic defoliation of affected trees.

These are but a few examples of fungi and their effects on ornamental plants Many more examples are catalogued by Sinclair et al. (1987) and Westcott (1971) There are also many fungal diseases which have not yet been discovered or understood. Diseases of unknown etiology continue to perplex pathologists and as we grow new and different ornamental plants we will necessarily cultivate their fungal pathogens that may also be new to science

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An Experience with Propagation of Rare and Native Plants in Western Australia

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INTRODUCTION

The flora of Western Australia is famed for its diversity and consists of about 20,000 species of flowering plants. Some of the hard-leafed vegetation include *Eucalyptus*, *Banksia*, *Hakea*, *Grevillea*, *Dryandra*, and *Acacia* that dominate Australian flora. There are about 600 *Acacia* species restricted to Australia and at least 400 species of *Acacia* are recorded for Western Australia.

I had the opportunity to spend 7 weeks in Perth, Western Australia, and another 2 weeks in Tasmania at Westland Nurseries While at Perth (Mediterranean desert), very constructive time was spent both at the Department of Plant Sciences, University Western Australia, and Micropropagation Laboratory at King's Park and Botanic Garden (KPBG). The primary objective of my visit to Australia was to learn new propagation techniques of arid and native Australian plants The second objective was to work on a short-term project related to the tissue culture of rare and endangered semi-arid and arid plants The third objective was to do research to find new tree species that can be grown and introduced in Arizona's climatic conditions.

SEED COLLECTION AND SEED STORAGE FACILITY

While the trees/shrubs were at flowering stage, the plants at various locations were marked with colored ribbons according to the uniform intensity of flowering to obtain seeds of uniform maturity. After the seed collection and cleaning process, seeds were dried in an oven at 35C packed in aluminum foil bags, carbon dioxide was filled into the bags, and bags were sealed. Seeds were stored at room temperature as well as at -18C freezer Seed germination and seed viability tests were performed routinely at the laboratory

GRAFTING AND CUTTING PROPAGATION OF AUSTRALIAN ARID-ZONE TREES

Various grafting techniques were used to graft *Darwinia macrostegia* on the rootstocks of *D citriodora* and *Verticordia grandis* on the rootstocks of *Darwinia* species, etc The grafted plants were placed in a bell jar or plastic bag covered over the potted plant and these were misted occasionally Four to six weeks later, a union had formed and new growth began on successful graft unions.

Cutting propagation of some drought tolerant trees and shrubs including clones of *Grevillea* species were conducted at KPBG as well as at Westland Nurseries, Tasmania A few techniques were different; for example, a new form of rooting hormone was used called "Esi-root", a formula containing hormone in gel. Esi-root contains two active ingredients: indole-3-butyric acid (IBA) and naphthalene acetic acid (NAA), contains no alcohol, exhibits anti-fungal activity, and contains wetting agent. A wet thick blanket or moist bed of sand (6 inches deep) was placed over the bottom heat cables on the propagation bed and this provided even heating and moist

heat to the root zone of cuttings. Rainwater (30 ppm salts) was collected in tanks and used for mist propagation. Rooting trials on difficult-to-root grevellia clones, were conducted using pre-treatment of cuttings with smoke water before application of various hormones. Rooting trials on *Stylidium adnatum* (trigger plant), *Lochonontia* hybrid, and *Westringia dampieri* cuttings were also done and most of them rooted successfully. Two weeks were spent at Westland Nurseries, Hobart, Tasmania to gain experience with cutting propagation of cool climate flowering plants and some semi-arid plants Large-scale cutting propagation of some familiar species such as *Verbena*, *Myoporum parvifolium*, *Anisodontea*, *Rhododendron* (azalea), *Gazania*, *Hardenbergia*, *Dianthus* (carnation), *Rosa* (mini roses), *Dodonaea*, and other Australian natives was performed under a fog system

MICROPROPAGATION OF WESTERN AUSTRALIAN FLORA

The majority of my time was spent on projects related to tissue culture of rare and endangered arid-zone plants of Western Australia at the Micropropagation Laboratory at KPBG The team leader of this internationally acclaimed research facility is Dr. Kingsley Dixon. This facility is well known for innovative plant conservation research including tissue culture, cryostorage, genetic DNA fingerprinting, and ecology of rare and endangered plants. In vitro rooting trials were performed with two rare and endangered species of the family Lamiaceae, *Hemiandra gardneri* and *Hemigenia exilis.* These arid- or semi-arid-zone plants are difficult to propagate vegetatively (i e , cuttings), and there is very little information on availability or germination of seed The optimization of in vitro root induction of these species is of great importance to the endangered plant program at KPBG In vitro rooting trials were performed on shoot tips of these species. After experiments with various growth hormone treatments, 20% to 40% of *Hemiandra gardneri* shoots rooted in vitro after 4 weeks Rooted shoots were transplanted and acclimatized in the glasshouses Although root induction was low, this work has provided valuable information for further in vitro studies on these highly recalcitrant species.

TISSUE CULTURE AND PLANT BREEDING OF FLOWERING PLANTS, PLANT SCIENCES DEPARTMENT, UNIVERSITY OF WESTERN AUSTRALIA, PERTH

I had the opportunity to work with a group of researchers at the Plant Science Department at the University on a project related to plant breeding and tissue culture of *Boronia* and waxflower.

The two leading native Australian plants, Geraldton waxflower (*Chamelaucium uncinatum*) and flowers of genus *Boronia* and its wide range of colorful forms grow from mild damp to extremely arid soils of western Australia, are used worldwide for floriculture market. Waxflower is present in large populations in the wild and there are several reports of interspecific and even intergeneric hybrids from within the *Chamelaucium* alliance, therefore, breeding offers enormous potential for improvement While crosses produce viable embryos, seeds do not germinate readily or embryos abort during development. Some *Boronia* species are used for striking flower color while other species are used for extraction of perfume oils The University of Western Australia researchers have been breeding new varieties of Boronia. However, there are obstacles in breeding *Boronia* because of a very poor germination rate of most Boronia species (Plummer and Concidine, 1995) The

Boronia and waxflower embryos can be removed after fertilization and grown in aseptic cultures on filter paper bridges The researchers were able to optimize conditions for shoot multiplication on germinated embryos of the hybrids and later in vitro root induction on shoots.

NATIVE PLANT CONSERVATION PROGRAM

I was able to visit Geraldton mining site with research ecologists who were conducting research on germination of native arid vegetation in response to plant-derived smoke. KPBG has pioneered research on the promotive effect of smoke (derived from burnt native vegetation) on seed germination of western Australian plants (Dixon et al , 1995) which had previously been recorded as extremely difficult or impossible to germinate using conventional techniques. A 3-day visit was made to Anaconda Nickel's Murrin-Murrin (Leonora) project mining site, one of the world's largest nickel projects. The rare species of *Hemigenia exilis* was discovered in 1895 This exists in Leonora as only seven to eight populations in the world. This species was rediscovered in Anaconda Nickel's Murrin-Murrin South Project development area in 1995 and was listed as Declared Rare Flora I was accompanied by research ecologists of KPBG laboratory to collect seeds and cuttings for conducting seed germination trials, cutting propagation, and tissue culture of this rare species.

The experience of visiting this arid desert (Leonora), called "Acacia Country", was very exciting. Thousands of trees of *A. notabilis*, *A. murrayana* (syn. *jennerae*), *A. quadrimarginea*, *A tetragonophylla*, seven subspecies of *A. aneura*, *A. craspedocarpa*, sandalwood tree, some species of *Casuarina*, *Banksia*, *Melaleuca*, and *Hakea* were growing in similar climatic conditions as that of Arizona. However, the soil in the entire area was of distinct reddish brown color, rich in iron but characteristically depauperate in most other minerals. Most of these *Acacia* species were very familiar because these have been introduced into Arizona.

To summarize, I had a fascinating experience learning about wonderful Australian flora and wildflowers of Western Australia The research programs at KPBG and their efforts to rescue and restore rare plants is unique and very impressive.

ACKNOWLEDGMENTS

I would like to thank Dr. Kingsly Dixon and Eric Bunn, KPBG Plant Science Lab; Prof. John Concidine, Plant Science Department at UWA, Perth; Tony and Rose of Westland Nurseries, Tasmania for their warmest hospitality. Financial support provided by I P.P.S -Western Region and Desierto Verde Inc is highly appreciated

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Question and Answer Period: Saturday AM General Session I

Jim Kresler: Have you done any studies where gypsum has been added to the potting mix?

Jim Downer: No. Others have worked on that When coarse gypsum (crushed dry wall) was added to make up to 5% of the medium, the physical and chemical properties of the mix change One is that the porosity of the mix is altered. That immediately has an effect on reducing the water content of the medium which is critical for eliminating *Phytophthora* diseases The other effect seems to be a chemical/fungicidal, calcium ion-based effect directly on the fungus that reduces the size of the sporangia and the number of spores produced.

Rooting Media and Plant Acclimatization ex Vitro

Atelene Normann Kämpf, Eunice O. Calvete, Soeni Bellé
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INTRODUCTION

The transfer of plants from a sterile environment to a greenhouse is known as acclimatization, which corresponds to the Stage IV in the process of micropropagation Due to its technical requirements this phase is considered one of the most expensive of the micropropagation process and, consequently, a possible limiting factor on a commercial scale (Lewandowski, 1991)

In vitro culture is done under artificial conditions like a constant long-day photoperiod (generally about 16 h day^{-1}) with a low luminance level (1000 to 2000 lux) and a narrowed light spectrum (fluorescent lamps without red and infrared waves). The usual temperature ranges from 20 to 25C Inside the flask the air humidity is very high and the CO_2 level is low. The culture medium fixes the plants in the right position and releases to them nutrients, vitamins, amino acids, and sugar. Under these conditions, the plant is considered heterotrophic (Fugiwara, Kozai, and Watanabe, 1988) or mixotrophic (Deng and Donnely, 1993) Leaf anatomy and morphology show typical culture-induced phenotype (CIP) reduced palisade tissue, no epicuticular waxes on the leaf surface, abnormal linkage between the conduction vessels from the root-shoot sequence, roots with less absorbent hairs and stomata with low photosynthetic efficiency (Waldenmaier, 1988, Preece and Sutter, 1991, Hartmann et al., 1997)

For the horticulturist, this stage of acclimatization involves transplanting, which needs special care to avoid plant stress and contamination from pathogens Preece and Sutter (1991) suggest the following parameters be considered for successful acclimatization: control of light and air humidity, use of antitranspirants, prevention of contaminants, reduction of fertilization, and selection of substrates Among these factors the selection of substrates is one of the least studied (Avanzato and Cherubini, 1993).

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ADVENTITIOUS ROOT FORMATION

Acclimatization depends on the development of adventitious roots and this is affected by the substrate Basically, the process is divided into two phases: root initiation (in vitro) and root elongation. The last phase depends especially on the properties of the rooting medium. Hartmann et al. (1997) listed four functions for the rooting medium: to hold the cuttings in place during the rooting period, to provide moisture, to permit air exchange, and to reduce the light penetration to the cutting base.

According to Drew (1990), one single cell produced by the meristem can complete the root initial development in a few hours. The root elongates through the continuous pores of the substrate and, if necessary, its tip can dig channels by displacing solid particles. The resistance of the particles against this movement can stress the root. As a consequence, apical dominance can be broken and the speed of cell division decreased. Hence, the roots will be shorter with more lateral branches. Considering these observations, we may add some items to Hartmann's list (Table 1) Each function is related to one or more physical or chemical properties of the medium, which must be considered in the evaluation of substrate quality.

Table 1. Functions of the root medium and related properties

Functions	Related properties
To fix the plant, cutting,	
or microshoot	Bulk density
To retain and deliver water	Meso and micropores
To permit gas exchange	Macropores (air space)
To promote root growth	Fertility (salinity), pH value
To permit root penetration	Penetrability (mechanical impedance)
To maintain the physical structure	Resistance to deformation

ROOTING MEDIUM

In Brazil, the substrate industry is just beginning and at this stage is unable to attend to all demands. So, growers prepare their own mixtures using local, available components. The most commonly used components we have are black and fibrous peat, mineral soil, vermiculite, organic composts and residues of the agroindustry like rice hulls (carbonized or burned), and *Pinus* and *Acacia mearnsii* bark The guidelines (Table 2) to evaluate these materials, pure or mixed, follow the concepts of De Boodt and Verdonck (1972), Roeber and Schaller (1985), Hartmann et al (1997), and Ballester-Olmos (1992).

Acclimatization can be done under mist or in indoor tents. The required properties of the medium for each situation are different. Under mist quick drainage is required. We use pure carbonized rice hulls (about 75% of water volume runoff) with good results for *Limonium platyphyllum* (syn. *latifolium*). Under the tents, besides drainage, the water retention can be a limiting factor, as demonstrated by the two following examples, *Eustoma grandiflorum* (prairie gentian) and *Fragaria ×ananassa* 'Campinas' (strawberry).

Table 2. Desired properties of root media

Properties	Values	Unity
Dry density	200 to 500	g liter^{-1} substrate
Total porosity	0 80 to 0 90	cm cm^{-3}
Air space	0 10 to 0 30	cm cm^{-3}
Easily available water	0 20 to 0 30	cm cm^{-3}
Water retention after drainage at 100 hPa	0 20 to 0 25	cm cm^{-3}
pH value	>5 0 to <6 5	
Total soluble salts substrate	<1,0	g KCl liter^{-1}
Mechanical impedance	<400	kPa

PLANTS

Eustoma grandiflorum.

In vitro-rooted microshoots of prairie gentian were transferred to three substrates based on mixtures of a mineral soil (classified as Cumulic Haplumbrept) + carbonized rice hulls or *Pinus* sawdust or a sugarcane compost. The medium varied significantly in the following properties. pH value (5 0 to 6.0), total soluble salts (0.7 to 4.2 g liter^{-1}), air space (0 18 to 0.41) and remaining water after drainage by suction at 50 hPa (0.17 to 0.44) The correlation of these properties and plant growth revealed a significant effect of air space and the remaining water volume on the biomass production (Fig 1). The results showed the importance of aeration in the root medium for acclimatization of *Eustoma*, suggesting a value of 0 40 cm^3 cm^{-3} for air space and 0.17 cm^3 cm^{-3} for remaining water at 50 hPa.

Fragaria ×*ananassa* 'Campinas'.

In this trial we compared the development of in vitro rooted microshoots of strawberry 'Campiñas' after transplant into eight media (Table 3), seven of them based on the following components: peat — a high mineralized black peat, corresponding to H9 in the von Post' Scale (Roeber and Schaller, 1985) and a fibrous red peat, corresponding to H3 in the same scale, carbonized or burned (ash) rice hulls; vermiculite with 0.5 mm diameter; and partially decomposed *Acacia mearnsii* bark, sieved to 5 mm particle size A commercial mixture of *Pinus* bark, black peat, and vermiculite was used as the control.

All the mixtures showed similar density and total porosity values, but differed significantly in air space (0.05 to 0.35), available water (0.15 to 0 38), and total soluble salts (1.14 to 2 15 g liter^{-1}). The acclimatization, evaluated by percentage of the surviving plants, dry and fresh mass of roots and shoots, plant height, and number of leaves was clearly affected by the quality of the substrates. The rice hulls

ash mixes produced better plants with more roots and leaves. The results submitted to correlation analysis (Table 4) indicated that the number of surviving plants, the plant height and the number of leaves are significantly related to the volume of available water and air space. Increasing the medium air space decreased significantly the percentage of surviving plants and plant height. The opposite occurred with the amount of available water The curves in Fig 2 suggest that the medium for acclimatization of strawberry 'Campiñas' must have 15 ± 5% air space and 33 ± 5% available water.

Table 3. Components of the media used as substrates for acclimitization of *Fragaria ×ananassa* 'Campinas'.

Treatments	Components (% by volume)
1	Black peat (50) + rice hull ashes (40) + vermiculite (10)
2	Black peat (50) + carbonized rice hulls (40) + vermiculite (10)
3	Black peat (45) + red peat (22 5) + rice hull ashes (22 5) + vermiculite (10)
4	Black peat (50) + red peat (25) + carbonized rice hulls (25)
5	Black peat (45) + rice hull ashes (22 5) + vermiculite (10) + *Acacia* (22 5)
6	Black peat (45) + carb rice hulls (22 5) + vermiculite (10) + *Acacia* (22 5)
7	Black peat (50) + rice hull ashes (25) + *Acacia* (25)
8	Black peat + Pinus bark + vermiculite + perlite (control)

Table 4. *Fragaria ×ananassa* 'Campinas' - correlation between substrate properties and plant growth

Properties		Plant growth parameters	Coefficient (r)	P (≥0.05)
Air Space	×	Plant high	-0 88	*
		Surviving plants (%)	-0 88	*
Available water	×	Number of leaves	0 74	*
		Shoot dry weight	0 76	*
		Plant high	0 78	*
		Surviving plants (%)	0 89	*

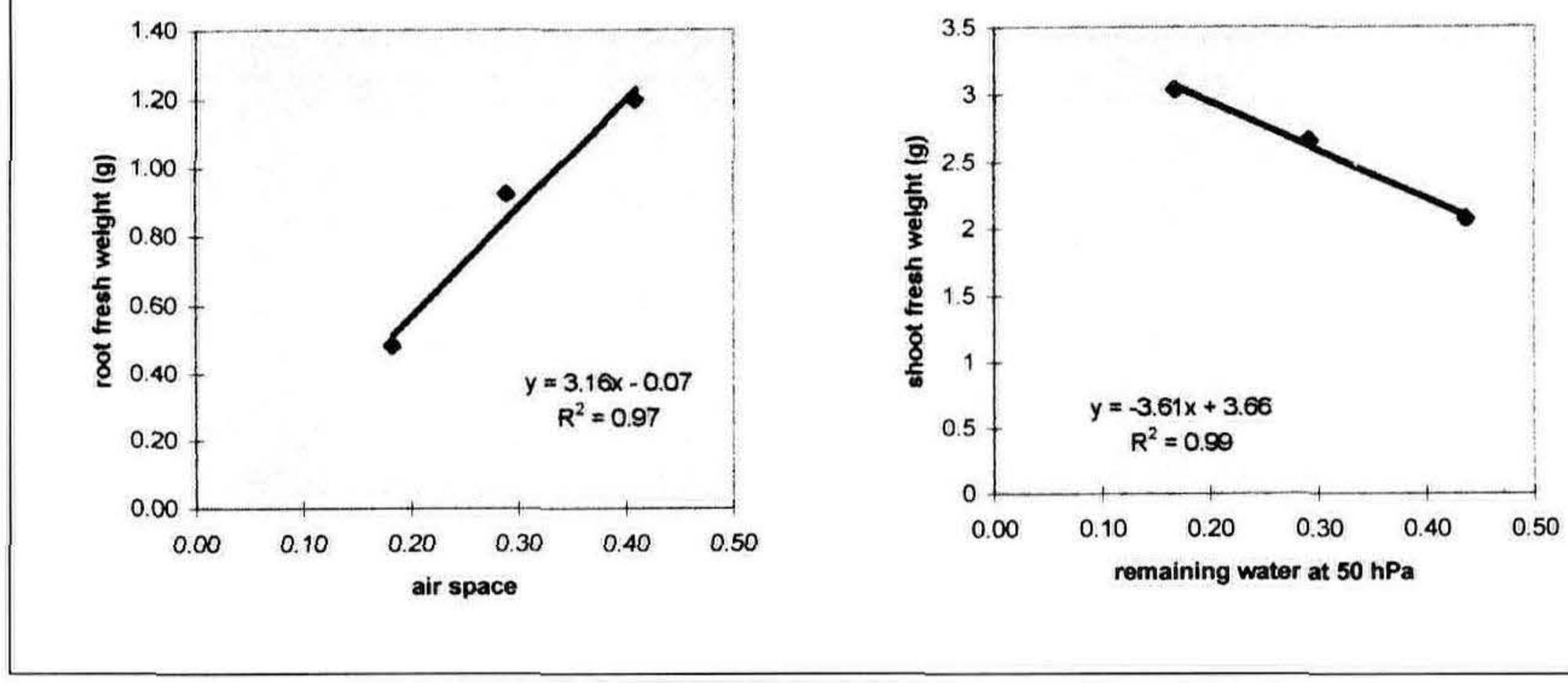

Figure 1. Acclimatization of *Eustoma grandiflorum* ex vitro. Left: Effect of air space volume (cm^3 cm^{-3}) of the rooting medium on the root fresh weight (g). Right: Effect of remaining water volume (cm^3 cm^{-3}) of the rooting medium on the shoot fresh weight.

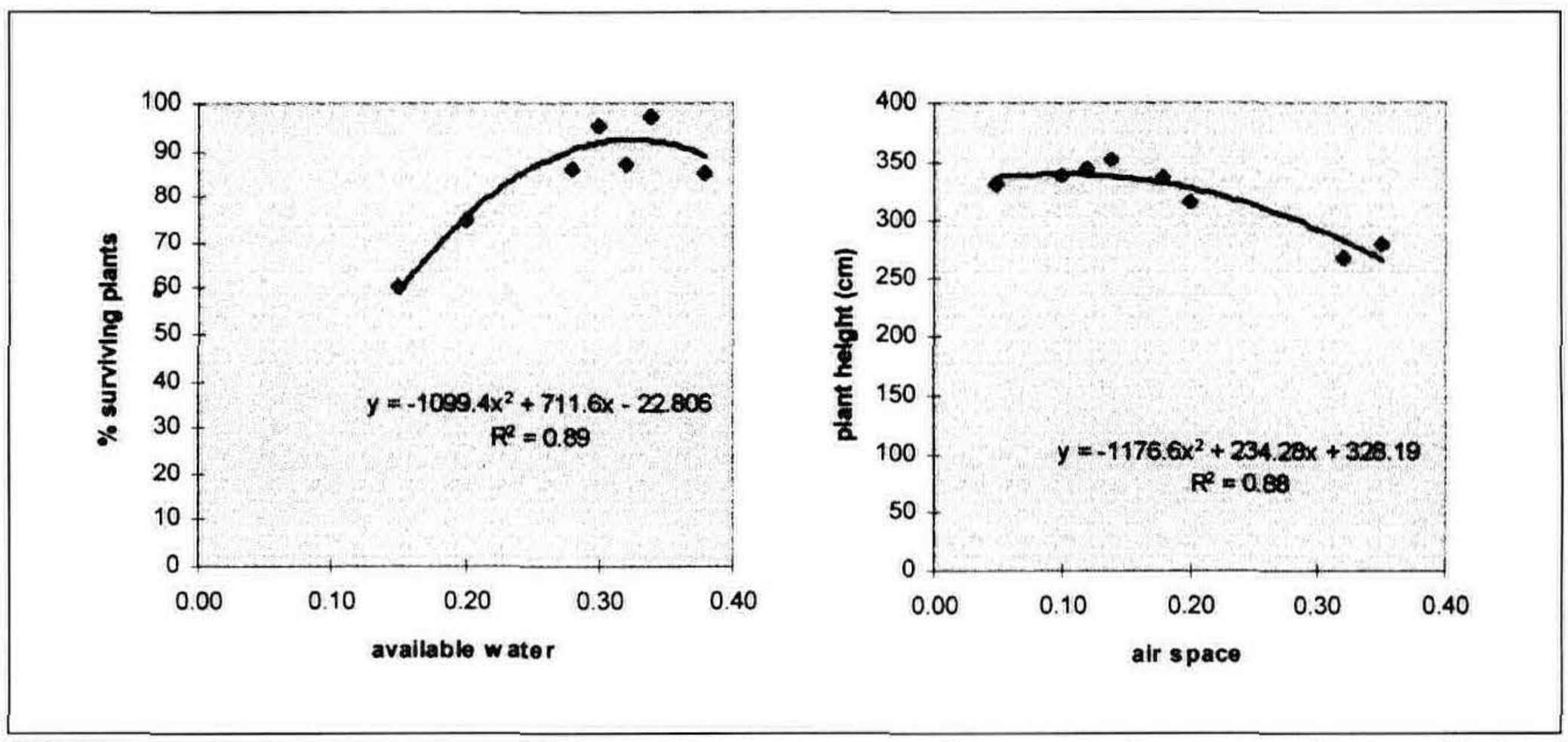

Figure 2. Acclimatization of *Fragaria* ×*ananassa* 'Campinas' ex vitro. Left: Effect of available water volume (cm^3 cm^{-3}) on the percentage of surviving plants. Right: Effect of air space volume (cm^3 cm^{-3}) on the plant height.

CONCLUSION

Knowledge of the requirements for adventitious root formation from each species and the selection of rooting media based on analysis of its properties can improve the ex vitro acclimatization of microshoots.

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Argentine Natives Worthy to be Grown

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When talking about the "pampa" area of Argentina, we're describing an area between 34° and 38° South Latitude (SL), with a temperate climate, 32 inches of annual rainfall, an annual average temperature of 61F, highest season average temperature of 74F, and the lowest season average temperature of 46F

Subtropical forest (Northeastern Argentina) is 25-28° SL, more than 50 inches of annual rainfall, annual average temperature 70F, highest season average temperature higher than 85F and lowest season average temperature higher than 60F

Cloud forest (Northwestern Argentina), 24° to 27° SL, more than 40 inches of annual rainfall, annual average temperature 66F, highest season average temperature higher than 70F, lowest season average temperature higher than 50F.

Patagonic Andes forest, 39° to -43° SL, 32 to 120 inches of annual rainfall; annual average temperature 41 to 50F, highest season average temperature 48 to 61F, lowest season average temperature 33 to 43F

***Dicliptera tweediana* - Acantaceae.**
Herbaceous perennial that can reach 2 ft in height It flowers continuously from spring to winter, with tubular-shaped scarlet flowers with two yellow anthers in the open mouth of the tube Lives with sun in nature, but prefers light shade conditions. Hardy down to 25F, prefers clay, alkaline soils. Easily propagated from its large seeds though it can be quite difficult to transplant. Its origin is pampa area (Central Argentina).

***Eryngium* - Apiaceae.**
Perennial, herbaceous plant up to 10 ft tall Foliage forming perennial rosettes of narrow leaves with toothed or spiny edges, very wide in some species, resulting in a bromeliad aspect Full sun. Clay soils, dry to moist The flower spikes are light green, silver, creamy or purple, with great ornamental value, attractive for more than 2 months. They're propagated from seeds, which are abundantly produced Hardy down to 22F. Habitat: pampa area, Central Argentina.

***Verbena patagonica* (syn. *Verbena bonariensis*) - Verbenaceae.**
Perennial, herbaceous plant up to 7 ft tall. Pink to lilac flowers, with perennial foliage Needs full sun and grows in clay soils. Hardy down to 22F It can be propagated from fresh seeds. Origin: pampa area (Central Argentina)

***Heteropterys angustifolia* - Malpighiaceae.**
Vine/shrub with long, narrow leaves, deciduous. The clusters of yellow flowers show for a long period, starting in spring. Attractive winged red fruits follow, prolonging interest for many more months. Propagated from seeds. Prefers full sun and clay soils. Hardy down to 22F Origin: subtropical forest (Northeastern Argentina)

***Pyrostegia venusta* - Bignoniaceae.**
Climber with perennial foliage The flowers of two orange tones show in winter and early spring. Full sun, clay soils. It's propagated from seeds and from cuttings taken in summer. Origin: subtropical forest (Northeastern Argentina)

adults or young plants) This made us think it's a spontaneous mutation with difficult or impossible sexual reproduction. Due to this, its propagation is being made by hardwood cuttings taken during the last weeks of August (late winter in Southern Hemisphere), planted on hot benches (65F) after IBA treatment So far, the progress is good. The cuttings have rooted and they seem to be healthy. But the final results and conclusions will come at the end of this next summer.

Los Verdes Prados — I.P.P.S. 1998 in Argentina

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The I.P.P S. motto, "To seek and to share," translates "Investigue y Comparte" in Spanish. This was certainly the attitude among 75 enthusiastic participants at the Second South America Area Meeting in Argentina, August 1998. The first Area Meeting was held in Buenos Aires in 1996 and served to "launch" I.P.P.S among the growers and horticulturists of South America In 1997, several members and others from South America got a glimpse of I P P.S. at the International Tour and Western Region Annual Meeting in Vancouver This year's meeting was a continuation of our expansion plan

The 3-day conference in Tucuman, a northern province in Argentina, included 14 presentations, two field trips, and a wonderful banquet at the closing A 5-day postconference tour to the northern province of Salta into the desert valleys of the Andean foothills was absolutely perfect in every way and made the whole experience "the trip of a lifetime "

Western Region I P P.S. has been actively involved with I P.P.S expansion in Latin America for 5 years. We have seen the most notable progress in Argentina, largely due to the consistent efforts of Graciela Barreriro, who runs our South American office in Buenos Aires. This year, she was assisted by Daniel Dieguez and his organizing committee, in planning a conference as complex as any Regional annual meeting. In fact, when you consider the planning, travel arrangements, accommodations, and activities on the tour, the meeting starts to look more like an International Board tour. And not unlike previous International tours I have attended, the food in Argentina was fantastic!

Several of you attended the International tour, hosted last year by Western Region and planned by President Bruce Macdonald. We had a chance to meet and interact with 25 members from South America and see their enthusiasm and dedication at each tour stop in Oregon, Washington, and British Columbia and throughout the conference in Vancouver As you recall, we provided simultaneous Spanish translation Many who had traveled last year to the Northwest participated in their own area meeting, this year greeting and hosting a few visitors from North America It was great to see so many familiar faces!

Traveling from North America to Argentina for the 1998 conference were, from Southern Region, David and Suzanne Tankard (David's Nursery), and from Western Region, Martin Grantham (U.C. Berkeley), Wilbur Bluhm (Secretary-Treasurer), and Mike Evans (Tree of Life Nursery) with wife, Hilda and daughter, Debbie English translation was provided for each presentation and tour stop. Each member

funded their own expenses entirely No I.P.P.S. funds were used for travel or other expenses. Travelling from Uruguay (30 h on a bus!) was member Tomeu Gelabert All the other attendees came from different parts of Argentina

At this time, there are 75 members in the Western Region Area of South America and Graciela is the Area Director on the Executive Committee As a result of the meeting in August, members in Argentina have formed an "Area Committee" which enables them to function similar to a Region The committee members are Graciela Barreiro (Buenos Aires), Daniel Dieguez (Tucuman), Patricia Tesone (Buenos Aires), Eduardo Alberto Flachsland (Corrientes), Rafael Kreibohm (Tucuman), and Tomeu Gelabert (Punta del Este, Uruguay).

Since new member recruitment and membership services are key issues in this emerging region, and there is much work to do, Graciela and Daniel certainly welcome the assistance of the new committee members. One of the immediate tasks is to follow up on all the attendees at the recent conference

The subjects of the talks at the conference included propagation media, use of peat, alternative media components, mycorrhiza, root systems, citrus germplasm, in vitro propagation of orchids, propagation of Restonaceas, greenhouse coverings, description of the Andean foothill forest vegetation, native cactus species, and new plants for southern Argentina. Our tours took us to nurseries growing citrus, flowering perennials, foliage, ornamentals, and a natural area with stops at a mountain resort and an old monastery. In a matter of a few days, we were introduced to all aspects of the horticultural, botanical, and scenic resources of the area.

The level of involvement at the conference and on tour was incredible. When three speakers, who had just given back-to-back papers on growing media got up after their presentations to clarify their points (seemingly contradictory in one instance), and the audience became engaged in a 15-minute discussion on pH, ion exchange, nutrient availability, and the finer details of root systems, you could say that you had witnessed the epitome of the I P P S purpose! Every seat was occupied for each speaker's talk, and the questions and comments were numerous throughout the conference Most attendees could be seen taking copious notes

It is noteworthy that while this I.P P S. conference had the assistance of a couple of related sponsors, the meeting stood on its own. It was not tied to a horticultural industry trade show, or similar event, yet growers from all over the country flew in or drove to Tucuman to attend. This shows the good planning and organization that went into the meeting, and proves the enthusiastic acceptance and desire for I.P.P.S. in South America, particularly in Argentina

For the 20 or so that took the postconference tour, the following 5 days were filled with unbelievable scenery, fantastic accommodations, and botanical/historical/cultural resources beyond description. We traveled through mountain passes into high, desert valleys on the eastern slope of the Andean Range. The landscape looked much like parts of the arid southwest of North America, but our average elevation was 2200 m above the level of the sea. Numerous species of cacti and unusual xeriphytic plants comprised the vegetation in valleys where the sun shines more than 330 days a year. The surrounding mountains are spectacular.

In Tafi del Valle, we caught a glimpse of ranch (estancia) life reminiscent of "old" Argentina and stone artifacts of an even earlier era In Amaicha we saw ruins of the Quilmes people, an ancient civilization which broke away from the domineering Incas, and in Cafayate we experienced wine tasting at a vineyard which has been

operational for a hundred years. As a finale, we drove through a pass (Quebrada de Cafayate) with red rocks and formations which compare to the colors and majesty of attractions such as Bryce Canyon or Zion National Park in southern Utah... a photographer's dream Our tour ended in the lovely town of Salta, known as "The Beautiful" in Argentina. We had a couple days for sight-seeing in and around the town. The colonial style architecture, lovely churches, convents, parks, and flowering street trees provided the perfect spot to appreciate the actual beauty while recalling the incredible time we had spent at the conference and on the road and to genuinely appreciate the people who had made it all possible.

All our Argentine hosts, not only showed us a remarkable part of their country, but also a wonderful, friendly spirit which made it hard to say good-bye. We had spent nearly 2 weeks together and I'm sure we made friendships that will last a lifetime. I could go into detail on each person who made the conference and tour, but this paper would soon grow very lengthy.

I believe that Graciela Barreiro, Daniel Dieguez, and all the members in Argentina deserve special recognition at this time for the fantastic job they are doing to promote I P.P.S. in South America. I.P.P.S is made up of hard-working, dedicated members like them, and each and every member should be proud that our Society is so competently represented on a new continent.