Impact of seed technology on seed germination in horticultural crops©

R.L. Geneve[a]

Department of Horticulture, University of Kentucky, Lexington, Kentucky 40546, USA.

INTRODUCTION

The relatively high initial cost of horticultural seeds has led growers to employ precision seeding and transplant production systems to maximize seedling stands. This places a high reliance on high quality seeds for maximal seedling emergence and uniformity. Specialization has led to increased capital investment in modern greenhouses, automated seeders and sophisticated transplanting robots. This has challenged the seed industry to provide seeds that perform under these demanding production systems.

The two aspects of seed technology that directly impact growers are seed testing and seed coating. The goal of seed testing is to provide useful information on a seed lot's quality. This is accomplished using standard germination and vigor testing. Standard germination evaluates the seed's ability to produce a normal seedling under near-optimal germination conditions. This is important information, but does not always reflect future greenhouse emergence. Seed vigor testing attempts to determine the potential for rapid, uniform emergence under non-uniform (i.e., greenhouse) germination conditions. It becomes apparent that seed lots with comparable standard germination percentages can vary widely in their vigor and that vigor testing can often provide a better predictive measure of seedling emergence.

The major seed coatings for greenhouse crops include seed pelleting and film coating. They are designed to facilitate mechanical sowing and can act as carriers of chemical or biological seed additives. The objective of this manuscript is to provide a brief overview of seed vigor testing methods and seed coating treatments.

SEED VIGOR TESTING

Standard germination is usually required to be reported for each seed lot offered for commercial sale. However, vigor test results are not routinely available to growers and must be requested separately. If they are not available from the seed seller, growers can send samples to a private seed testing lab or perform in-house vigor tests. Vigor tests include accelerated aging, controlled deterioration, cold test, cool test, electrolyte leakage, seedling growth rate, and seedling grow-out tests (Table 1). Details for procedures used to conduct vigor tests are found in the Association of Official Seed Analysts' handbook on seed vigor testing (AOSA, 2002).

Stress-related vigor tests

The most common stress-imposed vigor tests include accelerated aging, saturated salts accelerated aging, and controlled deterioration (Bennett et al., 2004; Geneve, 2005). These vigor tests expose seeds to high temperature (35 to 45°C) under a partially imbibed condition for several days prior to conducting a standard germination test. Accelerated aging suspends seeds above water and has been used most successfully with large-seeded crops. However, accelerated aging conditions can be too extreme for the small-seeded crops common to the greenhouse industry. Two alternative tests for small-seeded crops are saturated salts accelerated aging (Jianhua and McDonald, 1996) and controlled deterioration (Powell and Matthews, 1981). These tests are more useful for small-seeded crops because they limit seed hydration during the imposition of heat stress (Geneve, 2005). Saturated salts accelerated aging suspends seeds over a salt solution rather than water as in standard accelerated aging. Controlled deterioration exposes seeds to high temperature (40 or 45°C)

[a]E-mail: rgeneve@uky.edu

for a short duration (24 or 48 h) after the moisture content has been raised to approximately 20%. These tests have proven useful for flower crops like impatiens (*Impatiens walleriana*) and pansy (*Viola* × *wittrockiana*) (Jianhua and McDonald, 1996; Oakley et al., 2004). These tests require specialized equipment for controlled environmental conditions and may be best conducted by private seed testing labs.

Table 1. Categories of seed vigor arranged according to the germination parameters used to evaluate the seed lot.

Vigor test category	Vigor test	Unit of measure
Biochemical	1. Tetrazolium	Tetrazolium uses topology of red stain in embryo
	2. Electrolyte leakage	Electrolyte leakage uses electrical conductivity (μmhos g^{-1})
	3. ATP	ATP is a measure of energy availability
	4. Ethylene	Ethylene production is associated with germination and correlates to vigor
Germination percentage	1. Abnormal seedlings 2. Cold test 3. Thermal gradient germination 4. Aging tests a. Controlled deterioration b. Accelerated aging c. Saturated salt accelerated aging d. Natural aging	Percentage of normal seedlings under standard germination conditions; some studies only report radicle protrusion percentage; some tests impose a stress (temperature and/or moisture) prior to standard germination; thermal gradient germination uses variable temperature during germination rather than standard germination conditions; natural aging uses K_i from models for seed deterioration in storage
Germination speed	1. Germination speed 2. Seedling emergence	T_{50}; mean time to germination; expressed as unit of time (days or hours) to reach 50% radicle or seedling emergence
Seedling growth	1. Seedling size 2. Seedling growth rate 3. Vigor index	Linear (cm) or area (mm^2) after a specified time or rate calculated over time (cm or mm^2) per unit time (hour) Vigor index uses growth plus a measure of uniformity

Seedling growth vigor tests

Seedling growth tests include measures of time-to-radicle protrusion (germination speed), seedling growth rate after radicle protrusion, and sorting seedlings into strong or weak growing categories (i.e., grow-out tests).

AOSA (2002) considers germination speed (time-to-radicle protrusion) as an indicator of seed vigor. The most common measures are T_{50}, which determines the time to 50% germination in the population of germinating seeds, and mean time to germination (Maguire, 1962). Similar values can be calculated for the time to seedling emergence in greenhouse studies. Germination speed measurements can be tedious to conduct because they require daily (sometimes hourly) evaluation of germination. Several automated systems have been developed and these have been used by commercial seed labs on a limited basis (Fay et al., 1993; Geneve et al., 2006; Sako et al., 2001).

An alternative to repeated measurements over time is to evaluate seedling size after a predetermined time interval under a controlled environment. Seedling size can be measured by hand or using a vision system such as a flatbed scanner (Oakley et al., 2004). The slant-board method employs germination of seeds on an inclined board so that straight seedlings are obtained that are subsequently hand measured by an analyst (Smith et al., 1973). This test has been used commercially for several small-seeded horticultural crops and is a relatively easy in-house test for growers. An alternative to hand measurements is the use of computer-aided analysis for seedling size calculated from digital images captured by a camera or flatbed scanner. Free software is available on-line for measuring digitally captured seedling length or area and is another alternative for an in-house vigor test as long as seedling growth is under controlled environmental conditions.

Seed producers, brokers and greenhouse growers commonly use seedling emergence grow-outs conducted under greenhouse or growth chamber conditions to evaluate seed

vigor. Usable seedlings are evaluated under conditions similar to those used by commercial seedling plug growers. Seedlings are sorted into strong or weak growing categories and additional measures of seedling uniformity can be used to access seed lot vigor.

SEED COATINGS

Presowing seed treatments have become a common practice in the seed industry. Seed treatments are usually applied by seed producers. The objective of a seed coating is to either enhance the potential for germination and seedling emergence or to help mechanical seed sowing. Seed coating uses the same technology and equipment used by the pharmaceutical industry to make medical pills. The major reason to coat seeds is to alter the physical shape and size of the seed as an aid to mechanical sowing. In addition, coatings can act as carriers for various compounds that can enhance germination or seedling establishment, but these are more common for field rather than greenhouse-grown crops. The two most common seed coatings are seed pellets and film coating.

The objective of coating seeds as a pellet is to provide a round, uniform shape and size to small or unevenly shaped seeds in order to aid precision mechanical sowing. Pelletized seeds are tumbled in a pan while binders and inert powders (like clay or diatomaceous earth) form around seeds to provide a uniform, round shape. Traditional pellets can add material to increase seed size by 50 to 100 times. Recently, advanced coating techniques have allowed seed producers to produce thinner pellets (mini-pellets) that increase seed size by only 10 to 25 times.

Film coating uses a thin polymer film to cover the seed (Halmer, 2000). Film coating only adds 1 to 5% to the weight of a seed, but this can still aid in precision sowing by improving flowability and seed pickup during mechanical sowing. Fungicides and beneficial microbes can be added to both pellets and film coatings and is the major benefit to film coating.

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The "wicked" problem that is herbicide resistance of weeds©

C.F. Reinhardt[a]

Department of Plant and Soil Sciences, University of Pretoria, South Africa and Villa Academy, 65 Botes Ave, Glen Marais, South Africa.

INTRODUCTION

Sociologists define a "wicked" problem as one without clear causes or solutions, and thus difficult or impossible to solve. According to Jussaume and Ervin (2016), herbicide resistance meets the requirements of a wicked problem because the causes of resistance are obscured by a complex mix of biological and technological factors, and are fundamentally driven by the whims of human decision-making.

Human influence on not only plants called "weeds", but vegetation of all types, is an important factor contributing to the shaping of plant communities in various environments, both natural and man-made. The tools and technologies that humans employ for the management of growth and development of plants are diverse but usually of either chemical (herbicides, plant growth regulators, etc.) or physical (implements, machinery, structures, etc.) nature.

Even though this discussion focuses on a chemical means of manipulating plant growth and development, namely herbicides, weeds have the ability to adapt to, and survive, other practices employed for their control. Domination of specific weed species in a weed community could develop in response to any control method, irrespective of whether it is of chemical (herbicide), physical, or mechanical nature, in particular when the method is not effective on those species, but successfully controls other species in the same community. Such "species shifts", and domination of one or more species, evolves over time and usually takes a few years to become obvious and economically debilitating.

HERBICIDE RESISTANCE IN CROP PRODUCTION SYSTEMS

From the scientific-technical viewpoint, we know a lot about herbicide resistance, arguably enough to deal successfully with the challenge, and yet, the problem is running away at an alarming rate. The problem is especially rife in the field of agriculture, in particular in crop production, where herbicide resistance is arguably the most critical risk factor, outside of natural factors, facing producers and the herbicide industry. A study conducted in the USA estimated the economic impacts of glyphosate-resistant *Erigeron canadensis* (syn. *Conyza canadensis*) (horseweed), which is closely related to *E. bonariensis* (syn. *C. bonariensis*) (hairy fleabane), that has proven resistance to both glyphosate and paraquat in South Africa (Frisvold and Reeves, 2010). The conclusion of that study is that, across a 20-year horizon period, the estimated annual profit margin benefit attributable to resistance management of horseweed was R2,370 per hectare for maize (calculation based on $158 per hectare, $1 = R15). For soybean the increase in profit margin was R825 per hectare, and R2,055 per hectare in the case of maize-soya bean rotation system.

There is virtually no data available in South Africa on the scale of economic impacts that herbicide resistance has on the crop production and crop protection industries. Considering the direct growth and yield reductions caused by weed interference in all types of crop production, together with additional costs of managing herbicide-resistant weeds, the Rand-value of losses probably runs into many hundreds of millions on an annual basis.

Currently, based on information compiled by Dr. Ian Heap (http://www.weedscience.org/), 470 unique cases of herbicide resistant weeds have been reported globally, involving 250 plant species (145 dicots and 105 monocots). A most disturbing factor is that weeds have evolved resistance to 23 of the 26 known herbicide sites of action

[a]E-mail: creinhardt@villaacademy.co.za

and to 160 different herbicides. Herbicide resistant weeds have been reported in 86 crops in 66 countries.

In South Africa, there are nine weed species for which confirmed resistance to one or the other herbicide was recorded over the years, and alarmingly, some of these weeds have developed multiple-resistance, i.e. resistance to more than one herbicide mechanism-of-action (Pieterse, 2010). Nine species locally, when seen in the global context of 250 species, may not seem like much to worry about, but considering these weed types represent some of South Africa's worst weeds that occur in major crops, the magnitude of the problem hits home.

Consider the case of glyphosate-resistant weeds, where globally 34 species have been recorded to date. Of the 34, three also occur in South Africa, namely: hairy fleabane (*Conyza bonariensis*), narrow-leaved ribwort (*Plantago lanceolata*), and the complex of ryegrasses (*Lolium multiflorum, L. perenne, L. multiflorum* × *L. perenne*, *L. rigidum*). Three out of 34 may not appear significant, but mere numbers discount the prominent weed status of the afore-mentioned three species. Moreover, 16 other weeds among the 34 for which glyphosate resistance have been proven in some or other part of the world are well-established weeds in South Africa. In light of the doomsday scenario of 19 out of 34 species evolving glyphosate resistance in a single country, lax approaches to herbicide resistance management is simply unaffordable.

Equally perplexing is that, the world over, there exists little understanding of the "wicked" problem of herbicide resistance. Moreover, there generally is poor implementation of resistance management strategies. A survey conducted in the USA among more than 1,000 maize, cotton, and soya bean growers showed that only 39% "always or often" used herbicides with more than one mechanism-of-action, whilst 28% employed this best practice "seldom or never". Even in a country like Australia where there is tremendous hype plus action on best practices for resistance management, there is disappointingly low uptake of, and low consistency in adherence to, these practices. Similar information for South Africa either does not exist or is not available in the public domain.

Confounding factors in explaining low adoption of resistance management practices are generally accepted to be two-fold, firstly, because gains from managing resistance only accrue in the future there is uncertainty attached to it, and secondly, there are real short-term costs associated with resistance management which represent unwanted increases in already high input costs. Therefore, the conundrum is that it is expected of crop producers to spend money, time and effort on a problem that may not yet exist, or are still evolving and therefore uncertain. Ask anybody doing research or providing advice on herbicide resistance, it is a tough sell to generate hype around a problem that may or may not develop at an unfixed time in the future. However, reality check tells us that herbicide resistance is real, with us already, and day by day creeping steadily ahead.

Strategies and tactics with which to successfully manage resistance are well-documented and well-proven; therefore, why the despondency in certain quarters over an apparently lost battle? Shaw (2016) believes that "doing something different" is key to successful resistance management. There is powerful truth locked up in the simple understanding voiced by Amy Asmus, who isn't a scientist but works in agriculture, at the 20th Annual Conference of the International Consortium on Applied Bioeconomy Research (July 2016, Italy): "My advice for successful resistance management is to regard any herbicide-resistant weed as a brand-new weed". This approach would at least force a rethink on weed management options for combating the resistance problem, and would be tantamount to "out of the box" thinking, which we desperately need for tackling herbicide resistance head-on (Asmus and Schroeder, 2016).

According to Shaw (2016), the rethinking of herbicide resistance management strategies should include greater emphasis on IWM (integrated weed management that incorporates mechanical, biological, and chemical tools), as well as a multi-disciplinary approach that brings together in team context agronomists, weed scientists, economists, sociologists, extension advisors, consultants, and farmers. Surely, this is the new way to go!

RESISTANCE RISK IN NURSERIES

Many herbicides registered for use in nursery environments are associated with weed resistance because the same herbicides often find use in agricultural crop production. Moreover, many weed species are ubiquitous and occur across a wide spectrum of plant production systems. Exactly the same principles and practices for avoidance of herbicide-resistant weeds apply to nurseries and any other plant/crop production system. Combinations of weed/herbicide for which resistance have been recorded globally are posted on the website managed by Dr. Ian Heap, http://www.weedscience.org/

Overuse of any single herbicide product, and therefore, failure to rotate herbicide modes-of-action, is likely to promote the evolvement of resistance in one of more weed species occurring in the area targeted for weed control. In addition to rotating different types of herbicides, avoidance of dependence on any single method of control, whether it be hand-weeding or mowing, is key for ensuring that one or more weed species do not become dominant, especially if such a species has some or other harmful characteristic.

Plants of economic value produced in containers, especially those distributed widely, can be a means for bringing new weeds into an area where they did not occur before. Even more serious a problem would be the inadvertent distribution of weeds that have evolved resistance to an herbicide in the nursery. Nurseries therefore have the heavy responsibility to employ best management practices as far as weed management is concerned.

In most areas in life, including herbicide resistance management, we should take heed of these eternally wise words:

> "Insanity: Doing the same thing over and over again and expecting different results"—credited to Albert Einstein

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Growing the urban forest movement: opportunities and challenges©

G. Priest[a]

PO Box 489, South Perth, Western Australia 69510, Australia.

INTRODUCTION

The concept of the "urban forest" is increasingly becoming a topic of interest around Australia and internationally. The urban forest consists of the living environment and green spaces within urban areas, including both public and private gardens, parks and even individual trees. Research is increasingly showing the critical role the urban forest plays in supporting the health and wellbeing of our cities and their communities. Some commonly recognised areas which are supported by quality urban forest include the following (Table 1):

Table 1. Some commonly recognised areas which are supported by quality urban forests.

Social	Economic	Environmental
General wellbeing and quality of life	Real estate value	Urban cooling and heat island effect
Social cohesion	Sports field value	CO_2 emissions
Mental health	Industry turnover and employment	Carbon sequestration
Provides recreation	Economic activity in the tourism sector	Biodiversity
Reduces obesity	Energy minimisation for cooling in summer	Air quality
Reduces rime		Soil stabilisation
Juvenile delinquency		

This recognition is leading to a range of actions around Australia, with the creation of a number of initiatives and research projects which are seeking to advocate for urban forest protection and enhancement. There are numerous areas in which propagators and IPPS Australia (as their representative body) can get involved to create better, healthier landscapes and improve opportunities for the propagation industry.

DISCUSSION

In Western Australia, a group of peak horticulture industry bodies and aligned organisations from the landscape industry came together to form the Green Space Alliance (GSA). With the support of a number of WA Government agencies, the GSA is WA's lead representative body seeking to improve Perth and regional town's urban forests.

The GSA established a vision: To live in a community that values green spaces at its core, which deliver benefits to everyone through improved health, wellbeing and live ability by using innovative water and urban planning solutions.

The GSA worked with Josh Byrne & Associates (JBA) to run a number of consultation events with a wide range of network members, at which the GSA membership developed a set of principles which articulated their desire to see growth in green space. This resulted in the development of a Position Statement, as well as a Discussion Paper (Figure 1) which explores pressures on green space and opportunities to address these concerns.

[a]E-mail: greg.priest@dbca.wa.gov.au

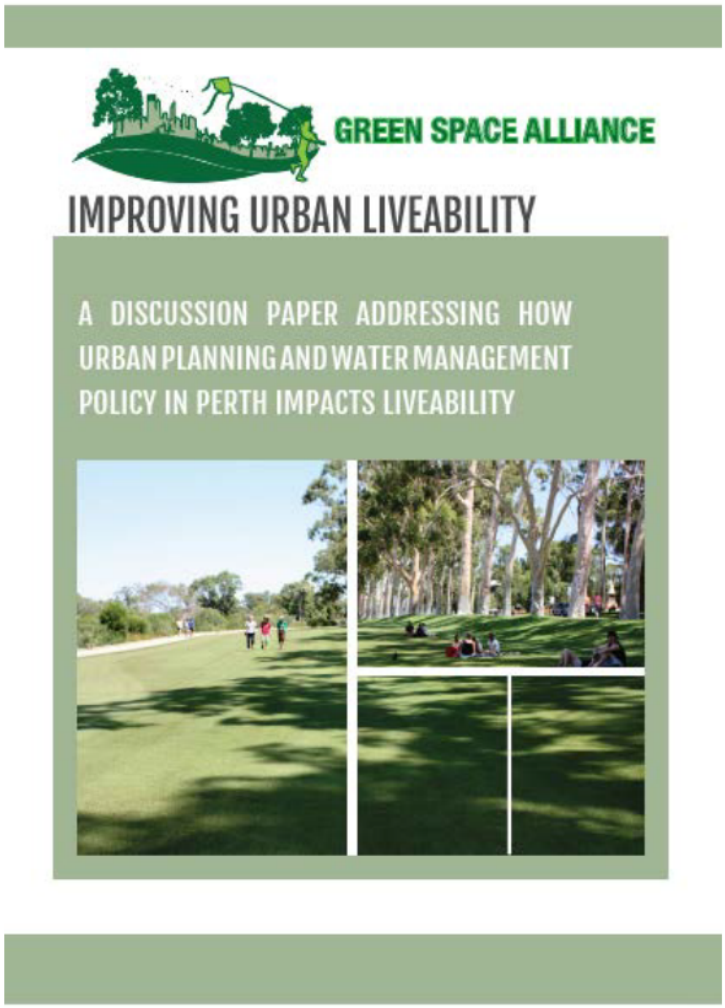

Figure 1. Discussion paper.

As an advocacy organisation, the GSA has met with Government Ministers senior bureaucrats to communicate to the need to develop progressive policies which address green space challenges and promote an environment of innovation which supports the development of green space for Perth.

The GSA model has been explored by other states and similar bodies which are starting to form in other States. No doubt these organisations would welcome the contribution of the IPPS and its members. The GSA also works with a national level initiative, the 202020 Vision.

The 202020 Vision, an initiative of Horticulture Innovation Australia, is a national program seeking to increase Australia's urban green space by 20 per cent by 2020 and is funded through levy by the sale of plants and trees. The 202020 Vision has hundreds of supporting organisations, ranging across private horticulture and landscape firms, to developers and engineering contractors through to government agencies.

The 202020 Vision is a successful blend of a community communications campaign, technical research, and resource development for organisations involved in urban forest creation. Research conducted by Josh Byrne & Associates for Horticulture Innovation Australia to support the 202020 Vision investigated the policy opportunities and challenges surrounding urban greening. The research recognised early on that this is a complex space and that there are a great range of stakeholders involved in the creation of green space (Figure 2).

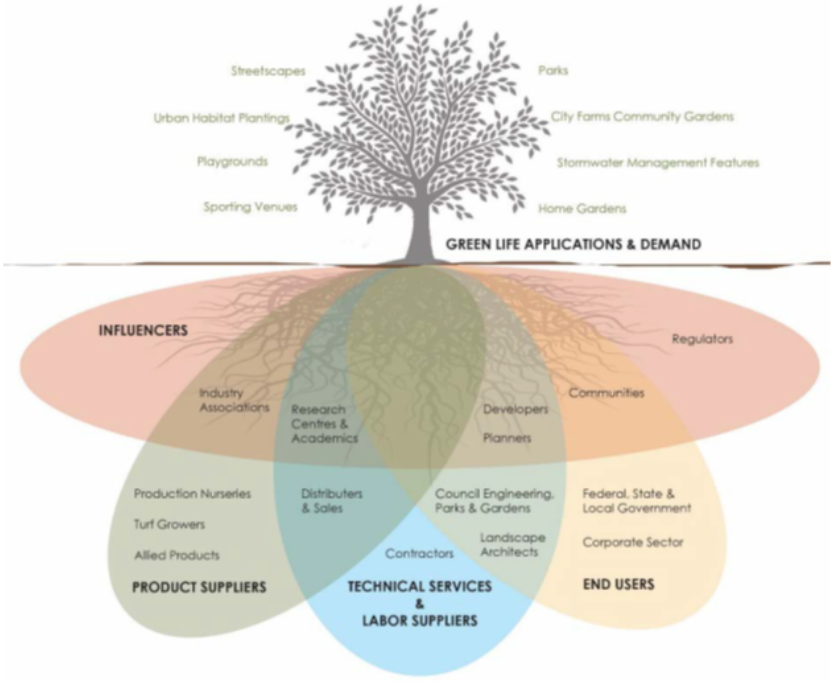

Figure 2. Stakeholders involved in the creation of green space.

The research took an inter-governmental perspective and found a lack of federal policy stifles progress being made in at state, territory, and local levels. Whilst state governments are seeking to support urban forest creation.

Local governments are the most active, but are not always well resourced and do not have the policy strength to deliver the desired outcomes. The research also revealed local government is the key provider of green space and it is this level of government that is well positioned to create change.

CONCLUSION

Creating significant policy change in Australia often requires industry to speak out. In the urban forest sphere, this is taking place around Australia via the 202020 Vision and in Western Australia through the GSA. IPPS-Australia and its members can leverage these activities all along the supply chain (and plant lifecycle) from plant propagation through to caring for mature plants in a public park or streetscape.

State, territory, and local government need to improve their understanding, planning, and management of current and future urban green spaces. Propagators can contribute to this process by sharing their knowledge with government, and groups like the GSA and 202020 Vision can provide this avenue. In short—get involved!

Selecting compact cultivars for horticulture from wild plant populations©

A. Stewart[a]

New World Plants P/L, Terrigal, NSW 2260, Australia.

INTRODUCTION

The demand for compact ornamental plant cultivars in world horticulture is being simultaneously driven by both consumers and plant producers. Increasing urbanization around the world is creating ever higher population densities in cities with the result that gardens are getting smaller and smaller and in many cases are confined to balconies, courtyards and rooftops. This is driving a demand for compact plants, preferably ones that can complete their entire life cycle in a container if there is no in ground garden area.

The demand for compact plants is also being driven by wholesale growers who will maximize profits by growing cultivars that require the most minimal of inputs. Compact cultivars that do not require pinching or pruning and can grow to a saleable size within a matter of weeks with minimal input of water and fertilizer represent the ideal nursery plant. Mechanization of production to lower costs also demands compact, preferably vegetatively propagated plants that provide the uniformity that will optimize the success of mechanical production. A height under 40 cm will also minimize freight costs to enable the maximum number of plants in a given volume of freight space.

STRATEGIES TO PRODUCE COMPACT PLANT CULTIVARS

There are several plant breeding strategies that can be used to increase the success rate when trying to produce suitable compact plant cultivars.

Traditional plant breeding

Australia is blessed with some excellent ornamental plant breeders such as Graham Brown of Nuflora in Sydney, and Digby Growns of Kings Park and Botanic Gardens in Perth. Both of these breeders have achieved global commercial success breeding compact plants for worldwide distribution. In the case of Digby Growns his breeding is based on selecting parents from the spectacular Western Australian flora and crossing them together to try and create compact plants that will service the modern market both in Australia and overseas. Graham Brown and his team at Nuflora have achieved great success with plants from outside the Australian flora such as *Argyranthemum* (Marguerite daisy) using conventional breeding techniques. Breeding work by me and other Australian entities with kangaroo paws (*Anigozanthos*) has involved collecting a range of species and forms within species and crossing them together to produce cultivars with a range of heights, colours, and flowering times that have resulted in a worldwide demand for this crop.

Selection of chance mutations

The Australian nursery industry has produced some outstanding cultivars through selection of novel genetic mutations from populations of commercial batches of plants during production cycles. Seedlings are an obvious source of genetic variation from which to select with the dwarf bottlebrush cultivar *Callistemon salignus* 'Great Balls of Fire' being an excellent example. Mutations can also occur at regular frequency in vegetatively produced crops with the almost white kangaroo paw *Anigozanthos* 'Bush Diamond' coming from a mutation of the pink cultivar 'Bush Pearl'. This represented a new colour in *Anigozanthos* at the time it was released.

[a]E-mail: angus@gardeningwithangus.com.au

Selection of dwarf forms from coastal plant populations

The author has been involved in a breeding and selection program at The Australian Botanic Garden, Mt. Annan to utilize germplasm collected from a coastal site at Catherine Hill Bay, a small town between Sydney and Newcastle that is nestled between nature reserves on either side that features incredibly diverse and spectacular botanical biodiversity in heathland plant communities. In particular, a wide range of species have formed genetic ecotypes depending on their proximity to the coast. Populations within a species form compact, often ground covering forms on coastal headlands as compared to more upright forms further back from the coast. Examples of species that display this characteristic include *Actinotus helianthi*, *Banksia spinulosa*, *C. linearis*, *Goodenia ovata*, *Hakea sericea*, *Isopogon anemonifolius*, *Lambertia Formosa*, and *Viminaria juncea*. Cutting propagation of these compact ecotypes results in genetically stable specimens that are potential candidates as commercial ornamental plant cultivars.

A further objective of the study was to establish whether the low growing form of such ecotypes could be reproduced by seed. Thus, seed was collected from plant populations of several species displaying the low growing phenotype, namely *Acacia myrtifolia*, *C. linearis,* and *Melaleuca nodosa*. Populations of approximately 50 plants of each species were germinated using standard techniques and grown under uniform shadehouse conditions in pots. The result was that uniform populations of seedlings displaying the compact growth habit were produced without exception.

This trial demonstrates the potential of creating genetically stable seed lines of compact coastal ecotypes of a wide range of species of Australian plants.

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PlantSelect website: connecting designers and growers©

G. Mostafa[a]

Greener Publishing & Media Pty Ltd, PO Box 3153 Eltham, Victoria 3095, Australia.

Abstract

Provide designers with a complete plant list they can select from, to forward order and secure plants at the design stage ready for planting when required as opposed to sourcing plants towards the end of the construction stage.

SITUATION

Landscape and garden designers, councils, and interior plantscapers struggle to find the right plants and greenlife to suit their designs and projects without wasting time and money looking for plants and suppliers. They want to obtain plants that would suit the design rather than resorting to plants that are available at the time of planting out and stop spending hours or even days, depending on the size of the project, ringing and running around to find plants specified for the design. If the desired plants are unavailable at that time, the design has to be re-addressed by the designer at their own expense.

They visit a large number of nursery websites searching for suitable plants, which may or may not be available. Or they deal with one or two nurseries for all their plant and greenlife needs limiting their choices.

Most nurseries email or fax plant lists on a fortnightly or monthly basis informing designers of available stock or the plants they are currently growing. The designers do not have the time to sift through each plant list to source plants. Most plant lists include the available pot size and cost per unit, they do not include relevant information designers require, such as height and width at maturity or shape.

There are a few websites that have grower plant lists, but stop short of connecting the designers with growers or nurseries.

Most nurseries are only growing stock they can sell quickly, rather than having excess stock waiting to be sold.

OBJECTIVES

- To help designers source plants and greenlife.
- Notify growers that grow the required plants listed for a project.
- Growers and suppliers to submit quotes to the designers.
- Expand the limited range of plants currently used in the landscape.
- Notify the designers of new plant releases.
- To get growers and suppliers to upload their complete growing list.

SOLUTION

- Develop a complete national plant database of all plants grown in Australia by their botanical and common names.
- Categorise them into plant groups i.e. tree, shrubs, ground cover, turf, grasses, etc. simplifying the selection of plants.
- Include the attributes and characteristics of each plant in plant groups. Characteristics such as - deciduous or evergreen, height and spread at maturity, sun hardiness, foliage or trunk colours, flower colours, flowering time, etc.
- The designer has the option to select plants by name, or plant group or attributes and characteristics including pot and or bag size.

[a]E-mail: gabe.mostafa@greenerpublishing.com.au

- Introduce new plant releases which are released from time to time by the nurseries.
- Notify the designers of the new plant releases by email and text message with a link to the PlantSelect website to view.
- A comments panel for the designer to include any special requirements or specifications they may have for the grower or nursery to include in the quote for the project.
- The designers can select and save their selected plants into a plant list from the national plant database. Once completed, the plant list is matched against all the uploaded growing lists and only nurseries that grow or have the required plants will be notified.
- An email and text message with a link to the PlantSelect website is sent to those nurseries informing them of the pending job. They can then login and download the list together with any specifications, including the designers contact details, to submit the required quote. If some of the plant specifications are not available, then the closest available will be suggested.
- Once the designer selects a nursery, they deal directly with that nursery to place an order and mark that job closed. They also have an option to save the closed list for future reference or if they wish they can delete it.
- All related emails and text messages will have a link to PlantSelect where they can download the plant list.
- Nurseries can upload their complete plant or growing lists to the PlantSelect website, where it is automatically matched against the master plant database and any plant that doesn't match, will be highlighted for manual checking and added with its attributes and characteristics.
- A minimum number of related allied industry advertisements would be included to keep subscription costs down for designers and growers.

An integrated methodology for propagation from seed of Perth, Western Australian provenance, native plants©

M. Patel[a]

Natural Area, 99c Lord Street, Whiteman WA, 6068, Australia.

Abstract

This paper outlines the methods that I have developed in conjunction with my colleagues, to provide continual improvement to outcomes from our seed propagation work. Some 80% of our propagation is from seed, with the majority sourced from our own in house collections. The underlying issue for successful propagation, is the connection between all the aspects of this work; the seed sourcing, the seed quality assessment, the timings and treatments of seed, the trialling of new methods to achieve germination and the detailed recording of the seasonal results to inform future work.

SEED SOURCING

The level of communication and accuracy of information exchange with the seed collection team is paramount. The precise location and date of collection are of utmost importance as a guide for future collections based upon the germination outcomes. Increasing our seed collection sites, and arranging our seed collection team to make timely and site specific collections, is what I need and ask for.

So much of my work suggests to me that native seed has enormous variability. For example, we recently sourced seed of the same species from five different sites and, despite utilising the same treatment at the same time, only one of the seed batches proved viable.

Another example involves *Gahnia trifida*, a common and often sought after native dampland sedge that propagators often have difficulty in growing. Such was the case for me for some years, until such time as we found stands of the plant that provided highly viable seed. In early times, we had collected seed from isolated and small clumps of plants without success. Upon collecting from large/monoculture size stands we found highly viable seed.

The type of reliability seen in the vegetable/horticultural seed is alien to our Australian native seed. There are likely many factors at work in determining germinability but I am convinced that outside of our scientific understanding of dormancy, nature plays a major role in determining what viable seed is and what is not. Additionally, the quality and integrity of the seed collection is fundamental.

There is an entrenched practice amongst many commercial seed collectors where collections are focussed on seed volumes, and are not necessarily driven by quality of the seed and viability outcomes. Our experience with seed sourced from outside is highly variable and often produces poor outcomes.

The majority of seed we use in our propagation is collected in house and we deliberately collect from a wide range of sites within our market area. The high number of collection sites provides an illuminating insight into what sites produce the best seed.

This part of my work involves very close liaison with our collectors and detailed records of where and when collections are made. Whilst seasonal variances occur, we have developed an excellent data base of the best seed sites for the particular species we seek. We have also developed a comprehensive seed collection manual to guide newly licensed staff to ensure seed is collected at the right times.

[a]E-mail: patelminkal@yahoo.co.in

SEED QUALITY ASSESSMENT

A very close assessment of seed is made before decisions are taken regarding treatments and sowing. Unformed (no embryo), badly shaped or discoloured from normal seed are either discarded or treated and bulk sown to achieve whatever. Cut tests and microscopic examination assist us but the best guide is our experience built over the years as to what good seed will look like and where it came from.

When we have ascertained that good seed is present, a decision is made as to utilisation in direct seeding via our auto air-seeding system or manual sowing. Our systems record the numbers of seed to be sown per cell unit on auto seeder or the seed weight per seed tray. Having years of data provides a working range within which we can normally avoid significant under/over sowing.

PREGERMINATION SEED TREATMENTS.

Previous propagators and myself, have developed comprehensive data bases to aid our work. These record date of seed collections, provenance detail down to site level, timings of treatments, type of treatments and outcomes.

Additionally, the timings of sowing for particular species is all important, and we have been surprised by the variance in seasonal temperature preferences that exist for many of our plants. We have no doubt that some propagators do not achieve success on some species as they have chosen the wrong time of the year, have the wrong treatment, and assume the seed is not viable.

Some examples of methods we employ on seeds are:

- Using enzymes to remove fleshy fruits
- Treating damp prone species seed with fungicide pre sowing
- Using a wetting agent when imbibing seed
- Using granulated fungicide when potting damp prone species
- Weathering
- Manual scarification (limited numbers)
- Hot and/or cold water treatment, can be repetitive
- Concentrated acid exposure (H_2SO_4)
- Extended conventional sowing (long term trays)
- Temperature stratification, hot and/or cold
- Extended imbibition, rainwater with wetter (allow seed to swell)
- Smoked water soak
- Physical smoke (often for extended periods)
- Heat (up to 100°C)
- Exposure to light (surface sow)
- Light deprivation
- Extended burial
- Inoculants and fungi added to selected species
- Exposure to plant hormones, e.g. gibberellic, jasmonic, and abscisic acids
- Exposure to potassium nitrate

Importantly, we have found that a combination of the above treatments has achieved or improved results. An example of nature's strange ways with seed germination was the research undertaken recently on *Persoonia longifolia,* that showed summer rain events were necessary to trigger germination in the following cooler months.

NOTABLE SUCCESSES

The integrated nature of my work as outlined has given rise to some outstanding results on what would normally be difficult and recalcitrant species. These include;

- *Adenanthos* sp.
- *Baumea* sp.
- *Dasypogon*
- *Hibbertia* sp.
- *Lepidosperma* sp.

- *Lomandra* sp.
- *Spinifex* sp.
- *Triodia* sp.

Success achieved with our seed work has also allowed us to source material with genetic traits that have given rise to selection of stock plants and provided items to take into tissue culture.

NEW CHALLENGES

There are still many plants in our market that we are not able to grow from seed as the secrets to unlocking dormancy have not been found. We continue to work on these and utilise available research material and references to guide us. Often previous success within the genus gives you a guide to a start point.

CONCLUSION

My work in propagation from seed is most stimulating and I am fortunate to have the opportunity of working in this field. I have taken a long term view on my work and over time, my knowledge has increased to the benefit of the Natural Area nursery business. It is also to be hoped that this paper will encourage others to work on their propagation from seed, and thereby widen the range of plants available to landscapers and those undertaking ecological restoration.

Biosecurity matters—challenges to New Zealand's biosecurity system©

K. Hurr[a]

Ministry for Primary Industries, PO Box 2526, Wellington 6145, New Zealand.

INTRODUCTION

New Zealand faces continuous risk from the introduction of new plant pests and diseases. Growth and diversity in trade and tourism, changing risk pathways, climate changes, and pressure from established pests require new strategies and measures to combat these challenges. The number of mail parcels has increased by 216%, sea containers by 37% and passengers by 47% since 2003. New Zealand is now home to 213 ethnicities and 160 languages (2013 census). A new plant species establishes wild in New Zealand every 39 days and climate change alters the risk of both new pests and diseases coming to New Zealand from our trading partners, as well as their ability to establish in New Zealand.

The Ministry of Primary Industries (MPI) has created "Biosecurity 2025", outlining 5 strategic directions which aim to address some of these challenges head on. The central strategy is a "biosecurity team of 4.7 million", seeking to enlist the help of all New Zealanders to play their part in keeping risk offshore and/or reporting and managing risk onshore. An informed and responsive public means that the biosecurity system is able to respond much more quickly to mitigate and manage biosecurity risk. We're all in this together.

The popular television show 'Border Patrol' gives some glimpse into the day-to-day working life of biosecurity and customs officers. However biosecurity risk is not managed only at the New Zealand border (the 'thin blue line') yet is done throughout a whole system starting offshore, through the development and implementation of international standards and rules, trade and bilateral agreements, and domestic import health standards which specify the requirements which must be met for the importation and clearance of commercial risk goods.

The Intelligence, Planning & Coordination function of the Ministry provides data and intelligence to assist with preparedness and planning, import management, so that efforts can be focused where they will achieve the greatest results.

The Risk Analysis teams consider the environmental, social, human health and economic risks from the potential introduction of new pests and diseases to the country, informing the Risk Management teams in MPI to set the measures for imports in an import health standard. The Risk teams also manage the emerging risk system which creates a network with the international community and the New Zealand public, professional groups and scientists alerting MPI about the spread of a new pest or disease overseas, a new host, or new trends in trade and travel which could negatively impact New Zealand primary industries. The import health standard teams set the "rules" for importation of goods to manage risk, and the role of the biosecurity inspectors at the border is to verify these measures have been met and decide whether the goods can receive biosecurity clearance.

Finally, the system also includes post-border management. MPI's pest and disease hotline [0800.80.99.66] is managed 24/7, providing advice to the public on what to do if they suspect a new pest or disease. MPI's Investigation team will follow up on any calls made to the 0800 number and in the event that a suspected pest or disease is confirmed, the team will determine whether the investigation proceeds to response.

CHALLENGES TO NEW ZEALAND'S BIOSECURITY SYSTEM

Myrtle rust—blowing on the wind

When the 2017 IPPS New Zealand Region conference committee and I first discussed

[a]E-mail: Kathryn.Hurr@mpi.govt.nz

possible topics for a biosecurity presentation for the 2017 conference, myrtle rust had not appeared on the mainland but was recently noted from Raoul Island in the Kermadec Islands. At the time I thought I would be speaking about the measures already in place to manage the risk from imports of nursery stock and cut flowers, however the detection of myrtle rust in a plant nursery and adjoining property in Kerikeri and then several sites in New Plymouth meant that MPI was in full response by the time the IPPS conference was upon us in May. Unfortunately this resulted in the cancellation of several field trips to nurseries planned as part of the conference.

As we well know, myrtle rust (*Austropuccinia psidii*) attacks the foliage, fruits, and flowers of myrtaceous species and there are over 445 known hosts. The disease is also known as guava rust, eucalyptus rust, and ohia rust, according to the main hosts in overseas countries. The disease was known from Hawai'i since 2005, infecting *Metrosideros* (Ohia). It is not known how it arrived in Australia, but appeared there in 2010, and subsequently spread to New Caledonia in 2013, Lord Howe in 2016, and showed up on *Metrosideros* in Raoul Island and New Zealand in 2017.

Interestingly during subsequent discussion at the conference on myrtle rust, Ian Duncalf talked about his experiences in response to the outbreak of poplar rust in New Zealand in the 1970s. Two strains of poplar rust showed up in New Zealand approximately 1 year after the outbreak in Australia, presumably from wind-blown spores. The first places they showed up were in Northland and Taranaki and the same pattern appears for the arrival of myrtle rust in New Zealand.

Early intervention gives the greatest chance for eradication. MPI thanks the nursery operators who notified the 0800 number about suspicious symptoms.

The rust fungus attacks young, actively growing leaves and shoots. Early detections in New Zealand have been in plant nurseries because the growing conditions are ideal and there are many vulnerable young plants in sheltered, warm and damp environments. Nursery industry and growers are also vigilant in checking their plants. Often the first sign of infection is chlorotic flecks on leaves and shoots, followed by the production of masses of bright yellow urediniospores. Lesions often turn red-purple then grey with age, and often have a purple or dark brown margin.

Under the Biosecurity Act, New Zealanders have a legal obligation to inform MPI of suspected new diseases. However, while in many plants the symptoms of yellow rust pustules are highly obvious, the disease can also present cryptic symptoms in some species.

A survey of New Zealand plants in Australia as "plant sentinels" has found that *Metrosideros* species are highly susceptible but manuka (*Leptospermum scoparium*) does not appear to be extremely affected.

Brown marmorated stink bug—hitchhiker pest extraordinaire

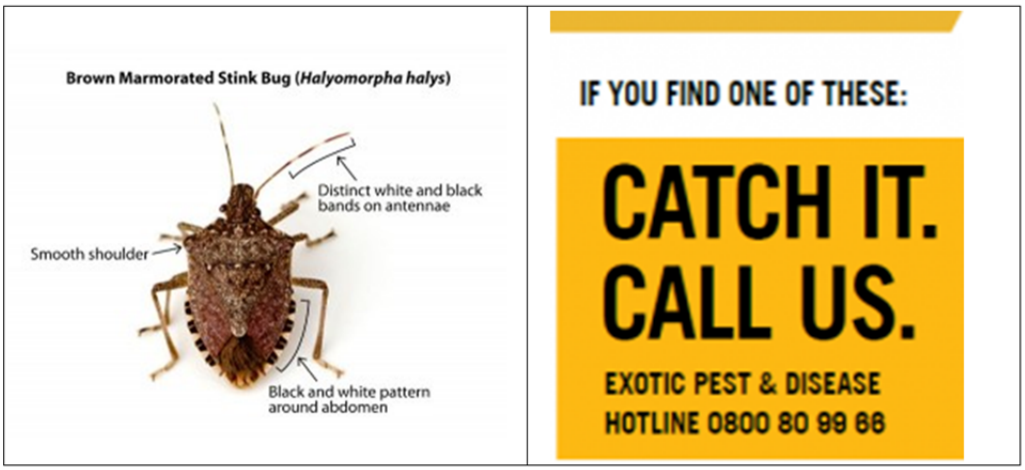
A bug which is keeping MPI extremely busy the past few years is the brown marmorated stink bug (*Halyomorpha halys*), or BMSB (Figures 1A, B). There are several look a-likes, but the way to tell these guys apart from the rest is the distinctive white and black bands on their antennae and black and white banding patterns around their abdomen. They are unlikely to turn up in your nurseries first but they quickly breed to high numbers and represent a substantial threat to our horticultural industries.

- Eggs laid on the undersides of leaves in host vegetation that surround crop plants.
- Adults fly into crops to feed, only nymphs reside in crops.
- Exhibit a preference for hosts with ripe fruit.
- When days shorten BMSB aggregate on the sides of buildings then move inside to overwinter. In a natural environment they overwinter under the bark of trees and yes, they apparently do stink.

***Xylella fastidiosa*—bacterial leaf scorch**

A bacterium which is being described as the world's most significant plant threat is high on MPI's radar at the moment. *Xylella fastidiosa* has been present in Central and South America since the 1880s, spreading into North America by the 1990s. Its recent spread in

Europe is cause for concern. The disease is known by many common names—Pierce's disease of grapevine (in California), almond leaf scorch, citrus variegated chlorosis (Brazil), phone peach disease, oleander leaf scorch, and recently as the causative agent of olive quick decline syndrome in Italy.



Figures 1. A. The brown marmorated stink bug (*Halyomorpha halys*). B. Promotion of the exotic pest and disease hotline for reports of the brown marmorated stink bug.

The bacterium grows in the xylem moving both upstream and downstream. It restricts or blocks the movement of water and nutrients through the plant. Deprived of sap, the plant dries out leading to wilt or leaf scorch symptoms. The bacterium is spread from plant to plant by xylem sucking insects, including leafhoppers, sharpshooters, spittlebugs and cicadas. The glassy-winged sharpshooter (*Homalodisca vitripennis*) is important in vineyards in California, while in Italy the spittlebug *Philaneus spumarius* is important. This spittlebug is also present in New Zealand, so should the bacterium be introduced to New Zealand, it is possible this vector could spread it far and wide.

In 2013 the bacterium was found in olive trees in the region of Apulia in southern Italy. The disease caused rapid decline in olive plantations and by April 2015, more than a million olive trees were infected, many of them century-old (Figure 2). The invasive disease is believed to have been introduced by ornamental plants imported from South America. In 2015, it reached Corsica and mainland France, and was detected in 2016 in Germany in oleander. In 2017, MPI received reports it is also in Spain, Majorca and Ibiza.

Five subspecies have been discovered so far.

- *fastidiosa*, affecting vines and coffee trees;
- *multiplex*, affecting almond, olive and oak trees;
- *sandyi*, affecting oleanders and coffee;
- *pauca*, affecting orange and coffee plantations in the Americas and more recently, olive trees pathogen, in southern Italy;
- The new subspecies *taiwanensis* sp. nov. affecting pear trees has also been proposed.

A host list is maintained by the Secretariat of the European and Mediterranean Plant Protection Organization (EPPO) (https://gd.eppo.int/taxon/XYLEFA/hosts). Across Europe, 359 plant species have now been identified as hosts of *Xylella.* Many of these species show no symptoms of the disease, and provide a reservoir for reinfection of other plants, making *Xylella* difficult to control. The trade in asymptomatic material is challenging international trade based on phytosanitary health certificates.

Figure 2. Mature olive trees in Pulia, Italy affected by olive rapid decline syndrome. Photo Robert Taylor, 2017.

Phytophthora

Another challenge to New Zealand biosecurity is the genus *Phytophthora*. These are not true fungi but "water moulds" and are very difficult to control in the environment once they have established. One of the most prominent species in New Zealand is *P. agathidicidae* the casual agent of kauri dieback in Northland. Several other species are causing economic and environmental impacts in New Zealand, including *P. cinnamomi*, affecting the production and viability of avocado trees and *P. pluvialis* (red needle cast) which showed up in *Pinus radiata* trees in 2015.

Phytophthoras are highly adapted plant pathogens with diverse spore forms. They can spread in the environment through soil, air, and rain splash and may be water and soil borne. They are very difficult to control once established in the environment.

MPI regulates the high impact *P. ramorum* (sudden oak death) and is currently reviewing the requirements for nursery stock, aiming to preventing the introduction of new species into New Zealand.

What you can do

- Be vigilant!
- Clean footwear after visiting overseas forests, woodlands. Wash clothes and personal belongings.
- Importing goods through mail and courier pathways? Check import requirements against MPI's Plant Biosecurity Index and IHSs.
- Contact MPI's Exotic Pest and Disease Hotline 0800 80 99 66 if you suspect a new pest/disease.
- Report information about new pests or disease threats to MPI's emerging risk system emergingrisks@mpi.govt.nz

Plant breeding at Auckland Botanic Gardens©

J. Hobbs[a] and E. Bodley

Auckland Botanic Gardens, 102 Hill Road, Manurewa 2105, Auckland, New Zealand.

INTRODUCTION

Auckland Botanic Gardens (ABG) has a long history of plant breeding. It is best known for developing the 'Wiri' series of *Hebe* and *Leptospermum*, and has worked collaboratively with Dr. Keith Hammett on crops including *Dahlia*.

The stated objective of ABG is to 'Engage people with plants and gardens.' To this end it actively promotes sustainable gardening practices including recommending plants suitable for Auckland conditions, and we practice and advocate a minimal spray regime.

ABG promotes plants that perform to a high standard in Auckland conditions without applications of insecticides and fungicides. Trials are undertaken to ascertain the best performing plants according to criteria that includes flowering periods, foliage and habit, and general plant health. The very best of the are labelled "Star Performers", and these are featured in display gardens and promoted to the public on the ABG website, social media, printed material and on plant labels.

Many popular groups of garden plants include numerous cultivars that were not primarily bred for garden performance. Some such as dahlias, camellias, daffodils, chrysanthemums, and many others were bred to produce exhibition quality flowers for the show bench. Numerous ornamental commercial crops have been bred to produce flowers on young compact plants that have high aesthetic appeal at point of sale. This is an understandable commercial imperative, but it does not necessarily result in plants that perform well in gardens. In fact it often diminishes garden performance as evidence by popular crops such as many compact perennials and precocious annuals that are flowering when purchased but not for much longer.

The reason ABG breeds plants is to fill some of the gaps that commercial and amateur plant breeders do not cover. The primary ABG priority is always to produce attractive ornamental plants of outstanding garden performance with particular focus on high health.

BREEDING PROGRAMMES

Hemerocallis

1. Objective.

The ABG daylily breeding programme aims to develop rust resistant, evergreen daylilies with long flowering periods in a range of flower colours and with attractive foliage. They must require little maintenance and make effective ground covers.

2. Background.

This breeding programme is a direct result of the devastating impact daylily rust (*Puccinia hemerocallidis*) had on many popular cultivars when it arrived in New Zealand. This included decimating many of the best performing cultivars identified over more than 20 years of trials at ABG.

Although many cherished daylilies became unsightly overnight, a few showed little or no effect from the new incursion. ABG has continued to trial daylilies with emphasis on plant health, and in 2015 published an updated list of recommended cultivars.

The breeding programme was initiated in 2014 and has been led by Jack Hobbs and Emma Bodley, with support from Nikita Engels (2015), Keely Paler (2016), Mere Brewer (Senior Gardener Plant Collections), and ABG propagator Billie Elliot.

[a]E-mail: jack.hobbs@aucklandcouncil.govt.nz

3. Description.

The daylily breeding programme is based on using rust resistant cultivars. The main parent used to date has been *H.* 'Squeaky', an evergreen cultivar with attractive narrow arching foliage and relatively small yellow flowers throughout most of summer. Although the flowers are less flamboyant than those of many cultivars, it remains an exceptional garden subject with its dense spreading habit making it an effective groundcover.

During the summer of 2014/2015 a selection of 23 rust-resistant cultivars was used to pollinate 30 plants of *H.* 'Squeaky' which was the sole seed parent. In the summer of 2015/2016 the number of pollinators was reduced to 12 rust-resistant cultivars used to pollinate 30 plants of *H.* 'Squeaky' which again was the sole seed parent.

In the summer of 2016/17 *H.* 'Squeaky' was mainly pollinated with *H.* 'Oriental Ruby', *H.* 'Cade Stewart', *H.* 'Zella' and *H.* hybrid 2.

Other pollen recipients were, *H.* 'Oriental Ruby', *H.* 'Cade Stewart, *H.* hybrid 2, *H.* hybrid 24 (pollinated with hybrid 2 and 'Zella'), *H.* 'Zella' (pollinated with hybrid 24), and hybrid 22 (pollinated with 'Cade Stewart').

Pollination is mainly undertaken in the afternoon when it is warmer and abundant pollen is available. Seed is collected once the fruit is plump and immediately it is beginning to turn brown. The seed is stored until all seed is collected. The ABG nursery germinates and grows the seedlings which are planted into trial beds.

The first batch of seed was sown in autumn 2015 and placed under grow lamps that extended the day length to around 16 hours. This worked well with all seedlings growing vigorously through the winter months including those that when mature turned out to be deciduous. The balance of seed was sown in spring.

To date three *H.* 'Squeaky' hybrids have been selected that meet our criteria:

- Hybrid 2: Lemon-yellow flowers with hint of green in throat, evergreen (Figure 1).
- Hybrid 22: Purplish flowers, healthiest in this colour range.
- Hybrid 24: Gold flowers, attractive dark green foliage (Figure 2).

In 2017/18 it is planned to increase the use of *H.* 'Squeaky' hybrids in the breeding programme including undertaking sibling crosses.

Figure 1. Hybrid 2.

Figure 2. Hybrid 24.

Camellia breeding

1. Objective.

The ABG camellia breeding programme aims to develop a range of attractive garden hybrids resistant to camellia flower blight caused by the fungus *Ciborinia camelliae*. Desirable characteristics include handsome glossy foliage, attractive flowers (in a range of sizes but larger than *Camellia transnokoensis* and *C. lutchuensis* flowers), and they must be resistant to flower blight. Additional desirable characteristics include long flowering periods, blooms that drop cleanly way when spent, and attractive colourful new growth. Scented blooms are a bonus. Small to medium sized trees of slender habit have particular value in small gardens and containers.

The process involves crossing petal blight resistant species (mainly *C. lutchuensis* and *C. transnokoensis)* with a selection of larger flowered hybrids such as japonicas and reticulatas.

The hypothesis is that crossing petal-blight resistant *Camellia* species with large flowered cultivars will produce ornamental hybrids with increased disease resistance. Over time it should be possible to increase the flower size and colour range of disease resistant cultivars and restore the status of camellias as first rate garden plants.

2. Background.

The fungus *C. camelliae* rapidly spread throughout New Zealand following its accidental introduction in the early 1990s. It infects the blooms of many ornamental camellias, notably spring flowering cultivars, causing them to turn brown and fall early.

Field surveys of cultivars susceptible to camellia petal blight conducted during spring 2016 at ABG confirmed 190 camellias infected with petal blight. The total number is likely to be much higher as many cultivars were not flowering during the survey period and will be re-surveyed.

There are 500 *Camellia* species and cultivars in the ABG Camellia Garden, including 60 species. This extensive collection has significant educational and conservation value, and some species have considerable ornamental value.

Following the introduction of camellia flower blight into New Zealand, Matt Denton-Giles (Massey University) tested 39 camellia species in the ABG collection for susceptibility to Camellia flower blight and found variable degrees of susceptibility (Denton-Giles et al., 2013).

This research identified four species as having flower blight resistance: *C. lutchuensis* (Figure 3), *C. transnokoensis* (Figure 4), *C. yunnanensis,* and *C. yuhsienensis*. The first three species are primarily being used in the ABG breeding programme.

Figure 3. *Camellia lutchuensis*.

Figure 4. *Camellia transnokoensis*.

In 2015 the Auckland Branch of the New Zealand Camellia Society and the Friends of the Auckland Botanic Gardens established the Neville Haydon Fund to assist with the breeding of petal blight resistant ornamental camellias.

Neville Haydon was the driving force behind the establishment of the Camellia Garden in 1985, donating most of the plants and advising on the layout of the plantings. He also donated most of the species camellias in our collection.

The first crosses were made in 2015 but produced few seedlings. This was partly due to some selected parents proving infertile. Subsequently more vigilant observation of the reproductive capacity of potential parents was undertaken before finalising breeding programmes.

The ABG breeding project has been led by Rebecca Stanley (Curator) and Emma Bodley (Botanical Records & Conservation). Support has been provided by Billie Elliot (Propagator), Mark Fielder (Collection Curator Magnolias & Camellias), and Jack Hobbs (Manager). Neville Haydon, former proprietor of Camellia Haven, has been an invaluable source of information and plant material. Matt Denton-Giles has also provided advice and information. Students contracted to undertake the pollination and recording of crosses have

been Jess Ryder (2015), Keely Paler (2016) and Matthew Savage (2017).

3. Description.

The first step was to identify flower blight resistant species and cultivars (mainly *C. japonica* and *C. reticulata*) for use in the breeding programme. *Camellia lutchuensis* and *C. transnokoensis* have been the main species used as parents, *C. yunnanensis* has been sparingly used and *C. yuhsienensis* has not yet been used.

Surveys were then undertaken to ascertain the relative petal blight resistant of *C. japonica* and *C. reticulata* cultivars. Cultivars resistant to petal blight were subsequently surveyed to identify those that set viable seed to inform planning of future crosses.

Breeding plans were then prepared that considered using parents with compatible chromosome numbers which is critical to informing genetically compatible crosses.

Camellia japonica consists of diploid (2*n*=30) and triploid (2*n*=45) cultivars. Many of the *C. japonica* cultivars originally selected as potentially useful parents have not set seed.

Camellia reticulata (2*n*=90) cultivars have been used sparingly in the breeding programme. However autumn flowering camellias such as *C. sasanqua* (2*n*=90) cultivars have not been included in the programme as they mainly escape blight by being early flowering, and also the flowers shatter fairly quickly when spent. Therefore they remain fine garden subjects with many cultivars widely available. However some hybrids such as *C. sasanqua* × *C. fraterna* 'Yoimachi' have been included.

Camellia transnokoensis × *C. lutchuensis* 'Transluscent' is of particular interest as a parent being a cross (by John Lesnie) of the two most resistant species, *C. transnokoensis* (2*n*=90) and *C. lutchuensis* (2*n*=30). Therefore *C.* 'Transluscent' should have a chromosome count of (2*n*=60), making it a good fit with hybrids between *C. reticulata* and *C. japonica* which should also have a chromosome count of (2*n*=60).

Camellia 'Transpink' (Figure 5) is a *C. transnokoensis* hybrid raised by Neville Haydon that he believes should have a chromosome count of (2*n*=60). It sets seeds and should be compatible with diploid *C. japonica* cultivars (2*n*=30).

Figure 5. *Camellia* 'Transpink'.

Species camellias chromosome counts:

- *C. yunnanensis* (2*n*=30)
- *C. lutchuensis* (2*n*=30)
- *C. transnokoensis* (2*n*=90)
- *C. yuhsiensis* (2*n*=45, 75, and 90)

Hand pollination is undertaken by students both ways when possible (i.e., where both

potential parents set seed and produce pollen). The flowers of pollen recipients are emasculated prior to pollination. Different coloured pipe cleaners are used to identify different pollinators.

Pollen of donor plants is often stored in refrigerators so it can be applied to the recipient plant when receptive.

Students complete field data collection sheets that include recipient and donor name, bed location, number of flowers pollinated and date of pollination.

Mesh bags are placed over all visible fruit to collect seed as it ripens and prevent it being lost. Seeds are germinated and grown in the ABG nursery and accessioned to ensure records are kept in the ABG database. Seedlings are planted at ABG. They should flower approximately after 18 months which will enable identification of resistance early on and discarding of any susceptible to petal blight.

SUMMARY

Developing disease resistant garden plants through breeding for genetic resistance aligns with ABG's pesticide minimisation programme that precludes the use of pesticides on ornamental plants.

As anticipated the *Hemerocallis* breeding programme is producing promising offspring more quickly than the *Camellia* breeding programme. However it will be a few more years before the first new daylily cultivars arrive in the market. The *Camellia* breeding programme is a much longer term project.

Literature cited

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IPPS Western Region Exchange 2016©

P. Watt[a]

Ardmore Nurseries, 230 Clevedon-Takanini Road, Clevedon, Auckland 2582, New Zealand.

In October 2016, I travelled to the other side of the world and came back a better propagator. When I first heard about the IPPS Western Region exchange offered by the IPPS New Zealand region, I was very excited about the possibility of going but it was surprising to learn of the small number of applications from the IPPS New Zealand region.

My exchange was hosted and co-ordinated by Jim and Andi Connors of Alta Nurseries, San Jacinto, California, the same couple that hosted the 2015 exchange recipient, Kat Scott of Scott Base Nurseries, Whenuapai. I had high expectations before I arrived based on Kat's report and I wasn't disappointed in the slightest. Jim and Andi were wonderful hosts, thoughtfully looking after me during my stay at their condo in Oceanside and at the conference in Phoenix, Arizona.

On the first week of the exchange, I was taken to a different nursery each day in San Diego County and usually given a tour by a manager or owner. Then I would get my hands dirty or wander around by myself. The nursery line up was pretty similar to what Kat had visited the previous year.

With a population of 39 million, California has a few more plants moving about than New Zealand has, so you would expect some of them to come from some large nurseries. Hines was the largest I visited—a multi-site producer for big-box store, Home Depot. The quantity of plants was staggering. Even though I kind of expected it, I still couldn't believe my eyes to see 30-odd trucks waiting to be loaded at the dispatch yard. This was only at Rainbow Valley, one of the four Hines sites, and if that wasn't impressive enough then there's Colorspot, the parent company with 16 production facilities to its name, each at around 100 acres or larger.

However, not all are large. Out the window of Jim's cherry red Dodge Ram I saw plenty of modest, "Mom and Dad" nurseries.

First Step Greenhouses was boutique compared to Hines, growing seedling plugs under 1.5 ha of glass: very memorable for its network of rolling benches with tables that could switch tracks using compressed air.

Village Nurseries was another large multi-site company. At their Escondido facility, I helped with the potting and cuttings. Village had a very low-tech, conveyorless production system. It seemed to be working perfectly fine for them but they may be forced to adapt as the minimum wage for the workers of California is taking a massive hike, from $10 USD to $15 USD by 2021.

Olive Hill Greenhouses not only specialises in indoor flowers and foliage, they also specialise in quality, with seven hectares of showroom standard product. The uniformity was mind blowing to witness and it was a great example of the use of Plant Growth Regulators to synchronise flowering.

At my request, Jim added Tree of Life nursery to the itinerary to show me a native, eco-sourced producer. Tree of Life is owned by IPPS member John Bone and Western US IPPS past-president Mike Evans. It was interesting to hear about using fire to help germinate native chaparral species.

At Jim and Andi's Alta Nurseries, I jumped in a truck and helped stack plants California-style using a thin strip of timber at the base of each row to create the perfect angle. The 100 acre nursery had the beautiful backdrop of the San Jacinto mountain range. It was easy to see why Jim is such a revered propagator in the Southwest.

Euroamerican Propagators was another plug tray specialist I visited. I was invited to sit in on a lean manufacturing meeting with the management team. Ardmore Nurseries has recently finished a lean program so I enjoyed the opportunity to see another nursery put

[a]E-mail: emile.nz@live.com

their thinking caps on and iron out some kinks.

When I wasn't visiting nurseries, I was being spoilt with Andi's cooking and meals out. Oceanside has a beautiful waterfront with a pier that reaches 400 m out to sea. We went to night markets, flash wineries and breweries and I even took a day trip to San Diego to see the Midway Aircraft Carrier Museum and the city's world famous zoo.

Part two of my exchange was the conference in Phoenix, Arizona. The conference was themed "A Different Point of View" and sought to highlight the unique approach to growing the diverse range of plants in Arizona's various climates.

The programme itself was diverse and rich in content. It began with a pre-conference tour of the Museum of Northern Arizona in Flagstaff, where I learned some of the history of the Colorado Plateau.

The next day, the conference kicked off at the Tempe Mission Palms with guest speakers delivering presentations on disease prevention, use of rice hulls as mulch, micro-propagation of *Grevillea* species and commercial propagation of *Cannabis sativa.*

Later, we loaded into buses to visit three nurseries in the area: Zvida Growers, Arid Zone Trees and Greenfields Citrus.

On day two, our speakers' topics were integrated weed management, genetic engineering and dealing with witches broom in Palo Verde—Arizona's threatened state tree.

Tony Shireman, last year's USA exchange in the IPPS New Zealand/Western Region partnership, whom some of you met during his visit, gave a presentation on his New Zealand experience. I also delivered a presentation about myself and my work at Ardmore Nurseries. I'm pleased to say it was well received, with many people afterwards asking me questions and sharing their New Zealand experiences.

Again, we spent the latter half of the day out in the beautiful sunshine, this time going to Desert Tree Farm, Arizona Wholesale Growers and the Desert Botanical Museum.

That evening we had a banquet to celebrate the end of the conference. Guest speaker - author, botanist and plant hunter—Greg Starr kept us entertained with accounts of his journeys to Mexico where he had made a new species description for the unusual *Agave ovatifolia* and brought back many other new species to introduce to the US commercially. It was amazing to see some of these nondescript plants from the desert landscape come to life in cultivation.

The post-conference tour of the Arizona-Sonora Desert Museum was a high note to end on. The museum is a combination of botanical garden, aquarium, natural history museum, zoo and art gallery.

A huge thank you to all the IPPS New Zealand members for making my fantastic trip possible, and to those responsible for co-ordinating the exchange with our IPPS Western Region peers.

Thanks also to Jim and Andi Connors and the organising committee of the Western Region conference for making my experience so unforgettable.

Rotoroa Island: from rehabilitation to revegetation©

A. Maloy[a]

27 Tetley Road, Waiheke Island, Auckland 1081, New Zealand.

Rotoroa is one of many islands in the Hauraki Gulf, close to Auckland, the largest city in New Zealand. Rotoroa Island lies just east of Waiheke Island close to Chamberlins Island (Ponui) and Pakatoa Island.

Rotoroa's land area is around 82 hectares (approx. 200 acres) in an interesting shape with gentle to steep sloping hills, several beautiful bays with sandy beaches ideal for swimming, rocky coastal outcrops and some crumbly cliffs that drop sharply to the sea.

In 1908 the Salvation Army purchased the island for a reported 400 pounds to expand their existing drug and alcohol rehabilitation facility which was running out of space on nearby Pakatoa Island. By this time it seems all the original native vegetation had been cleared from Rotoroa and the land largely used for grazing sheep and cattle. Photos taken around the 1950s show some of the extensive buildings the Salvation Army erected including large dormitories, hospital, kitchens, washhouses, staff houses, and a chapel in a prominent central position on the hill, workshops, a jailhouse and butcher's shop. There were also large vegetable gardens and tennis courts. This was all centred around what is known as Home Bay or Front Bay, close to the only wharf on the island.

With much of the rest of the island a working farm, along with the produce from vegetable gardens and orchards the island population was largely self-sufficient for food. Plantings of pine (*Pinus radiata*) and Monterey cypress (*Cupressus macrocarpa*) provided some shelter as well as a ready source of firewood and timber.

City life was several miles away by boat, so being on the island was an effective way of breaking the cycle of drug and alcohol abuse. However, a large proportion of people released from this environment back to the mainland soon fell into their old ways.

By 2005 the Salvation Army had disestablished their rehabilitation services on Rotoroa (nearby Pakatoa having been sold in 1964) by which time many of the buildings were in poor repair, and the place lay derelict for several years.

In 2008 Rotoroa Island Trust was formed, funded through the philanthropy of Neal and Annette Plowman and, with the aim of creating a conservation park, the trust purchased a 99-year lease of the island from the Salvation Army. The trust's vision is for Rotoroa Island to become a sanctuary where people can experience the wonder of New Zealand's wildlife and to be a leader in conservation management and education, at the same time respecting the island's heritage and history as a place of recovery and renewal.

On taking over the lease of the island the trust immediately set to work clearing away most of the old buildings and a major revegetation project was instigated. Much of this required a range of heavy machinery which was barged in. Some of the twenty or so buildings that were demolished contained asbestos, which needed specialist removers. Seven houses were kept and renovated; three are now used for staff, the other four now offer Qualmark™ accredited accommodation for up to 44 visitors, including 18 in the so-called Superintendents House which has been converted to suit backpackers.

The most cost effective way of dealing with the twenty thousand or so pines, cypresses and other exotic trees was to cut them down and feed them through a monster chipper, turning them into mulch which was spread over areas soon to be planted with native plants.

Revegetation also began in 2008 and over the next 4 years 400,000 native plants were planted by contractors, almost all 1-L-pot grade, brought over from the mainland. In most areas plants quickly established and now in 2017 have formed dense areas of growth several metres high interspersed with a network of tracks, some gravel others grassed and providing visitor access throughout the island.

Some areas have been left open grassland to provide grazing for ground dwelling

[a]E-mail: ra.maloy@xtra.co.nz

native birds like the endangered takahe of which there are now five on the island.

A few of the most notable existing exotic trees have been left, including a mature stand of 11 Norfolk Island pines, *Araucaria heterophylla.* The health of some of these is deteriorating and measures have been taken through feeding and mulching to improve their condition. There are also twelve mature *Phoenix* palms, probably *P. canariensis*. They seem in good health and are prolific seeders. To minimise the risk of seedlings emerging in revegetated areas the seed heads are cut off each year – and any seed that does drop to the ground carefully collected up.

In 2015, after aerial bait drops and much trapping Rotoroa Island was declared predator free. There are over 100 rat trackers and traps on the island in an attempt to keep it that way. Rats are the hardest to control as they can swim from nearby islands. Three have been caught in the last couple of months, emphasising the need for constant vigilance to maintain that predator-free status.

Rotoroa Island Trust entered into a partnership with Auckland Zoo and the Department of Conservation which has resulted in the release of several endangered native species on to the now predator-free island, including kiwi, takahē, tīeke (saddleback), pāteke (brown teal) and skinks, and many of these are now breeding successfully. Future releases of other endangered species are planned.

Artificial floating islands on the ponds provide resting places for a range of birds. The roots of plants on these islands grow deep into the water and provide a favourable breeding environment for native fish to be released into these ponds in the future.

Enclosures have been created to encourage rare skinks to breed. Moko skinks and shore skinks have been released into these and are breeding successfully.

New buildings on the island include an award-winning visitor centre with a museum acknowledging the history of the Salvation Army on the island, and a student learning centre. The latter provides facilities for educational field trips available to schools, focussing on practical ways students can become involved in conservation.

Public access to Rotoroa is via ferry leaving from Auckland which stops at Orapui on Waiheke Island then Rotoroa Island on the way to Coromandel.

To learn more about Rotoroa Island, visit: www.rotoroa.org.nz

Subantarctic islands: an intrepid journey and brief history©

T. Hatch[a]

Joy Plants, 78, Jericho Road, RD 2, Pukekohe, 2677, New Zealand.

MY INTREPID JOURNEY

It was with a sense of both trepidation and expectation that I boarded the shuttlebus setting out on the once busy road from Invercargill to Bluff – long gone were the miners, seafarers, polar explorers and whalers of yesteryear. Off on a long awaited journey to the islands of the subantarctic at the kindest time of the year – in January of 2016. Never a mariner, the quote came to mind "one does not discover new lands without consenting to leave sight of the shore" (André Gide). Arriving at the dock with an elect group of birdwatchers and animal photographers from various lands we boarded our sea vessel the Spirit of Enderby hosted by Heritage Expeditions.

Overnight we sailed the 130 km south to the Snares Islands with their steep cliffs only to be viewed from Zodiac boats. The vegetation grows in deep peat soil full of breeding seabirds where the endemic *Olearia lyallii* reaches 5 m or more tall, and its tangled branches cover the myriads of muttonbird nests.

The yellow-flowered tree daisy, *Brachyglottis stewartiae*, along with *Veronica* (*Hebe*) *elliptica* covered in white flowers were hanging off the rocks. The megaherb *Stilbocarpa robusta* (Figure 1), the endemic *Anisotome acutifolia* (Figure 2), *Asplenium* ferns and *Poa* grass draped down to the tide edge. Snares crested penguin numbering around 60,000, and three albatross species nest here as well as New Zealand fur seals and New Zealand sea lions in small numbers.

Figure 1. *Stilbocarpa robusta.*

Figure 2. *Anisotome acutifolia.*

[a]E-mail: hatch.clan@xtra.co.nz

Overnight we travelled on to the Auckland Islands in choppy seas, in a small 5 m swell, cold, and windy. Now about 465 km out from Bluff, we landed in a sheltered cove, with thick bull-kelp covering the rocks and the tiny Auckland Island teal bobbing about in the surf. Our Zodiac dropped us on shore and we had a short walk past clumps of healthy southern nettle, *Urtica australis* to a long sandy bay where prone New Zealand sea lions were having their pups, and the huge beach-masters, 1000 kg bull-seals kept guard over their harems. The seals come up to us to sniff and then turn away to resume skua patrol as the birds were looking for afterbirth and dead seal pups. A few yellow-eyed penguins strolled about, going up to their nests in the scrub.

The plant life is rich on the Auckland Islands (the largest of New Zealand's subantarctic islands) having more than 200 recorded species. Dwarfed southern rātā forest, *Metrosideros umbellata*, is impressive with other trees making 15 m tall (Figure 3), and their brilliant scarlet flowers were just opening amongst the foliage of green, red, bronze and almost violet shades.

Figure 3. Taller trees of *Metrosideros umbellate*.

There were masses of ferns, including *Polystichum vestitum* (Figure 4) of large dimensions and *Asplenium*, and *Blechnum* in the open areas.

Figure 4. *Polystichum vestitum*.

Tangled clumps of weeping matipo, *Myrsine divaricata* give some shelter to flat exposed areas of the Auckland Island gentian, *Gentianella cerina* (Figure 5), of violet to white flower colours. Many other small herbs grow there interspersed with orchids, small ferns, clubmosses, lichen, mosses, and tiny fungi species.

Figure 5. *Gentianella cerina.*

The most spectacular plants of the Auckland Islands are undoubtedly the megaherbs, including *Stilbocarpa polaris* (Figure 6), usually placed in the *Araliaceae* family, with large pleated foliage and umbels of fruits, and *Anisotome latifolia* (Figure 7), a giant member of the carrot family (*Apiaceae*), with glorious cauliflower-type heads of flowers in purples to pinks, and paler lavender forms.

Figure 6. *Stilbocarpa polaris*.

Figure 7. *Anisotome latifolia.*

Pleurophyllums are the crowning glory giants of the perennial daisy family, with *Pleurophyllum criniferum*, *P. hookeri,* and the spectacular *P. speciosum* all in flower when we visited them. *Pleurophyllum criniferum* has rounded greenish-grey leaves with brown button flowers on 50-90 cm stems. *Pleurophyllum hookeri* has pointed silver leaves and smaller stems 50 cm or so tall with brown button flowers. *Pleurophyllum speciosum* (Figure 8) has large pleated silver leaves that are covered in hairs, keeping the temperature five or more degrees warmer in the pleats. This giant has flower stems 1 m or more in height with large

flowers that are blue, violet, pink and all tones in between. Interestingly, there are a number of hybrids with varying length of petals in shades of warm violet-blue.

Figure 8. *Pleurophyllum speciosum.*

We had a day trip to the defunct Hardwicke settlement, now a forest of rātā, with masses of ferns and the tiny orchid *Corybas oblongus* (Figure 9) with maroon flowers and sporting a white "beard". This orchid was popular with the photographers and had a number of portraits taken.

Figure 9. *Corybas oblongus*.

In the early days cultivation of vegetables had been trialled at the Hardwicke settlement but with the soils being acid peats, plus the adverse weather, they fortunately failed any efforts made. Considering the lush native plants compared to the failure of cultivated food crops, I wonder if mycorrhiza associations help the native plants to flourish in such poor soils?

Ever onwards we sailed overnight to our last stop—Campbell Island a further 270 km southwest of Auckland Islands. It was a nasty night in the furious 50s, with huge seas. Now that this island is free of pest species, including rats, sheep, horses, cattle and (for most of the time) humans, the environment appears to have recovered.

The first day on Campbell Island was a short walk through massed flowers of *Bulbinella rossii* (Figure 10) in full golden flowered glory, like huge hyacinths, with numbers of albatross nesting and having reunion parties. The wind in all its fury was blowing some of the lighter folk over, but what an amazing day of botanical wonder.

Figure 10. *Bulbinella rossii*.

The following day provided the option of Zodiac boating or a 12 km hike through some tough going. So the party split, and I opted for the hike! Sure of a trip to a wonderland of plants, the track climbed steadily through massed *Pleurophyllum*, *Bulbinella*, *Anisotome*, past albatross nesting), sitting tight in the short hailstorm, then further on to a rest for lunch with the black-eyed daisy, *Damnamenia vernicosa* (a subantarctic monotypic genus closely allied to *Celmisia*) (Figure 11), massed *Dracophyllum* scrub, *Coprosma foetida*, orchids, and then onwards in the falling snow.

Figure 11. *Damnamenia vernicosa*.

Traversing soggy peat tracks with seal wallows, someone tried one on for depth! Onward, down to the coast with amazing scenery, seascapes and smaller Islands. Now quite damp, with showers of rain and huge tussocks over my head, we made our way down onto the beach past reclining elephant seals and their pups which gave us a smile! Near the end of the hike was a cave shelter for refreshments and a beautiful clump of *Ranunculus pinguis* (Figure 12) in full flower.

Figure 12. *Ranunculus pinguis*.

Then we made a last effort down to a cove, and by now we were all very cold and wet.

What an amazing day for a last goodbye to a group of elephant seals, before heading back to the mothership for a hot shower. It had been a trip to another world and a privilege to be able to enjoy the jewels of the southernmost South Pacific.

HISTORICAL DISCOVERY

In November 1791 the Snares Islands were discovered by the Europeans. Traces of earlier discovery have been found and a few Polynesian artefacts collected.

Discovery of the Antipodes, Auckland and Campbell Islands followed from 1800 to 1809 and by 1810 all the Subantarctic Islands were on the map. The subantarctics abounded in life which was to be ruthlessly destroyed, whales for oil and bone, seals for skins and oil, elephant seals for oil, and penguins also for oil.

Many other birds and plants would be collected for specimens. Most of the animals were taken to the verge of extinction, hundreds of thousands of seals for "top hats" and perhaps millions of penguins for oil used in rope making and machine lubrication.

In the procurement of these products numerous shipwrecks and loss of human life was expended as British, Norwegian, American, French, and sundry others all rushed to the bounty and bonanza to be had. By the early 1900s the animal life had plummeted.

During those early years, 1866–1868, pigs were liberated on Campbell Island, weka released on Enderby Island, plus the bonus of rats and mice from ships. There was a whaling base in 1849 which soon failed, and a human settlement on Enderby Island in 1849 that would exist for 2 years and then fail, leaving behind a small cemetery and a pile of bricks. In 1880 Andreas Reischek, an Austrian taxidermist, naturalist, ornithologist and collector, would blast away at the birdlife, using his gun for profit.

Scientific visits were made by Sir Joseph Hooker and David Lyall who made collections of plants which formed "Flora Antarctica" (The Botany of the Antarctic Voyage of H.M. Discovery Ships Erebus and Terror in the years 1839-1843) in 1844, and in 1890 Thomas Kirk visited the Islands and made further collections. Other collections of flora and fauna were made in the 1900s of which most went overseas, and in 1903 Leonard Cockayne collected extensive plant specimens. A large expedition organised by the Philosophical Institute of Canterbury was made in November 1907 and incorporated all the sciences which resulted in two large volumes printed in 1909.

From 1874 leases were let out to sheep "farmers" and the initial introduction of several hundred sheep escalated to 8,000 by 1907. Thirty-six years of sheep desecration of the flora followed, plus the disruption of nesting albatross sites through lack of cover. And the Government had a loss of revenue which in those days was the large sum of 40 pound per year. Even today's archaic fishing methods are killing wildlife around the area.

On a brighter note the sheep are gone, rats were eradicated from Campbell Island in 2001 and mice from Antipodes, with perhaps now only a few pigs and cats remaining on the Auckland lslands, and a few tourists now and then. The history for such a remote place is huge and there are a number of books for reference that tell their story.

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Assessing fertility in horticultural selections of *Agapanthus*©

M. Dawson[1,a], E. Bodley[2,b], R. Stanley[2,c], I. Duncalf[3,d] and E. Morgan[4,e]

[1]Manaaki Whenua Landcare Research, P.O. Box 69040, Lincoln 7640, Canterbury, New Zealand; [2]Auckland Botanic Gardens, 102 Hill Road, Manurewa 2105, Auckland, New Zealand; [3]Plant Struck, 139 Te Puna Road, Te Puna 3176, Tauranga, New Zealand; [4]Plant & Food Research, Private Bag 11600, Palmerston North 4442, New Zealand.

INTRODUCTION

Agapanthus is a genus of herbaceous, perennial, and rhizomatous monocots that are endemic to Southern Africa (Leighton, 1965). There are six currently accepted species, several hybrids, and numerous cultivars especially involving *A. praecox* and its subspecies (Snoeijer, 2004). Collectively, these are known under the common names agapanthus, African lily, and lily of the Nile.

Their low maintenance and abundance of flowers have made agapanthus a deservedly popular garden plant, widely grown throughout warm temperate regions of the world. However, agapanthus have typically high seed production and other undesirable weedy traits. These traits have allowed agapanthus to escape cultivation and become naturalized in several countries.

In a response to demands from the public to have selections they can still buy and grow, and from government agencies and environmental groups for less invasive alternatives, New Zealand and more recently Australian nursery industries have released a range of cultivars marketed under various terms, such as “eco-friendly”, “environment safe”, “low-fertility”, “non-invasive”, “self-sterile” and “sterile”.

However, these claims of sterility, and associated terms, were rather anecdotal and had not previously been substantiated by underpinning research. This paper outlines several approaches for assessing fertility of horticultural selections of agapanthus.

TAXONOMY AND SPECIES OF AGAPANTHUS

Agapanthus have been placed in several different families including the *Alliaceae*, in their own family the *Agapanthaceae*, and in the old catch-all concept of the *Liliaceae* (the lily family). The Angiosperm Phylogeny Group classification is based on DNA sequencing studies and places *Agapanthus* in the *Amaryllidaceae* family (under a monogeneric subfamily, *Agapanthoideae*; APG IV, 2016).

The most recent revision of *Agapanthus* species and cultivars is by Snoeijer (2004) who accepted Zonneveld and Duncan’s (2003) proposal to recognize six species equally divided into two sections:

1) Section *Lilacinipollini*:
   - *A. campanulatus* (subspp. *campanulatus* and *patens*)
   - *A. caulescens* (subspp. *angustifolius*, *caulescens* and *gracilis*)
   - *A. coddii*.

2) Section *Ochraceipollini*:
   - *A. africanus* (subspp. *africanus* and *walshii*)
   - *A. inapertus* (subspp. *inapertus*, *hollandii*, *intermedius*, *parviflorus*, and *pendulus*)
   - *A. praecox* (subspp. *minimus*, *orientalis* and *praecox*).

The Plant List (www.theplantlist.org/tpl1.1/search?q=agapanthus) currently rejects some of the subspecies accepted by Zonneveld and Duncan (2003), and accepts some other

[a]E-mail: dawsonm@landcareresearch.co.nz
[b]E-mail: emma.bodley@aucklandcouncil.govt.nz
[c]E-mail: rebecca.stanley@aucklandcouncil.govt.nz
[d]E-mail: ian@duncalf.co.nz
[e]E-mail: ed.morgan@plantandfood.co.nz

species in *Agapanthus.* These include *A. dyeri* Leight. (considered by Zonneveld and Duncan (2003) as a synonym of *A. inapertus* subsp. *intermedius* Leight.), *A. nutans* Leight. (considered by Zonneveld and Duncan (2003) as a synonym of *A. caulescens*), and *A. walshii* L.Bolus (reduced to the new combination *A. africanus* subsp. *walshii* (L.Bolus) Zonn. & G.D.Duncan by Zonneveld and Duncan (2003)).

AGAPANTHUS AS A VALUED GARDEN PLANT

Snoeijer (2004) cited a figure of 625 agapanthus cultivars that have been named worldwide, and provided a comprehensive listing of them that included synonyms, origins, descriptions, and notes. Some of the cultivars listed by Snoeijer (2004) are historic and no longer commonly available, others are only available in certain countries, and new cultivars have been raised and released since then.

A range of cultivars are popular and widely available in world markets with mild climates, such as Australia, New Zealand, California, South Africa, and warmer parts of the UK. *Agapanthus* taxa are grown commercially in large quantities. They are easy to propagate through division of clumps and through tissue culture; this clonal propagation is essential for retaining the characteristics of the named selections. *Agapanthus* taxa are also easily propagated from seed, but this method should only be used for bulk production of species and subspecies, and not for cultivar propagation.

Agapanthus possess many horticulturally desirable qualities, including minimal pest and disease issues, low maintenance, hardiness, drought tolerance, able to grow in partial shade or full sun, well-suited for coastal plantings, perennial growth habit, fast growth, lush foliage, showy flowers and long flowering season.

They are useful garden, container and amenity plants used for mass plantings in herbaceous borders, along driveways and roadside banks, and on traffic islands (Figures 1 and 2).

Figure 1. Mass planting of a medium height white-flowered agapanthus cultivar to enhance an industrial street front. Photo: Murray Dawson.

Figure 2. Tall-growing white- and blue-flowered *Agapanthus praecox* subsp. *orientalis* planted between driveways. Photo: Murray Dawson.

Agapanthus has resistance to glyphosate (e.g., Roundup®) so amenity plantings can easily be kept clean of emerging weeds by spraying the ground around them—agapanthus are not bothered by minor overspray.

Their strap-like leaves are usually green or with a blue-green waxy (glaucous) surface and leaves of some selections have purple bases. Several cultivars have green leaves that are variegated with white and/or yellow bands (Figures 3 and 4).

Figure 3. *Agapanthus* 'Goldstrike', a variegated green- and white-leaved cultivar. Photo: Lyndale Nurseries.

Figure 4. *Agapanthus* 'Tigerleaf', a variegated green- and yellow-leaved cultivar. Photo: Barrie McKenzie.

Furthermore, their thick rhizomatous growth makes them useful for stabilising slip-prone land, and their fleshy leaves are fire resistant and can regrow from the base of the plants.

Although blue and white are the two basic flower colors often stated for agapanthus, in reality pure blue is rare and instead comes in numerous tones of violet, purple, and lavender. Flowers can also be pure white or off-white. Flowers are usually six-tepaled (The term tepal is used when petals and sepals are relatively indistinguishable from each other.), although some selections have more numerous tepals—those flowers are loosely referred to as "double" or "semi-double". Agapanthus flowers are sometimes used in the cut flower market (Burge et al., 2010).

As a general guide, selections range in stature from about (100-)200 to 500 mm for the low-growing (so-called "dwarf") selections; from 600 mm to 1.2 m for medium-sized selections; and up to 1.8(-2) m, including height of flower stems, for the tallest cultivars. Over time, many of the dwarf selections will exceed the ranges stated here and in nursery catalogues, but their foliage always remains narrow, linear, and held relatively close to the ground.

The great majority of tall-growing cultivars are selections or hybrids of *A. praecox* subsp. *orientalis*. Most narrow-leaved and low-growing cultivars are selections of *A. praecox* subsp. *minimus*. These dwarf cultivars are well-suited to smaller garden areas and have become more popular than the taller growing selections.

AGAPANTHUS AS A WEED

Agapanthus is reported to have naturalized in countries including Australia, New Zealand, Jamaica, Mexico, Ethiopia, and the UK.

Wild populations of agapanthus can threaten remnant indigenous ecosystems, and flourish in coastal, frost-free (or lightly frosted) warm temperate climates. Agapanthus is tolerant of a wide range of soil types and growing conditions—from dry exposed environments to damp, lightly-shaded sites. Among other habitats, it has naturalized in coastal areas (Figure 5), along roadsides, and in wasteland. There is no biocontrol available, and (as previously mentioned) it is relatively resistant to herbicides.

Figure 5. Blue- and white-flowered *Agapanthus praecox* subsp. *orientalis* naturalized at Opito Bay on the Coromandel Peninsula. Photo: Trevor James.

Agapanthus can spread by vigorous rhizomatous growth eventually forming dense and robust monocultures. Its rhizomes are extremely difficult to dig out and remove, and any left behind may regrow. It can also spread by the illegal dumping of garden waste (Figure 6).

Figure 6. Roadside dumping of *Agapanthus praecox* subsp. *orientalis*. Photo: Murray Dawson.

Agapanthus typically produces abundant seed (Figure 7) that germinates readily. This seed can spread by wind and water—particularly along drains and waterways (Figure 8). Deadheading (removing seed heads before the capsules split open) to reduce seed dispersal is timing dependent, and for large areas tedious and impractical.

Figure 7. Mature head of a typical high seed set, tall-growing *Agapanthus praecox* subsp. *orientalis*. Photo: Murray Dawson.

Figure 8. *Agapanthus* spreading along a drainage ditch, outside of a lifestyle block, north of Auckland city. Photo: Murray Dawson.

Furthermore, agapanthus sap causes severe ulceration of the mouth and is also a skin irritant (NPPA TAG, 2006). *Agapanthus praecox* is among the New Zealand National Poisons Centre's top 10 poisonous plants and regularly involved in childhood poisonings (Popay et al., 2010).

In New Zealand, *A. praecox* subsp. *orientalis* was first cultivated from about the mid-1800s, and, some 100 years later, was first recorded as naturalized in 1952 (Ford and Dawson, 2010; Dawson and Ford, 2012).

In recent years, there has been increasing concern about the spread and invasiveness of *A. praecox* subsp. *orientalis*, especially in the Auckland Region. In 2008, Auckland Council (then as Auckland Regional Council) banned large-growing forms of agapanthus from sale, propagation, distribution and exhibition in their municipal region. Also in 2008, *A. praecox* was added to the consolidated list of environmental weeds in New Zealand (Howell, 2008). There have also been recent submissions to include it as a National Pest Plant Accord (NPPA) species (NPPA TAG, 2006).

FERTILITY ASSESSMENTS IN NEW ZEALAND

The nursery industry responded to the Auckland Council ban of large-growing forms (*A. praecox* subsp. *orientalis*) by selling existing low-growing cultivars (dwarf selections with *A. praecox* subsp. *minimus* parentage) considered to be less invasive. Various terms have been applied to them, with various degrees of accuracy, including "Auckland safe", "eco-friendly", "environment safe", "low-fertility", "non-invasive", "self-sterile" and "sterile".

While some of these dwarf cultivars subjectively set less seed, others such as *A.* 'Streamline' are obviously highly fertile, and, with a shorter history of cultivation in New Zealand, may have similar weedy potential to the banned tall-growing forms.

Consequently, Auckland Council funded Manaaki Whenua Landcare Research to independently study and quantify fertility of agapanthus. Sterility and low fertility claims made of two dwarf cultivars, *A.* 'Finn' PVR (Figure 9) and *A.* 'Sarah' PVR (Figure 10), were used as exemplars and studied in detail. They were compared against tall-growing *A. praecox* subsp. *orientalis* and the fertile dwarf cultivar *A.* 'Streamline'. A wide range of techniques were used, to determine the levels of both male and female fertility, including pollen staining, pollen-tube germination, artificial crossing experiments (self, sib and outcrosses), seed counts and germination rates.

Figure 9. *Agapanthus* 'Finn' PVR, a low fertility cultivar with white flowers. Photo: Lyndale Nurseries.

Figure 10. *Agapanthus* 'Sarah' PVR, a low fertility cultivar with soft blue flowers. Photo: Lyndale Nurseries.

These techniques quantified male (pollen) and female fertility (seed set and germination), and confirmed low seed set in *A.* 'Finn' PVR and *A*. Sarah' PVR. However, as both were found capable of producing germinable seed neither could be described as sterile or seedless. The results of this work were presented as a technical report (Ford and Dawson, 2010) and popular articles (e.g., Dawson and Ford, 2012), and pointed the way to future research and fertility assessments.

In 2012 an Agapanthus Working Group (AWG) was established to co-ordinate activities of Auckland Council Biosecurity, Auckland Botanic Gardens, Manaaki Whenua Landcare Research, Plant & Food Research, New Zealand Plant Producers Incorporated, and the nursery production industry.

This partnership provides an excellent example of a council/regulator, botanic garden, researchers, and the commercial plant production industry all collaboratively working together. The AWG are seeking a "win-win", to resolve an environmental weeds issue by identifying true low fertility (ideally sterile) cultivars that the public and amenity sector can continue to buy, grow, and enjoy, and to support the plant production industry.

Drawing from the intensive fertility assessments made on relatively few exemplars by Ford and Dawson (2010), the AWG considered which techniques were easy, effective and scalable for assessing the full range of cultivars available on the market.

The AWG agreed that low female fertility (low seed set and seed viability) is more significant for reducing the weed risk to the environment than low male fertility (pollen viability). Low female fertility decreases propagule pressure and effectively restricts new plants escaping from cultivation into the wider environment via seed dispersal.

The AWG advocated in the first instance for a common garden experiment—a rapid non-quantitative screen to detect which of the commercially available cultivars have low seed set when grown together for comparison. The results would provide a shortlist of low seed setting candidates suitable for formal quantitative fertility assessments.

Field trials were initiated at the Auckland Botanic Gardens (ABG; Figure 11) in 2012 to assess natural (open-pollinated) seed set of existing cultivars planted together in a common garden environment (in contrast to Ford and Dawson's 2010 artificial crossing experiments in a glasshouse). In addition to the gardens staff (led by Emma Bodley and Rebecca Stanley), Ian Duncalf contributed his expertise to the outdoor trials. ABG are well-placed to conduct these agapanthus trials as they regularly run trials on other horticultural plant groups to determine superior cultivars to recommend for the Auckland region.

Figure 11. *Agapanthus* cultivar trials at Auckland Botanic Gardens, January 2017. Photo: ABG.

Open-pollinated seed set observations from the ABG trials were complemented by Murray Dawson who made separate observations for an agapanthus collection grown in glasshouses and shade-houses at Manaaki Whenua Landcare Research, Lincoln, Canterbury. Observations from both locations (Auckland and Canterbury) were made each fruiting season from 2012 until the present time (2017).

DEFINITIONS OF STERILITY AND MARKETING TERMS USED IN AGAPANTHUS

In 2016, the Agapanthus Working Group began re-evaluating definitions of infertility and criteria for "acceptable" levels of fertility for agapanthus cultivars. A workable definition was required for updating Auckland Council's Regional Pest Management Plan (RPMP), in light of the shortcomings of their previous RMPM, banning sale of all large-growing forms while still allowing all dwarf forms of agapanthus, irrespective of their fertility.

A biological definition of reproductive sterility in plants, for both female and male gametes, is to consistently have no seed capable of germination and no viable pollen produced. In other words, if the term "sterile" is being applied to agapanthus without qualifiers, this should refer to full female and male infertility. Full sterility could be considered the "gold-standard" to achieve in agapanthus selections, although of the two, female sterility is more significant when considering weedy potential.

For plants that never produce viable seed, but may have viable pollen, the following terms are appropriate: "seedless" (where all fruit capsules abort early in their development, or they persist but are either empty or with obviously undeveloped seed; Figure 12) or "female sterile" / "seed sterile" (where there can be a few apparently fully developed seed produced, but they are not capable of germination). Seed sterility of agapanthus cultivars restricts their dispersal and, like full sterility, is highly desirable.

Although these definitions may appear to be obvious, they have not been applied accurately or consistently in the trade. Furthermore, a distinction should be made between these biological definitions of infertility and marketing terms such as "Auckland safe", "eco-friendly", "environment safe", and "non-invasive". These marketing terms have also been used inconsistently and it's confusing to the consumer to have multiple terms with similar meanings.

To provide a straightforward marketing term for certified low fertility and/or sterile agapanthus, the name "Ecopanthus™" was trademarked in 2013 by the Nursery and Garden Industry Association of New Zealand Inc. (New Zealand Intellectual Property Office—967291—Trade Mark—Ecopanthus: https://app.iponz.govt.nz/app/Extra/IP/Mutual/Browse.aspx?sid=636523084468057031) (now the New Zealand Plant Producers Inc.). "Ecopanthus™"(or "Ecopanthus™ Series") may well be useful (main label) marketing terms, but for accuracy a fine-print qualifier such as "Seedless agapanthus" or "Produces less than 2% viable seed" could be considered for mandatory labelling purposes.

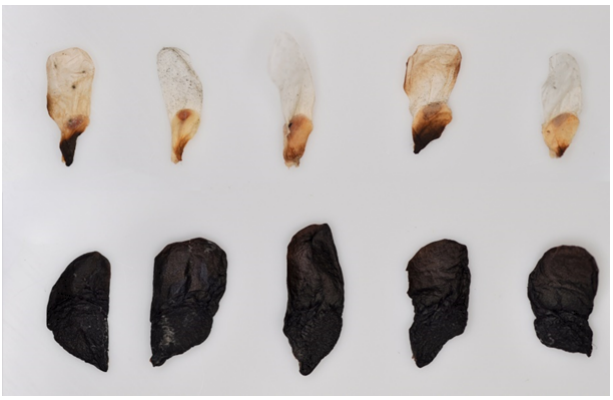

Figure 12. Undeveloped seed in *Agapanthus* is easy to recognize: upon maturity of the fruit capsule, inviable seed is lighter colored, smaller, and flattened (top row). In contrast, filled, "viable" seed is black / dark brown and broader (bottom row). Photo: Murray Dawson.

Adoption of "Ecopanthus™" for certified low fertility agapanthus cultivars would rely on agreement within the nursery industry and availability of the NZPPI trademarked name to all growers. There would also need to be agreed exemptions for certified low fertility agapanthus from regulatory authorities (such as exemptions within regional councils' RPMP's and potentially in the New Zealand Ministry of Primary Industries NPPA listings) that may ban propagation, sale, and distribution of the fertile counterparts.

FIELD TRIAL RESULTS: OPEN-POLLINATED SEED SET OBSERVATIONS OF EXISTING CULTIVARS

The natural (open-pollinated) seed set results at Auckland Botanic Gardens were compared with seed set observations made at Manaaki Whenua Landcare Research in Lincoln. The results were relatively consistent for each cultivar between locations and field sites (outdoor evaluation trial beds in Auckland, and glasshouses and shade-houses at Lincoln), and between years (2012-2017). The results were also reasonably consistent with earlier observations made by Jennifer Barrett from plants growing in Auckland Botanic Gardens (unpubl. data, June 2010). This consistency confirmed that open-pollinated seed set observations were a useful screening technique, and our combined results are summarized in Tables 1-3.

Collectively, Table 1-3 lists a broad range of 40 named cultivars currently available in New Zealand and assessed in this paper. Synonyms and brief descriptions are provided for each cultivar, to help confirm their identity. Descriptions based on our living material were closely compared to those published by Snoeijer (2004) and in Plant Variety Rights databases. This information helps resolve instances where the same selection is sold under different names and different selections are sold under the same name.

Although the female fertility descriptors (putative sterile, very low, low, medium, high, very high) are not quantified here with seed set percentages, they do provide an effective coarse screen of the best candidates for more critical evaluation.

Many of the stated plant heights in Tables 1-3 for foliage and flower heads (inflorescences) were measured from well-established plants at Lincoln and Auckland, and thus may be greater than descriptions in nursery catalogues and the size classes given earlier in this paper (dwarf, medium, tall), especially those of the dwarf cultivars. Cultivars have the usual six tepals unless otherwise stated in Tables 1-3 for the multi-tepaled / semi-double / double-flowered cultivars (Figures 13-16). Six-tepaled flowers produce the usual three-locular seed capsules, whereas flowers with eight tepals go on to develop four-locular seed capsules.

Table 1. Putative seedless and confirmed lowest female fertility cultivars of agapanthus based on completed open-pollinated seed set observations.

Cultivar	Female fertility/seed set	Brief description
A. 'Agapetite' PBR, PVR	Sterile?	Very dwarf and compact stature—one of the smallest growing cultivars, foliage to 100 mm tall, short wide blue-green leaves up to 130 mm long and 17 mm wide, white flowers, additional tepals (about 9), 7-23 flowers per inflorescence, flower heads to 270 mm tall.
A. 'Blue Finn' PVR (was provisionally named *A.* 'Ecostorm')	Sterile?	Dwarf stature, foliage to 170 mm tall, short wide green leaves up to 280 mm long and 17 mm wide, blue flowers, 18-20 flowers per inflorescence, flower heads to 350 mm tall.
A. 'Dorothy Edwards'	Sterile?	Medium stature, foliage to 670 mm tall, wide blue-green leaves up to 540 mm long and 40 mm wide, dark blue flowers, numerous additional tepals (24-30), 59-94 flowers per inflorescence, flower heads to 650 mm tall.
A. 'Finn' PVR	Very low	Semi-dwarf stature, foliage to 330 mm tall, narrow light- to mid-green leaves with cream bases and up to 310 mm long and 17 mm wide, white flowers, 18-60 flowers per inflorescence, flower heads to 730 mm tall.
A. 'Golden Drop' PBR, PVR (syn. *A.* 'Gold Drops')	Very low	Dwarf compact stature, foliage to 340 mm tall, narrow mid-green leaves that are variegated light green and golden yellow and up to 350 mm long and 12 mm wide, lavender blue flowers, 5-11 flowers per inflorescence, flower heads to 550 mm tall.
A. 'Goldstrike' (syn. *A.* 'Gold Strike')	Very low (– low)	Semi-dwarf compact stature, foliage 380 to 600 mm tall, green leaves that are variegated golden-yellow (aging to cream as the leaves mature) up to 500 mm long and 20 mm wide, dark blue flowers, 16-22 flowers per inflorescence, flower heads to 670 mm tall.
A. 'Pavlova' PBR, PVR	Very low	Semi-dwarf stature, foliage to 410 mm tall, short wide green leaves with cream bases up to 250 mm long and 30 mm wide, creamy-white flowers, 64-144 flowers per inflorescence, flower heads to 670 mm tall.
A. 'Sarah' PVR	Very low (– low)	Semi-dwarf stature, foliage to 350 mm tall, narrow light- to mid-green leaves with cream bases and up to 200 to 315 mm long and 19 mm wide, soft blue flowers, abnormal stigma and styles, additional tepals (6-12) common, 20-58 flowers per inflorescence, flower heads 570 to 900 mm tall, multi-locular seed capsules.
A. 'Snowdrops' (syn. *A.* 'Snowdrop')	Sterile (– very low?)	Dwarf stature, semi-upright foliage to 300 mm tall, dark blue-green leaves up to 250 mm long and 24 mm wide, white flowers, additional tepals (6-12) common with conversion of inner flower parts, 9-20 flowers per inflorescence, and flower heads to 500 mm tall. This description is based on material growing at Lincoln. Plants currently growing at Auckland Botanic Gardens under the name *A.* 'Snowdrops' are excluded from our assessments as they are not the same selection (they are taller growing, don't have additional tepals, and are moderate seed setters).
A. 'Thunder Storm' PVR (syn. *A.* 'Thunderstorm', *A.* 'DunAga02')	Sterile?	Semi-dwarf stature, foliage to 340 mm tall, relatively broad green leaves that are variegated cream (with a yellow-green basal flush when shaded) and are up to 290 mm long and 20 mm wide, blue flowers, 26-50 flowers per inflorescence, flower heads to 600 mm tall.

Table 2. Suspected low female fertility, borderline results, or uncertain cases where candidate cultivars of agapanthus require further assessments.

Cultivar	Female fertility/seed set	Brief description
'Baby Pete' PBR (syn. *A.* 'Benfran')	Low (– medium)	Semi-dwarf compact stature, foliage to 500 mm tall, mid-green leaves up to 515 mm long and 19 mm wide, pale blue flowers, 37-83 flowers per inflorescence, flower heads to 1030 mm tall.
A. 'Bertsbrook' (was provisionally named A. 'Bertsbrook Blue')	Low	Semi-dwarf compact stature, foliage to 720 mm tall, dark green leaves up to 580 mm long and 19 mm wide, mid-blue flowers, variable number of tepals (5, sometimes 6), 5-12 flowers per inflorescence, flower heads to 900 mm tall.
A. 'Blue Baby'	Low – medium	Dwarf stature, foliage to 200 mm tall, narrow mid-green leaves, light blue flowers, 16-25 or more flowers per inflorescence, flower heads to 600 mm tall.
A. 'Blue Storm' PBR (syn. *A.* 'Bluestorm' and *A.* 'ATIblu')	Very low (– low). Limited observations	Dwarf stature, foliage 150 mm or more tall, narrow mid-green leaves with cream bases up to 200 mm long and 11 mm wide, soft violet blue flowers, additional tepals (6-12) common, 8-33 flowers per inflorescence, flower heads to 610 mm tall. This description is based on a dwarf plant with very low to low seed set. However, there may be two different selections under this one cultivar name and further work is required to confirm the true identity and fertility of *A.* 'Blue Storm'.
A. 'Debbie's Dwarf'	Sterile or low? Limited observations	Very dwarf, compact stature, foliage to 130 mm tall, narrow green leaves up to 110 mm long and 5 mm wide, blue flowers, occasional flowerer, 14-20 flowers per inflorescence, flower heads to 200 mm tall.
A. "Plantlife Var" (unnamed selection, grown at AGB as *A.* 'Variegata')	Low? Limited observations	Semi-dwarf stature, upright foliage to 450 mm tall, relatively broad, sparse grey-green leaves that are variegated yellow and cream and are up to 420 mm long and 26 mm wide, blue flowers, 50-60 flowers per inflorescence, flower heads to 650 mm tall.
A. 'Purple Cloud'	Limited observations	Tall stature, erect foliage 570 mm to 1000 m tall, blue-green leaves with dark purple bases that are long and narrow—up to 620 mm long and 23 mm wide, deep purple-blue flowers, 44-70 flowers per inflorescence, flower heads 1200 to 1800 mm tall. This description is based on relatively young plants—the dimensions of mature plants could be greater than measured here.
A. 'Sea Coral'	Low – high?	Medium stature, foliage to 770 mm tall, green leaves up to 500 mm long and 17 mm wide, white flowers that flush coral pink with age, 45-52 flowers per inflorescence, flower heads 800 to 1040 mm tall. This description is based on material currently growing at Auckland Botanic Gardens under this name. Further work may be required to confirm the true identity and fertility of *A.* 'Sea Coral'.
A. 'Sea Foam' (syn. *A.* 'Seafoam')	Low (– medium)	Medium stature, foliage to 600 mm tall, green leaves up to 520 mm long and 23 mm wide, white flowers, 47-54 flowers per inflorescence, flower heads 870 to 1200 mm tall.
A. 'Senna' PBR	Limited observations. Claimed to be sterile by some nurseries	Medium stature, foliage to 290 mm tall, deciduous even in mild New Zealand conditions, dark blue-green leaves with dark purple bases up to 310 mm long and 23 mm wide, dark purple-blue flowers, 24-55 or more flowers per inflorescence, flower heads 700 to 960 mm tall.
A. 'Surprise Storm'	Sterile? Limited observations	Dwarf stature, foliage to 150 mm tall, blue/green leaves variegated with white margin up to 190 mm long and 15 mm wide, blue flowers, occasional flowerer, 30-40 flowers per inflorescence, flower heads to 290 mm tall.
A. 'Timaru'	Low (–medium). Limited observations. Seems to be one of the few taller cultivars that produce relatively little seed.	Medium/tall stature, foliage to 730 mm tall, mid-green leaves with cream bases up to 700 mm long and 60 mm wide, dark purple-blue flowers, 193-369 flowers per inflorescence, flower heads to 1680 mm tall.
A. 'Tinkerbell'	Low – medium. Irregular flowerer, but can have moderate seed set when it does flower.	Dwarf compact stature, foliage to 200 mm tall, narrow green leaves that are variegated cream up to 220 mm long and 12 mm wide, occasional blue flowers, flower heads 400 to 508 mm tall.

Table 3. Cultivars of *Agapanthus* that set abundant seed.

Cultivar	Female fertility/seed set	Brief description
A. 'Black Pantha' PBR (syn. *A.* 'Black Panther')	High. Has been claimed by some nurseries to be "virtually sterile", but plants growing at ABG sets abundant seed.	Medium/tall stature, foliage to 550 mm tall, mid-green leaves with purple restricted to bases and up to 450 mm long and 55 mm wide, dark purple-blue flowers, 30-55 flowers per inflorescence, flower heads to 1350 mm tall.
A. 'Blue Blazer'	Medium (– high)	Medium stature, foliage to 300 mm or more tall, light green leaves with cream bases up to 390 mm or more long and 25 mm wide, dark blue flowers, 15-60 flowers per inflorescence, flower heads to 1070 mm or more tall.
A. 'Blue Dot'	High	Semi-dwarf stature, foliage to 340 mm tall, narrow light green leaves with cream bases up to 350 mm long and 15 mm wide, mid-blue flowers, 5–33 flowers per inflorescence, flower heads 400 to 770 mm tall.
A. 'Gayle's Lilac'	Low – high	Medium stature, foliage to 240 mm tall, narrow mid-green leaves with cream bases up to 255 mm long and 21 mm wide, soft blue flowers, 27-55 flowers per inflorescence, flower heads to 640 mm tall.
A. 'Gayle's Sapphire'	Medium – high	Medium stature, arching foliage to 370 mm tall, light green leaves with cream bases that are relatively long and narrow—up to 415 mm long and 16 mm wide, dark blue flowers, 8-24 flowers per inflorescence, flower heads 780 to 1000 mm tall.
A. 'Glen Avon' (syn. *A.* 'Glenavon', *A.* 'Fragrant Glen')	High	Medium/tall stature, foliage to 560 mm or more tall, mid-green and broad leaves with cream bases up to 650 mm long and 67 mm wide, rounded flower heads, lilac blue striped flowers, additional tepals (6-8, possibly up to 10) common, 46-185 or more flowers per inflorescence, flower heads 1000 m to 1330 mm tall, capsules commonly 4-locular (instead of the usual 3).
A. 'Lapis' PVR	Medium	Medium stature, dense foliage to 410 mm tall, light- to mid-green leaves with cream bases and up to 430 mm long and 20 mm wide, dark purple-blue flowers, 17-69 flowers per inflorescence, flower heads to 930 mm tall.
A. 'Moonshine'	Medium – high	Medium stature, foliage to 380 mm tall, light green leaves with cream bases and up to 270 mm long and 20 mm wide, very pale lavender (almost white) flowers, 22-63 flowers per inflorescence, flower heads to 690 mm tall.
A. 'Olive Darragh'	High – very high	Tall stature, foliage to 720 mm tall, blue-green leaves with cream bases up to 560 mm long and 46 mm wide, blue flowers, 45-150 flowers per inflorescence, flower heads to 1500 mm tall.
A. 'Peter Pan'	High – very high	Semi-dwarf stature, foliage to 330 mm tall, light- to mid-green leaves with cream bases up to 260 mm long and 17 mm wide, mid-blue flowers, 11-32 flowers per inflorescence, flower heads 500 to 820 mm tall. Some nurseries claim to have a sterile form of this cultivar.
A. 'Regal Beauty'	Medium (– high?)	Medium stature, dense foliage to 650 mm tall, mid-green leaves with cream bases up to 650 mm long and 40 mm wide, dark purple-blue flowers, 10-134 flowers per inflorescence, flower heads to 1180 mm tall.
A. 'Sea Spray'	Medium – high	Semi-dwarf stature, foliage to 240 mm tall, narrow mid-green leaves with cream bases up to 170 mm long and 11 mm wide, white flowers with soft purple blue flush, 20-25 flowers per inflorescence, flower heads to 570 mm tall.
A. 'Silver Baby'	Medium – high	Semi-dwarf stature, foliage to 340 mm tall, narrow blue-green leaves with cream bases up to 300 mm long and 16 mm wide, white flowers flushed pale blue on tepal tips, 18-33 flowers per inflorescence, flower heads to 630 mm tall.
A. 'Snowball' (syn. *A.* 'Snow Ball')	Medium – high	Dwarf stature, foliage to 310 mm tall, white flowers, flower heads 400 to 600 mm tall.
A. 'Snow Storm' (syn. *A.* 'Snowstorm')	High	Semi-dwarf stature, dense foliage to 305 mm tall, narrow yellow-green to mid-green leaves, white flowers, 60 flowers per inflorescence, flower heads 700 to 900 mm tall.
A. 'Streamline'	High – very high	Semi-dwarf stature, foliage 300 to 440 mm tall, narrow blue-green leaves up to 375 mm long and 13 mm wide, abundant mid-blue flowers, 8-33 flowers per inflorescence, flower heads 600 to 850 mm tall.
A. 'Wavy Navy'	High	Medium stature, foliage to 390 mm or more tall, light to dark green leaves up to 370 mm or more long and 32 mm wide, dark blue flowers, 17-78 flowers per inflorescence, flower heads to 990 mm or more tall.

Figure 13. *Agapanthus* 'Glen Avon', showing a flower with six tepals and six anthers. Photo: Murray Dawson.

Figure 14. *Agapanthus* 'Glen Avon', showing a flower with eight tepals and eight anthers. Photo: Murray Dawson.

Figure 15. *Agapanthus* 'Snowdrops', a low fertility cultivar showing pataloid conversion of anthers creating an inner whorl of additional floral parts. Photo: Murray Dawson.

Figure 16. *Agapanthus* 'Sarah' PVR, a low fertility cultivar showing a flower with ten tepals. Photo: Murray Dawson.

Table 1 shows that sterility/very low seed set among the 10 cultivars listed is closely associated with dwarf selections, variegated foliage, and/or abnormal flower parts including multi-tepals (low fertility can occur in plant groups where anthers and other floral parts are converted into additional petal-like structures, disrupting normal functioning) (Figures 15-16) and aberrant stigma/styles (Figure 17).

Figure 17. Split styles (arrowed) and deformed stigmas, aberrations typical in the flowers of the low fertility cultivar *Agapanthus* 'Sarah' PVR. Photo: Kerry Ford.

Agapanthus 'Dorothy Edwards' is the only medium height cultivar assessed so far that appears to have low female fertility (no doubt due to its extreme multi-tepals). There are no tall-growing cultivars yet confirmed as sterile or to set very little seed.

Table 2 lists thirteen cultivars that require further assessments. They have not been accepted as seedless or with the lowest seed set; nor have they been rejected as being too fertile.

The variegated cultivar, *A*. 'Tinkerbell' (Figure 18), presents an interesting case in assessing fertility. Like some of the other variegated cultivars, it is an intermittent shy flowerer, and sets little seed per plant on an average season. However, seed set of *A*. 'Tinkerbell' is moderate per flower head when it does flower.

Figure 18. *Agapanthus* 'Tinkerbell', a cultivar with variegated leaves. Photo: Barrie McKenzie.

We uncovered five additional cultivars (currently grown in Australia) that are not yet available in New Zealand. They are claimed to be sterile (*A*. 'Double Diamond' and *A*. 'Little Boy Blue') or of low female fertility (*A*. 'Cloudy Days' PBR, *A*. 'Lilibet' PBR, and *A*. 'Queen Mum' PBR).

Table 3 lists seventeen cultivars that have been consistently observed setting abundant seed. These confirmed high seed-setters are rejected from our low fertility lists.

Interestingly, a few cultivars rejected here (Table 3) have not lived up to low fertility claims made by some in the nursery industry. For example, *A*. 'Black Pantha' PBR was said to be "virtually sterile" but the material we assessed set abundant seed in the outdoor trials in Auckland Botanic Gardens.

Material of *A*. 'Peter Pan' that we studied also demonstrated heavy seed set. However, it seems that there are two selections under the name *A*. 'Peter Pan'; one fertile and one of low fertility, as some nurseries have claimed it to be sterile, self-sterile or with low seed set (e.g., Snoeijer, 2004; Dawson and Ford, 2012).

SEED PRODUCTION ESTIMATES

Seed production is important to estimate when assessing the weedy potential of fertile plants and to provide a comparison against selections with reduced seed production.

Accordingly, we have calculated some actual and theoretical seed production estimates based on mature plants growing in publically accessible sites in Auckland and Canterbury.

The tall-growing "wild-type" (*A. praecox* subsp. *orientalis*) typically has a three-locular seed capsule (and occasionally four-locular; Figure 19). Each typical locule has the capacity to physically house up to eight seeds: 8×3 = up to 24 seeds per capsule.

Figure 19. Dissected four-locular capsule of *Agapanthus praecox* subsp. *orientalis* providing a comparison of the dark, broad, presumed viable seed with light colored, smaller, inviable seed. Photo: Kath Stewart.

The number of seed capsules per flower head (inflorescence) were counted from several plants and multiplied by the number of presumed "viable" seeds (filled and black / dark brown colored) counted; this was compared with the theoretical maximum number of seeds that could be produced per head (based on a maximum of 24 seeds per capsule): 640 ("viable") to 4,200 (theoretical maximum) seeds per flower head. The range we obtained here is a reasonable fit with that provided by Barrett (2011) of "1,500-3,000 mostly fertile seeds per flower head".

The number of seed heads produced in a season ranged from 13-40 per "wild-type" plant and the capsules per head ranged from 64-175.

Because of the rhizomatous and spreading nature of agapanthus, clumps with reasonably defined boundaries between them were chosen and considered to correctly encompass the original plant. This resulted in seed production estimates of: 12,880 ("viable") to 86,160 (theoretical maximum) seeds per "wild-type" plant (clump) per season.

Seed production estimates of the low-growing, narrow-leaved dwarf types (as exemplified by the highly fertile *A*. 'Streamline'), and probably corresponding to *A. praecox* subsp. *minimus* parentage, are different. For these, there are less seeds per capsule (a maximum of 18 physical places), many more seed heads are produced in a season (64-147 per plant), and there are fewer capsules per head (10-25). Using these parameters, seed production estimates for high fertility dwarf selections range from: 19,200 ("viable") to

29,290 (theoretical maximum) seeds per plant per season.

Our estimate here of 19,200 "viable" seeds for a plant of *A*. 'Streamline' provides an interesting comparison with an average of 3.15 "viable" seeds produced per plant for *A*. 'Finn' PVR over one season (based on 85 dark colored seeds set from 27 young plants). This comparison highlights the relative propagule pressure in the environment of a high female fertility cultivar with a low fertility cultivar.

SEED GERMINABILITY AND LONGEVITY

Observations made at Manaaki Whenua Landcare Research have revealed that seed germinability of high fertility (open-pollinated) plants can approach 100%.

This is supported by Ford and Dawson (2010) who obtained germination rates of 80-100% for controlled outcrossed seed from *A. praecox* subsp. *orientalis* and 61-95% for outcrossed seed of the high fertility cultivar *A*. 'Streamline' (as female parents).

Ford and Dawson (2010) reported generally lower outcrossed germination rates for the low fertility cultivars they tested—65% for *A*. 'Sarah' PVR (as a female parent) and 25-74% for *A*. 'Finn' PVR, depending on what male pollen parent was involved. Auckland Botanic Gardens obtained a range of germination rates from 40-78% for seed collected from five open-pollinated cultivars.

We found that agapanthus seed germinates readily, as soon as it is mature (i.e., when the capsules dry and split open to expose the mature seeds for dispersal), and agapanthus seed appears to lack a dormancy period. Duncan (1998) states: "Seeds of all agapanthus species have a limited viability and are best sown immediately after ripening … Fresh seed normally germinates within 6 to 8 weeks."

We have not conducted independent seed germination longevity experiments to determine how seed germinability declines over following months or years.

QUANTIFICATION OF A LOW FERTILITY THRESHOLD IN AGAPANTHUS

Determining an "acceptable" boundary for low female fertility in any plant group that has competing weedy and horticultural values is problematic and somewhat arbitrary.

However, practical and clearly stated methods for quantitatively measuring fertility and establishing an "acceptable" threshold becomes important for horticulturally useful but potentially weedy plants subject to regulatory conditions. This is especially true for borderline low fertility cultivars of agapanthus that growers still wish to market in Auckland, in other areas of New Zealand, and potentially in other countries where agapanthus is also becoming weedy.

Ford and Dawson (2010) recommended applying to other purportedly sterile or claimed low fertility cultivars the benchmark they established for *A*. 'Finn' PVR, which had substantially reduced pollen viability, was found to be self-infertile, and had <10% outcross seed set (Ford and Dawson, 2010). Ford and Dawson's (2010) seed set percentages, derived from the results of artificial pollinations, were calculated by dividing the actual yield (number of "viable" seeds produced) by the total potential yield (number of ovules) in a capsule at maturity and did not factor in total seed production potential as shown later in this paper.

Here we advocate following the regulatory precedence set in the State of Oregon for *Buddleja* (a genus that also has competing horticultural and weedy values), which uses the definition "produces less than 2% viable seeds compared to fertile cultivars that were evaluated under the same conditions and location". Cultivars of *Buddleja* approved by Oregon may be propagated and sold if labelled "Seedless Butterfly Bush*" or "*Produces less than 2% viable seed." Within the context of their regulations, these are treated as effectively sterile. Otherwise, any plant listed as "butterfly bush" is assumed to be *B. davidii* and is prohibited entry, transport, purchase, sale or propagation in the State of Oregon (http://plants.usda.gov/factsheet/pdf/fs_buda2.pdf). Evaluation parameters for assessing this are described by the Oregon Department of Agriculture and Oregon State University (2011). They provide protocols that could be adapted here for agapanthus.

HOW TO CALCULATE "PRODUCES LESS THAN 2% VIABLE SEEDS COMPARED TO FERTILE CULTIVARS THAT WERE EVALUATED UNDER THE SAME CONDITIONS AND LOCATION" FOR AGAPANTHUS?

Although this sounds like a relatively simple task, several aspects need to be considered, including growing conditions, climate, abundance of pollen sources and pollination vectors, self- and cross-compatibility of plants, seed set, seed germination, seed production, and methods of calculating percentage viability.

As stated in the above definition, plants should be grown together under the same conditions and location. Plants should be well-established before assessing fertility (e.g., at least two years old), and replicate plants (e.g., a minimum of three) of each cultivar being assessed should be grown together, alongside several high fertility reference comparators. These reference comparators (standards) should include different accessions of typical tall-growing agapanthus (*A. praecox* subsp. *orientalis*), *A.* 'Streamline' (likely to be a selection of *A. praecox* subsp. *minimus*) as a low-growing high fertility reference cultivar, and probably *A. inapertus* to cover a range of taxa as pollen sources (e.g., planted at a rate of one fertile cultivar for every three plants under investigation). Flowering times of the reference plants should overlap with the cultivars being assessed to maximize the likelihood of cross-pollination.

Capsules for seed counts should be collected over the course of a season, as each matures but before they split open—to ensure no lost seed which would adversely affect the accuracy of the seed set determinations.

As explained previously, mature, dark colored filled seeds (more-or-less assumed to be "viable") can easily be distinguished from pale aborted seeds that are clearly inviable. Also, the number of ovules that can potentially set seed within a capsule is easy to determine by examining the material.

The difference in growth form and the number of potential seeds/capsule (= number of ovules) means that "like should be compared with like". Tall-growing, broad-leaved 24 seeds/capsule cultivars should be compared against fertile "wild-type" agapanthus, whereas smaller growing, narrow-leaved 18 seeds/capsule selections should be compared to *A.* 'Streamline' which as a known high-fertility cultivar is an ideal standard comparator.

Instead of determining seed viability of the reference plants each season when grown alongside the candidate cultivars, another option is to use a predetermined upper limit for seed viability percentages for the fertile reference standards (such as 95% viability, and to make this publicly available as part of the assessment criteria).

Determining seed set and seed viability per capsule of tall-growing agapanthus

For this calculation, seed from 72 capsules of one open-pollinated tall-growing plant was counted, and 581 seeds were found to be filled and dark colored. Percent seed set per capsule is determined by:

$$\left(\frac{581}{72 \times 24}\right) \times 100 = 33.6\% \text{ seed set/capsule}$$

If, for example, 95% of those dark, filled seeds are capable of germination, then the figure for percent seed viability per capsule would be:

$$0.336 \times 0.95 \times 100 = 31.9\% \text{ seed viability/capsule}$$

Seed set (in this example 33.6%) can be treated as an upper estimate of seed viability (here 31.9%) in the absence of seed germination trials.

Although based on real data, the figure here of 33.6% seed set was derived from a plant examined late in the season (Figure 20), which may have incurred some seed loss through collecting capsules that were well open.

Figure 20. Large plant in seed of *Agapanthus praecox* subsp. *orientalis*, from Diamond Harbour, Canterbury, June 2016. Photo: Murray Dawson.

A more rigorous survey of tall-growing agapanthus was undertaken in Auckland, where 100 open-pollinated seed heads were collected from plants growing around the city, and an average of 10 fully formed (dark colored) seeds in each capsule was obtained. This equates to an average of 41.7% seed set per (24-place) capsule (the range was 33-96%).

When artificially sib-crossed, Ford and Dawson (2010) reported an average of 74% seed set (54-96%) for five tall-growing accessions from Canterbury. Open-pollinated field conditions are likely to produce lower seed sets, as evidenced here.

Determining seed set per capsule of low fertility cultivars against a fertile standard

Using the same approach for determining percent seed set per capsule of a known low fertility cultivar (*A*. 'Finn' PVR), and assuming a maximum potential of 18 seeds/capsule:

$$\left(\frac{85}{43 \times 18}\right) \times 100 = 10.98\% \text{ seed set/capsule}$$

Choosing not to incorporate seed germinability, and using a percentage of 84.3% seed set per capsule for our *A*. 'Streamline' comparator, then to calculate percent seed set per capsule compared to a fertile cultivar:

$$(0.1098 \div 0.843) \times 100 = 13.02\% \text{ seed set/capsule against fertile comparator}$$

These results (10.98% and 13.02%) are well above the <2% threshold that we advocate here, even if we factor in a 74% seed germination rate for *A*. 'Finn' PVR (determined through controlled outcrossing by Ford and Dawson, 2010). Yet clearly *A*. 'Finn' has very low female fertility (Figure 21).

Figure 21. Rare capsule formation on *Agapanthus* 'Finn' PVR, a confirmed low fertility cultivar. Photo: Murray Dawson.

THE PROBLEM WITH THE ABOVE APPROACHES FOR DETERMINING FEMALE FERTILITY

Percentage seed set per capsule is easy to calculate by dividing the actual yield (number of filled, dark colored "viable" seeds produced) by the total potential yield (number of ovules) in a capsule at maturity.

Percentage seed germination is likewise a useful measure of viability, but is usually assessed only on the filled (dark colored) seeds and not the visibly inviable seeds (aborted seeds or unpollinated ovules).

Although the calculations thus far combine both of these female fertility measures (i.e., seed set per capsule and seed germination), they overlook overall female reproductive potential (including seed that never formed and whole capsule abortion).

The illustration above (Figure 21) visually reveals the limitations of the calculation methods so far. For low female fertility cultivars such as *A*. 'Finn' PVR, we can see that capsule formation is rare, in stark contrast to the tall "wild-type" agapanthus (cf. Figure 7, where capsules have formed on nearly every peduncle (flower/fruit stalk)—close to 100% capsule formation per head).

Within each capsule that develops to maturity, *A*. 'Finn' PVR has low seed set (a mean of 1.98/capsule, with a range of 1-5 seeds per capsule for 43 capsules that developed), and it is probably these few seeds that help ensure retention of those few capsules on to maturity (Our observations for some cultivars, including *A*. 'Finn' PVR, is that if no seed is set within a capsule, then that capsule is likely to abscise early in development compared to a capsule with viable seed set. Early capsule drop in low fertility selections is a desirable trait as it results in more tidy fruit stalks (peduncles) and highlights the sterility of the plant.). Hence, on a per mature capsule basis, you would never get less than 4.2-5.6% seed set (for one filled, dark colored seed to develop from a maximum of 18 or 24 ovules per capsule). No account is made so far of the early and mass abortion of capsules of low fertility selections such as *A*. 'Finn' PVR, which obviously greatly reduces the overall female reproductive potential.

In other words, per mature capsule estimates alone don't produce fully meaningful female fertility estimates for agapanthus—further calculations are needed.

THE PROPOSED SOLUTION FOR CALCULATING "PRODUCES LESS THAN 2% VIABLE SEEDS COMPARED TO FERTILE CULTIVARS THAT WERE EVALUATED UNDER THE SAME CONDITIONS AND LOCATION"

A more biologically meaningful approach is to determine seed production potential and seed viability together. Results can be expressed on an averaged per seed head basis, which largely overcomes differences in the age of plants (where older and larger plants produce more seed heads).

Although whole plant estimates of female fecundity—viable seeds produced per plant per season—remains a useful metric and one that is easily understood, this is likely to be less reliable than per seed head determinations as per plant counts are more dependent upon age and growing conditions. Furthermore, the rhizomatous nature of agapanthus clumps can make discrimination of old plants problematic when they have been planted closely together and become intermixed.

Determining seed set per head of low fertility cultivars against a fertile standard

Following this revised approach for *A*. 'Finn' PVR data, a working example is provided as follows: 27 (young) plants were counted, with a total of 117 seed heads, and 3,931 peduncles (flower/fruit stalks—an average of 33.6 peduncles per seed head). From the total number of peduncles, only 43 capsules formed—resulting in an incidence of 1.09% of the potential capsule production (and 0.37 capsules formed per head), based on the theoretical assumption that all peduncles have the potential to form fruit.

The final calculation incorporating capsule formation for *A*. 'Finn' PVR (and assuming here an 80% capsule formation rate for the fertile comparator) would then be:

$$[(0.1098 \times 0.0109) \div (0.843 \times 0.8)] \times 100 = 1.6\% \text{ seed set per head against fertile comparator}$$

In other words:

$$\frac{\text{Seed set/capsule} \times \text{capsule formation/head (} \times \text{ germination rate if known) of test cultivar}}{\text{Seed set/capsule} \times \text{capsule formation/head (} \times \text{ germination rate if known) of standard high fertility comparator}}$$

Or more simply stated (and in agreement with Rounsaville et al., 2011), relative female fertility is determined by:

(% seed set × % germination of low fertility test cultivar) ÷ (% seed set × % germination of standard high fertility comparator)

In this example, the 1.6% estimate of seed set per head compared to a more fertile comparator is below the proposed >2% viable seeds threshold.

For cultivars that exceed this 2% threshold, germination rates could be added to the assessment; if below the 2% threshold, germination rate would not need to be factored in.

DISCUSSION

From our agapanthus collections, we have provided a shortlist of ten cultivars that have consistently demonstrated low natural seed set (Table 1). Following the methodology outlined in this paper, a more stringent next step is to quantify the percent seed set of each.

If regulatory authorities adopted the <2% seed viability threshold advocated here that aims to lessen the weed risk of agapanthus on the environment, then a formal legal exemption process would be required to be enacted.

Acceptance of a <2% seed viability threshold will undoubtedly greatly reduce relative propagule pressure in the environment, and the example is given earlier of 19,200 "viable" seeds produced by one plant of the high fertility cultivar *A*. 'Streamline' versus 3.15 "viable" seeds produced for *A*. 'Finn' PVR. However, progeny arising from low fertility selections have the potential to be highly fecund and for sensitive ecological environments "seedless" cultivars should be recommended.

If formal quantitative assessments of agapanthus fertility are to proceed, we

recommend that a list of approved cultivars and clear assessment guidelines are made publically available (e.g., on the Auckland Botanic Gardens website for plants regulated by Auckland Council) and promoted by the horticultural industry. This should be a working list where new "certified" low fertility cultivars are added over time.

An example of an online working list is provided by the Oregon Department of Agriculture list of approved cultivars of butterfly bush (*Buddleja*) (www.oregon.gov/ODA/programs/NurseryChristmasTree/Pages/ButterflyBush.aspx).

In New Zealand, there is legislative precedence for exempting sterile cultivars from their weedy counterparts. *Calluna vulgaris* is included in the current National Pest Plant Accord, but double-flowered cultivars of it are excluded.

Similarly, the Government of South Australia have exempted sterile cultivars of *Gazania* as a Declared Plant from their Management Plan (Hunter, 2015). Abell and Layt (2015) document low seed set selections of *Rhaphiolepis*, compare them with weedy *R. indica*, and argue for the exemption of the low fertility cultivars in Australia.

Ford and Dawson (2010) recognized the potential to breed novel low fertility or sterile agapanthus through non-GMO chromosome manipulations (to produce tetraploids and then triploids), and Barrett (2011) successfully induced tetraploids as part of her thesis work. Murray Dawson and Peter Heenan at Manaaki Whenua Landcare Research undertook an independent breeding programme that began in 2012, and a similar approach has been followed by Ed Morgan of Plant & Food Research who began 2010/2011. Several promising candidates have been selected from these programmes, which are in the process of being evaluated. They will be named as new cultivars if or when commercially released to the public.

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Ornamental pumpkin selection©

D. Grant[a]

Hybrid Seed Company New Zealand Ltd., 326c Patumahoe Road, RD 3, Pukekohe 2678, New Zealand.

Pumpkins or members of the *Cucurbitaceae* family have a number of uses. Ornamental uses include autumn decoration with Halloween types (Jack-o'-lanterns, carving, painting, displays and stackers), chucking pumpkins, giant pumpkins for competition and giants for boat racing. To complete the picture Cucurbits are well-known for their culinary use for baking, soups, pies and processing for canning (pies and baby food).

The *Cucurbitaceae* family contains the economically important species: *Citrullus lanatus* (watermelon), *Cucumis sativus* (cucumber), *Cucumis melo* (melon) and *Cucurbita*. The genus *Cucurbita* contains five domesticated species. *C. pepo* (summer squash, crookneck squash, marrow, acorn, gourd, pumpkin), *C. moschata* (winter squash), *C. maxima* (winter squash and pumpkin), *C. argyrosperma* (winter squash) and *C. ficifolia* (fig-leaf gourd). *Lagenaria siceraria* (bottle gourd) is another species from the *Cucurbitaceae* family which is cultivated for ornamental uses.

Ornamental cucurbit types can be classed into the following categories (Figures 1-4):

- Giant pumpkins (*C. maxima*): 150 to 250 kg.
- Big or extra-large pumpkins (*C. maxima*): 20 to 70 kg.
- Large sized Halloween (*C. pepo*): 10 to 20 kg.
- Medium sized Halloween pumpkins: 7 to 10 kg.
- Small to medium sized pumpkins: 3 to 7 kg.
- Small and pie sized pumpkins: 1 to 3 kg.
- Miniature pumpkins: less than 0.45 kg.
- Whites and other colours: range of sizes.
- Speciality or novelty types includes: super freaks, turbans, stackers, and coloureds.

Figure 1. *Cucurbita pepo* germplasm collection.

[a]E-mail: dougg@hybridseed.co.nz

Figure 2. Mini pumpkin germplasm.

Figure 3. Ornamental pumpkin display.

Figure 4. Super freak pumpkins.

Large-type ornamental gourds (*Lagenaria siceraria*) include the bottle gourds, Apple gourds, Snake gourds, Club types and Swan type gourds. Major uses are decoration, containers, utensils and musical instruments.

Breeding objectives of the Hybrid Seed Company programme for ornamental pumpkins includes developing Halloween and Super Freak type F_1 hybrid pumpkins for

appearance (size, shape and skin colour), disease tolerance, adaptability, plant habit and yield.

Pumpkins and squashes are herbaceous annuals with long vines or runners although bush plant habit forms exist. *Cucurbita* species are monoecious with bright yellow-orange flowers with separate pistillate and staminate flowers on the same plant. Flowers are pollinated by insects mainly honey bees and bumble bees. For breeding, self and cross pollinating is done by hand using paper bags to exclude insects form pollen contamination. Parent seed increases and small hybrid productions are carried out in cages with insect mesh. Larger seed productions are carried out in isolation in field blocks.

Germplasm used in the breeding programme is sourced from all over the world and also from material shared between collaborators to our programme. This includes the use of heritage-type varieties. Selections are made from segregating and back cross populations to develop inbred lines. Interspecific crossing has been used to incorporate important characteristics such as disease tolerance. *Cucurbita ecuadorensis* has tolerance to papaya ringspot virus, watermelon mosaic virus and powdery mildew. *Cucurbita okeechobeensis* has tolerance to powdery mildew and cucumber mosaic virus but is susceptible to watermelon mosaic virus I and II.

Inbred lines produced are tested for combining ability and experimental hybrids are then developed. Evaluation of experimental hybrids are carried out in trials throughout the world. Breeding lines are screened for disease reaction to powdery mildew, downy mildew and fruit rots.

Iran, a significant horticultural country©

N. Askari[a]

Department of Plant Sciences, University of Jiroft, P.O. Box 364, Jiroft, Iran.

Abstract

Iran is the second largest country in the Middle East and North Africa (MENA) region with respect to the number of inhabitants and economy. A production of 12 million tonnes of fresh fruits and 20 million tonnes of vegetables ranks Iran as 11th and 5th world fruit and vegetable producer, respectively. Pistachio (*Pistacia*), grape (*Vitis*), and apple (*Malus*) are the main fruits. In 2015, cucumber (*Cucumis sativus*) was the main greenhouses crop (84.1%) with 1.5 million tonnes. Almost 10% of the vegetables are produced in the greenhouse. About 10,000 flower and plant nurseries are producing ornamental plants using 3,500 ha outdoor and 2,200 ha indoor. Several provinces produce high quality medicinal plants. Iran is the main world saffron producer with 351 tonnes yearly.

GEOGRAPHY AND CLIMATE

Iran is located between 25 and 40N in latitude and 44 and 64E in longitude. With a surface of 1,648,000 km^2 it is the 17th largest country in the world. Iran has 2440 km coastline and 5894 km boarders with a number of countries, viz., Turkey, Afghanistan, Pakistan, Azerbaijan, Armenia, Turkmenistan, and Iraq. The population of Iran is 80 million. This makes it the second largest country in the Middle East and North Africa (MENA) region. The highest point and the lowest point of Iran are Damavand mountain (5610 m) and the area around the Caspian Sea (-28 m) respectively (Heshmati, 2007).

Iran is an arid (73%) or semiarid (24%) country. The Caspian Sea plain is the most humid region of the country. The mean yearly precipitation of Iran is 240 mm with maximum amounts in the Caspian Sea plains, Alborz and Zagros slopes with more than 1,800 and 480 mm, respectively. The variation in precipitation (<100 mm in 28%, 100-250 mm in 47%, 250-500 mm in 16%, 500-1000 mm in 8%, >1000 mm in 1%) shows a wide variety of climates (Ghaffari et al., 2015). The minimum and maximum average temperatures are 4 and 30°C in Northeast and Southeast, respectively. Annual potential evapotranspiration (PET) in Iran is 2100 mm (3-fold world average) with a minimum of 830 mm and a maximum 3627 mm (Dinpashoh, 2006). Iran's suitability for agriculture is ranked as very good 0.4% of the surface, good 2.2%, medium 7.9%, poor 11.4%, very poor 6.3%, unsuitable 60%, and excluded areas 11.9% (Mesgaran et al., 2017).

HORTICULTURE IN IRAN

Fruit production

The production of 12 million tonnes of different fruits ranks Iran as the 11th world major fruit producer (FAO, 2013). Iranian habitats support about 8000 species of plants (belonging to 167 families and 1200 genera), from which almost 1700 are endemic. So rich genetic resources are available for fruits breeding and 60 different fruits are produced in Iran. Table 1 shows the production and value of major fruits in Iran.

The quality of Iranian pistachio is unique as the centre and first pistachio producer of the world. Totally 2,600,000 ha horticultural fields are producing different horticultural crops all over of the country. Table 2 shows the top ranked of Iranian fruits in world according (FAO, 2013).

[a]E-mail: na.askari@yahoo.com

Table 1. The main fruits production and value of Iran.

Fruit crop	Weight (tonnes)	Value (USA Dollar)
Apple	434,000	188,000,000
Pistachio	184,000	1,650,000,000
Date	168,000	227,000,000
Kiwifruit	93,000	43,000,000
Pomegranate	14,000	12,000,000
Citrus	11,000	5,700,000
Almond	2,710	240,008

Table 2. World ranking of some fruits in Iran (FAO, 2013).

Crop	Ranking	Crop	Ranking
Pistachio	1	Cherry	3
Pomegranate	1	Almond	3
Apricot	2	Walnut	3
Date	3	Apple	3

Ornamental plants production

Iranian floriculture industry consists of over 10,000 flower and plant nurseries. The area used for flower production is around 3500 ha outdoors and 2200 ha in the greenhouse (95% plastic tunnels and 5% glasshouses). Cut flowers are the most important ornamental plants produced in 1800 ha. In the second and third position are potted plants with 300 ha and ornamental trees and shrubs with 100 ha, respectively. The most common cut flowers in Iran are *Gladiolus*, rose (*Rosa*), *Polianthus*, *Dianthus*, and *Chrysanthemum*. According to official data, nearly 30-40% of the ornamental plant wholesale business is running via cut flower wholesale markets. Iran is a large country and transport is one of the most important issues for all growers. Transportation costs are nevertheless not too high (Azadi and Van der Ploeg, 2016).

Vegetable production

Iran is the 5th world vegetable producer with 20 million tonnes production (FAO, 2013). Around 767,000 ha is used for growing vegetables. Table 3 shows the Iranian worldwide ranking of some vegetables (FAO, 2013). In 2015, the area of greenhouse vegetable production was 8000 ha. Cucumber, tomato and pepper were the main greenhouse crops with 74.8, 7.4 and 5.2% of area, respectively. In addition, the major vegetables were cucumber, tomato (*Solanum lycopersicum*), and pepper (*Capsicum annuum*) with 84.1, 8.7, and 3.1% of total greenhouse vegetable production (Karimi et al., 2015).

Table 3. World ranking of some vegetables produced in Iran (FAO, 2013).

Crop	Ranking	Crop	Ranking
Watermelon	3rd	Pumpkin and gourd	4th
Eggplant	3rd	Tomato	5th
Cucumber	3rd	Onion	5th

Medicinal plants production

Over 2400 species of medicinal plants are growing in Iran. 90% of the world's medicinal species occur in Iran. Saffron and cumin are the main medicinal plants. Iran is the first saffron producer worldwide with 92,000 ha area and 351 tonnes yearly production. Damask rose, tea, tarragon, peppermint are other medicinal plants of Iran (Karimi et al., 2015).

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Special thanks to Dr. Geert-Jan De Klerk, Wageningen University, Dr. Mehdi Massoumi, EuroTiss, Dr. Pejman Azadi, The President of Iranian Ornamental Plant Society, Dr. Mahmoud Hossein Nia, Ministry of Jihad-E-Agriculture of Iran, Dr. Mahmoud Roozban, Tehran University, Dr. Korush Vahdati, Tehran Universty, Dr. Javad Hadian, Shahid Beheshti Universty, Kees Eigenraam, Rhizopon, for their support and contributions.

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Take control over horticulture by listening to the genes©

P. Balk[a]

Binnenhaven 5, 6709AA Wageningen, The Netherlands.

INTRODUCTION

Long before changes in the condition of cultured plants become visible, changes on the gene activity level already occurred; changes that originate from varying climate conditions or infection by pathogens. Also changes provoked by horticultural measures, on the climatological level, by nutrition, or application of agrochemicals.

NSure is a company specialised in detecting early changes in the activity of genes related to specific traits. NSure proved that analysis of these early changes adds value to decision support systems. One can act early and before it is too late. In what follows, a few examples of applications are being discussed in order to illustrate how this approach functions in practice. But first, some background information about the methodology is given.

METHODOLOGY

To get insight in changes in gene activity, NSure applies so-called Next Generation Sequencing (NGS). This technology results in knowing what genes are active at a certain moment and to what extent they are active. By comparing for instance plants that have or have not been treated with certain agents, one can investigate which metabolic pathways are being triggered as a result of this specific treatment. Upon considering that plants are ever changing during their lifecycle, one needs a sound trial design to make the correlation and draw the right conclusion. That is where expert knowledge becomes a prerequisite. Based on experience three different focus areas have been defined where the technology adds value. The first focus is on physiological switches. Early recognition of cold tolerance, bud break potential and exact ripening stage helps stakeholders to meet logistic challenges and optimise yields. The second focus point is early warning. First signs of upcoming diseases, before symptoms occur, can be recognised and harvests can be saved by acting on the knowledge gained. The third focus area of NSure is the so-called bioresponse. Effects of for instance biostimulants are being studied in detail. Insight in the mode of action of these agents is obtained and product claims supported. Moreover, once it is known what genes are most affected by the applied agent, activity measurements of such genes can assist optimisation of the application. Different formulations or dosages can be easily and quickly compared, application and reapplication moments can be optimised.

Regarding the latter, there is a connection with the focus area physiological switches. Maximal efficacy often depends heavily on the actual stage of the plant. Detailed insight in such a relevant stage increases the success rate of the application.

Once gene activity indicators are being found via NGS, their activity can be measured routinely by PCR. This method is focused on activity measurements of single genes and is more cost effective in comparison to before mentioned NGS. PCR-based measurement of gene activity for a pre-defined set of genes, the indicators, is called a molecular test.

EXAMPLES

In what follows two molecular tests are being highlighted: the ColdNSure and the recently released BreakNSure. In addition, an example of a mode of action study is described.

The ColdNSure test is being used by nursery managers producing Pine and Spruce seedlings. The users are situated mainly in Scandinavia. In autumn, at the end of the growing

[a]E-mail: info@nsure.nl

season, one- or two-year-old seedlings become dormant and frost tolerant. At a certain moment, seedlings are being packed and put in frozen storage until next spring. Then they are distributed and planted at their final location. Seedlings cannot be stored in frozen storage until they are fully hardened. Otherwise, upon replanting, severe losses are being observed.

By using the ColdNSure test one can get certainty about full frost-tolerance. As can be seen in Figure 1A, the switch from frost sensitive to frost tolerant is realised within a single week. This switch can be recognised in the activity pattern of certain genes (Figure 1B). By measuring the activity of these genes, one can conclude whether a given batch of seedlings is ready for storage or not yet (Stattin et al., 2012).

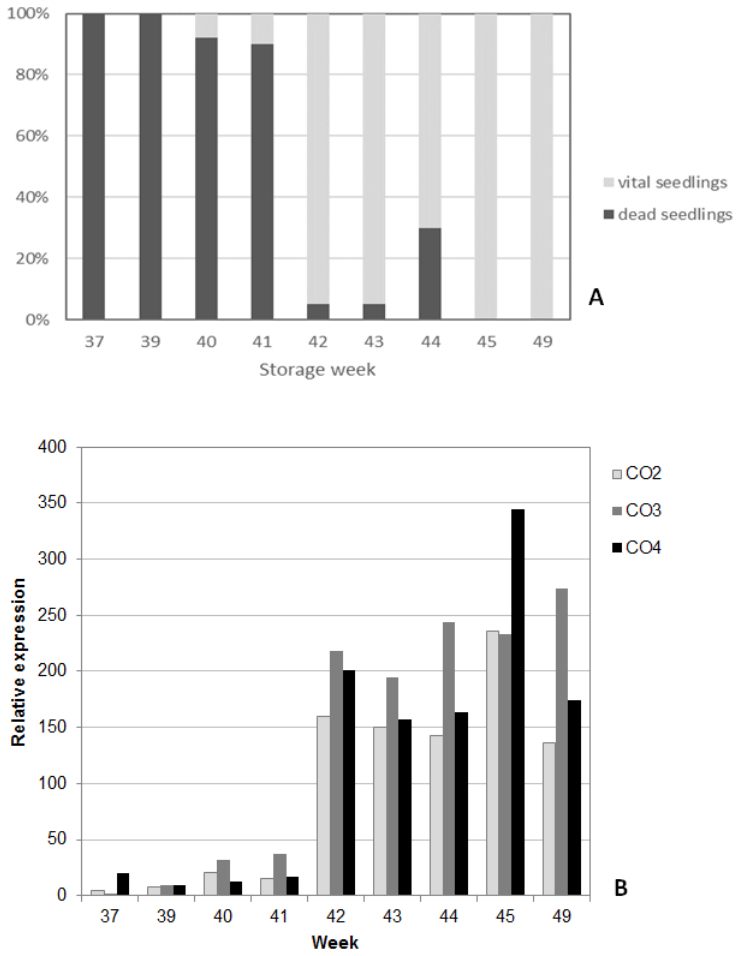

Figure 1. A: Vitality of *Picea abies* seedlings after storage and upon replanting in relation to the moment of transfer to frozen storage. From Week 41 on, seedlings can be stored safely. B: A clear switch in the activity of specific genes coincides with the indicated moment where seedlings can be transferred safely.

The BreakNSure test is meant to define the proper moment to apply bud break enhancing agents in kiwifruit (*Actinidia*) production. Maximal and synchronous flowering is gained by the application of such agents but only when the vines are in the right stage. Gene activity measurements assist in defining the proper stage. Figure 2A shows that the optimal moment of application varies, in this case between the years. Suboptimal application results in a considerably lower number of bud break, flowers, and subsequently fruit. A gene index, based on activity measurement of carefully selected genes, can be used to advise the proper

moment of application (Figure 2B). Since 2016 this test is being used for the application of HiCane by Zespri growers in New Zealand. At this moment NSure is evaluating the use of the test for optimisation of the application moment of alternative bud break enhancing agents, both in Italy and New Zealand (Hoeberichts et al., 2017). In addition, the BreakNSure test is being developed for other fruit, including sweet cherry and table grape (Balk et al., in press).

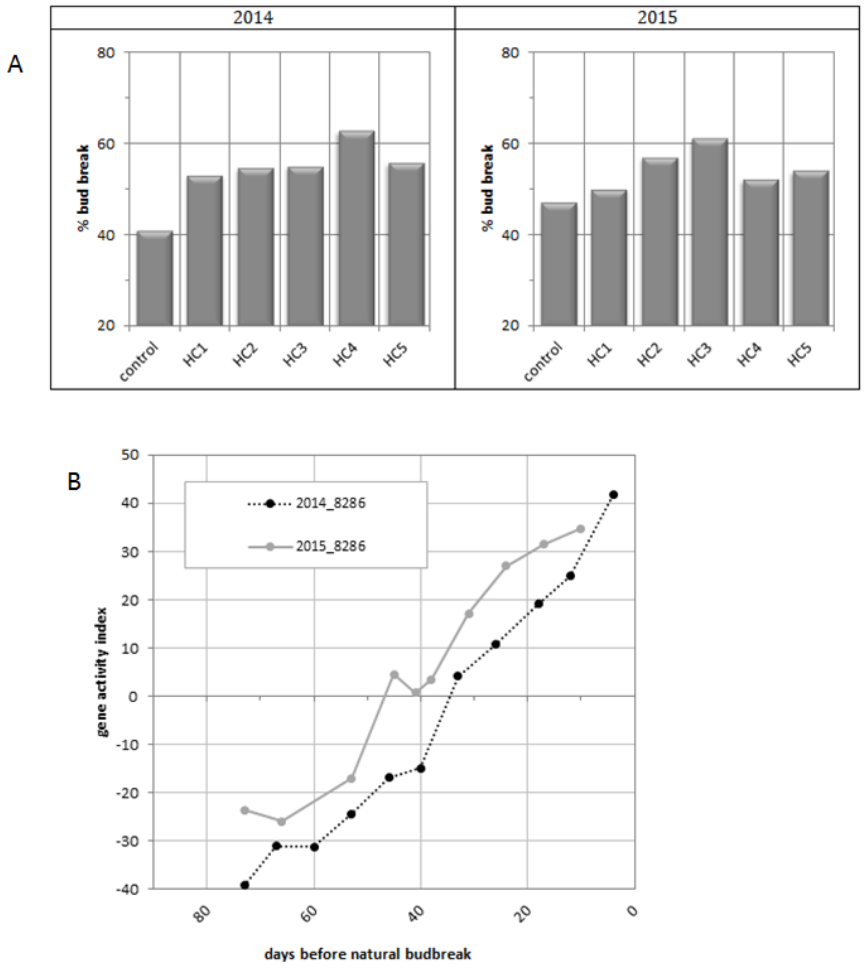

Figure 2. A: HiCane application at five subsequent moments results in increased percentages of bud break. However, a distinct optimal moment of application can be observed: moment 4 in 2014, moment 3 in 2015. B: By using a gene activity index, one can define a range of scores where HiCane can be applied with optimal result.

Any of NSure's molecular tests consists of two steps, sampling and analysis. The easy sampling method developed by NSure is can be used on location and is done by the customer. Analysis of the collected sample is performed at a nearby laboratory. Results are delivered within 2 working days.

Gene activity measurements can also be applied for gaining insight into the mode of action of, for example, a biostimulant. This particular biostimulant enhances wound healing in tomato plants after deleafing (Figure 3A). The risk of infections is reduced by stimulated scar tissue formation. Already 6 h after application, considerable changes in gene activity were observed. The nature of these genes point towards the direction of an enhanced abscisic acid (ABA) mediated response. Figure 3B shows three of such genes, all involved in the well described ABA response. Scientific evidence for stimulation of scar tissue formation

mediated by ABA (Leide et al., 2012) in combination with the gene activity data provides evidence that this specific biostimulant indeed promotes wound healing via an enhanced ABA mediated response.

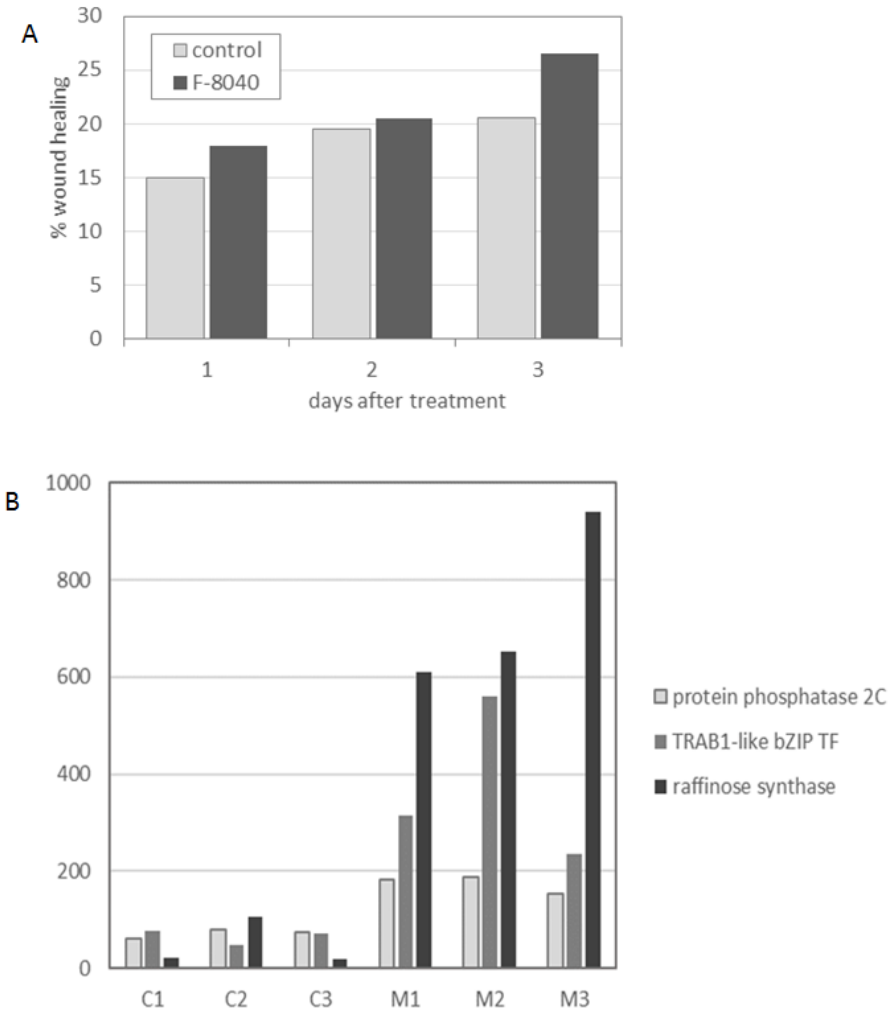

Figure 3. A: The Biostimulant F-8040 stimulates wound healing in tomato. Shortly after application positive effects can be observed. B: Among numerous affected genes, several related to the response to abscisic acid were observed. The activity of three such genes are displayed here in triplicate samples (C = Control, M = Treated with F-8040).

CONCLUSION

Focus on gene activity provides insight into what is going on inside a plant in preparation of changing performance. The above examples show that activity measurements of specifically selected genes may assist agricultural practice. Production is optimised and spoilage can be actively reduced. Gene activity measurements therefore fit perfectly well in a more sustainable agricultural practice: know when to act and at the earliest stage.

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Plant trials in the Netherlands and Europe©

R. Houtman[a]

Secretary Trials Committee, Royal Boskoop Horticultural Society, Boskoop, The Netherlands.

HISTORY

The Koninklijke Vereniging voor Boskoopse Culturen [Royal Boskoop Horticultural Society (RBHS)] has a long history in assessing plants (Figure 1). The society was founded in 1861 with the main goal "to put the correct names to the plants grown." The board members used to visit nurseries themselves to check plants and correct naming. The Trials Committee was founded in 1895 and the first four awarded plants all received an "Award of Merit". Among those were *Sambucus racemosa* 'Plumosa Aurea' and *Spiraea japonica* 'Anthony Waterer'; still widely grown and still recommended.

Figure 1. Koninklijke Vereniging voor Boskoopse Culturen logo.

Since its founding the Trials Committee is an important branch of the RBHS. Other branches of the Society are the Dutch Plant Collections (http://www.plantencollecties.nl/), various publications and the Harry van de Laar Garden (http://www.sortimentstuin.nl/). In co-operation with the Dutch Dendrology Society (NDV), the yearbook *Dendroflora* is published. All trial reports, as well as articles about (mainly) woody plants and their use are published in *Dendroflora* (Figure 2).

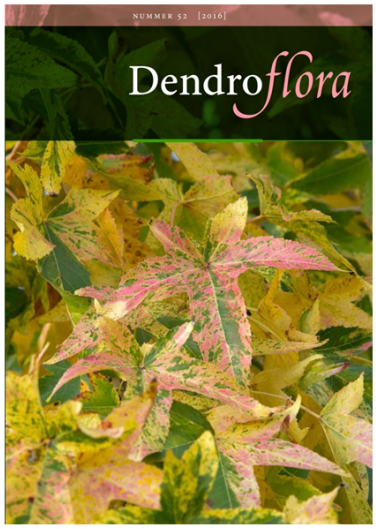

Figure 2. Dendroflora.

The Trials Committee is formed by growers, traders, and consumers (both

[a]E-mail: info@sortiment.nl

professional and private) from all parts of the Netherlands.

TRIALS

Field trials

In the past 120 years many new plants have been assessed and awarded by the Trials Committee. These trials were initially started to inform growers, traders, and retailers. As a society of growers and traders, informing the general public wasn't the main goal. This has changed over the years.

The basic type of trial conducted by the RBHS is the so-called "Field Trial". A Field Trial always concerns one cultivar, new to the market that is planted in the field (in a batch of 10 plants). Each plant is trialled according to standard criteria that basically have not changed during the committees' history: ornamental value, suitability as a garden plant or for amenity use, health, winter hardiness, and differences to similar cultivars. Apart from these criteria, special criteria for specific plant groups can be added. Each plant is assessed as many times as is needed during the year to come to a final verdict. The following awards are possible: KVBC-Award Bronze, KVBC-Award Silver, and KVBC-Award Gold. Among the hundreds of awarded plants are many familiar ones: *Acer palmatum* 'Garnet' (First Class Certificate; 1962), (*Buddleja* 'Pink Delight' (First Class Certificate; 1985), *Chamaecyparis lawsoniana* 'Stewartii' (First Class Certificate; 1906), *Cornus kousa* 'Satomi' (First Class Certificate; 1986) (Figure 3) and *Ilex aquifolium* 'J.C. van Tol' (Award of Merit; 1904), to name but a few.

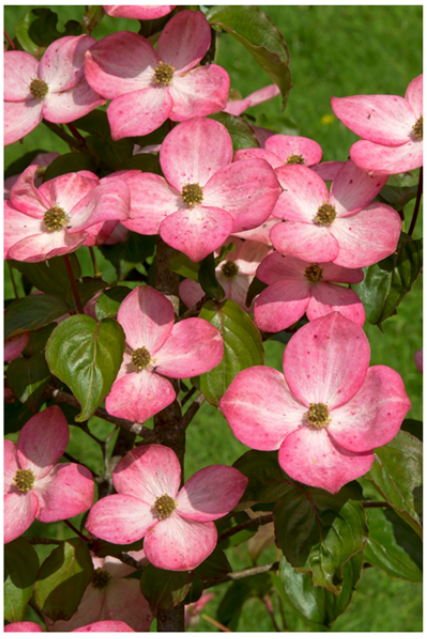

Figure 3. *Cornus kousa* 'Satomi' First Class Certificate, 1986.

More recently, cultivars like *Choisya* × *dewitteana* 'Londaz', White Dazzer® Mexican orange blossom (KVBC-Award Gold, 2015), *Ilex crenata* 'Icoprins11', Dark Green® Japanese holly (KVBC-Award Silver, 2015) and *Spiraea betulifolia* 'Tor Gold', Glow Girl® birchleaf spirea (KVBC-Award Silver, 2016). In the past Field Trials were done in the nurseries of the applicants. Since 2013 the RBHS has an area in the Sortimentstuin Harry van de Laar in Boskoop where trial plants can be planted.

Trade show trials

The RBHS Trials Committee assesses plants at the two main Dutch trade shows.

Starting in 1990, new plants were assessed at the Plantarium Trade Show in Boskoop (August). Since 1998 new plants are also assessed at the GrootGroen+ Trade Show in Zundert (October). Contrary to the Field Trials these Trade Show Trials are more or less snapshots. Each plant has to be assessed in a brief moment, the day before the show opens. Although the basic criteria are the same, the Trade Show Trials are a light weight version of the Field Trials. Plants can be awarded a medal (certificate) in Bronze, Silver, or Gold. On top of these awards a best new plant is chosen at each show.

Comparative trials (Star trials)

The first records of assessments of groups of cultivars belonging to one genus or species date back to the early 1940s when various groups of *Rhododendron* were trialled. This was the start of what is now the most important type of trials by the RBHS: the Comparative trials, usually called Star trials.

Before planting a Star trial, as many cultivars of a genus or species are collected. They are then propagated at the same time and later planted as a Star trial, thus assuring all plants in the trial have the same cultivation history. Depending on the type of plant, three to five plants per cultivar are planted. Apart from the area in the Sortimentstuin Harry van de Laar, Star trials are planted in the nurseries of members of the RBHS. Once planted the Trials Committee starts assessing the plants, again using the same basic criteria that go for the Field trials. A very important aspect of the Star trials is that plants are also compared to each other. Usually the plants are divided to colour, size, or shape. Goal is to award the best plants in each group, provide advice to growers, traders, retailers, and the general public which plants to choose. Unlike the Field trials and Trade show trials, the awards are given in "stars": *** = excellent, ** = very good, * = good and o = surpassed by other cultivars with similar ornamental value, but better qualities. Finally an "s" can be awarded, meaning this is a plant for special purposes. In practise the "s" is usually given to a cultivar with a unique feature; for example a pendulous cultivar in a range of upright shrubs.

During about 75 years of Star trials the RBHS has assessed thousands of cultivars. Some of the more important Star trials were: *Acer* (Japanese maples), 1969; *Berberis*, 1972; *Clematis* (large-flowered), 1985; *Deutzia*, 1991; *Fraxinus*, 1989; *Hamamelis*, 2002 (Figure 4); *Mahonia* (usually called Berberis in the USA.) (*M. aquifolium*, *M. repens*, *M. ×wagneri*), 2004; *Potentilla fruticosa*, 2011; *Prunus*, 1990; *Symphoricarpos*, 2012; *Viburnum*, 1998; *Weigela*, 2007 (Figure 5); and *Wisteria*, 1997.

The RBHS is not unique in performing these kinds of trials. In other European countries plants are assessed in a similar way. In 2002 this resulted in an international co-operation, called Euro-trials.

Figure 4. *Hamamelis* × *intermedia* 'Aphrodite'; *** in the 2002 trial of *Hamamelis*.

Figure 5. Euro-trial of *Weigela* in Stoneyford, Ireland, 2011.

Euro-trials

In several European countries plants are assessed primarily on ornamental value, suitability as a garden plant or suitability for amenity use, health, winter hardiness etc. In February 2002, co-operation between the Netherlands and Germany in trialling plants was established and it was agreed that cultivars of *Hydrangea paniculata* (Figure 6) would be the first group to be trialled internationally. The German trials committee is formed by the Bund deutscher Baumschulen (BdB) backed by the Bundessortenamt (German Plant Variety Rights Office). Before collecting and propagating the plants, co-operation was sought with the Royal Horticultural Society (RHS) and the French Agro Campus Ouest (University of Angers).

Figure 6. Euro-Trials *Hydrangea paniculata* in Boskoop, The Netherlands, 2007.

These four initial parties agreed on the following: participating organisations must be independent and not commercially tied to the horticultural industry. In this way, the highest levels of objectivity can be and are maintained.

Because fashion, trends, and local preferences vary between countries, it is quite possible that a cultivar that is rated very highly in one country, will not receive an award in another. All organisations have trial committees that consist of growers, traders, and gardeners. These committees will judge the plants at various times through the year. Of course each organisation carries out trials according to their own standards. However, because the data must be exchangeable, a high level of standardisation of documents is maintained. When rating plants, scores on a scale from 0 to 10 are used: 0 is the worst and 10 is excellent. All committee members are free to write comments on their lists and these comments help when discussing the final rating for each cultivar. Apart from judging the

plants, another goal of trialling plants is to make sure the assessed cultivars are true to name. To avoid erroneous interpretations, incorrectly labelled cultivars will be regarded “not assessed”.

After the trials have ended, all participants are free to write publications according to their own tradition. In the Netherlands, for instance, the RBHS will publish the Dutch report in *Dendroflora*. In addition to the national reports one overall report is published in English. This report contains all the results from all participants so that readers are able to see the results per cultivar in one view.

The aims for setting up Euro-trials are simple. It is more meaningful to co-operate and find ways to trial the same plants at the same time under different climatic and cultural circumstances. Professional growers will benefit from the results of Euro-trials. Of course each country has a home market, but pan-European trade in plants is now much greater and it is becoming increasingly important to have information to support this. Of course anyone who is interested can compare the specific circumstances in their own gardens with the results at a trial site that most closely matches their own garden.

Participants agreed to have a maximum of two trial sites per country. Even though the first Euro-trial was planted on only six sites, the aim of Euro-trials was to have as much variation in soil, hardiness zone, annual precipitation and pH as possible.

As a whole, Euro-trials are coordinated by the RBHS. When starting new Euro-trials, other organisations will co-ordinate these by rotation. In this way the work will be spread evenly over all participating organisations. Further the organizations each carry the costs for their national part of the Euro-trials. To cover overhead costs each organization pays an annual contribution.

The Euro-trial of *H. paniculata* was a good project to set the precedent for future Euro-trials. Plants of 34 cultivars were collected, propagated and planted in four participating countries. After the successful start to the first Euro-trial, other countries showed interest in participating. In 2006 the Austrian Höhere Bundeslehr- und Forschungsanstalt für Gartenbau (HBLFA), based in Vienna, joined the Euro-trials. In summer 2006 the second Euro-trial started. Fifty-seven cultivars of *Buddleja* were propagated and they were planted in spring 2007. The plants were judged in 2008, 2009, and 2010. This particular trial was coordinated by the BdB and the final results were published in 2012. A third Euro-trial was coordinated by the RHS: *Weigela* (Figure 5). This trial focused especially on coloured-leaved cultivars. In 2010 a new participant entered the Euro-trials group: the Irish semi-governmental organisation, Teagasc. In 2011 the fourth Euro-trial started. Nineteen cultivars of *Vinca minor* were planted to be assessed from 2012 until 2015. Meanwhile a seventh participant entered Euro-trials—the Belgian Proefcentrum voor Sierteelt (PCS). This national research station already had a history in assessing plants, so it was only a small step to join Euro-trials. However, due to lack of funding, the PCS had to temporarily leave the Euro-trials since 2015. In 2013 National Finnish research station LUKE in Piikkiö, Finland, joined Euro-trials.

In Spring 2012 the most prestigious Euro-trial so far started. The French collected and propagated 65 cultivars of *Hibiscus* (mainly *H. syriacus*) (Figures 7 and 8). In Spring 2014 these were delivered and planted on trial sites in the participating countries. The Euro-trial most recently started is the trial of *Physocarpus* (Figure 9). All plants were collected and propagated in the Netherlands and delivered to the trial sites late autumn 2016. Judging these plants will start in Summer 2017; the final report is expected in 2019 or 2020.

Figure 7. Discussion about *Hibiscus*, Vienna, Austria, 2016.

Figure 8. Euro-trial *Hibiscus*, Ellerhoop, Germany, 2017.

Figure 9. Euro-trial *Physocarpus*, RHS Wisley, United Kingdom, 2017.

In 2017 preparations for a seventh Euro-trial are being made (Figure 10). In this trial low-growing taxa of *Spiraea* will be assessed. The Finnish research station, LUKE, will co-ordinate this project.

Figure 10. The Euro-trials group in Piikkiö, Finland, 2014.

Since the first international trial ended and several trials are ongoing, the participants are eager to continue the process. Each year the participants hold an annual meeting. During these meetings all possible Euro-trials related topics are discussed, as well as proposed new trial subjects.

In the past years, considerable work has been done to develop Euro-trials into a highly effective co-operation between leading horticultural organisations in Europe. A lot of work still has to be done and all parties will learn from each other during the process. But our mutual goal, to test and publish objective information about the best cultivars for different parts of Europe, is steadily being reached (Figure 11).

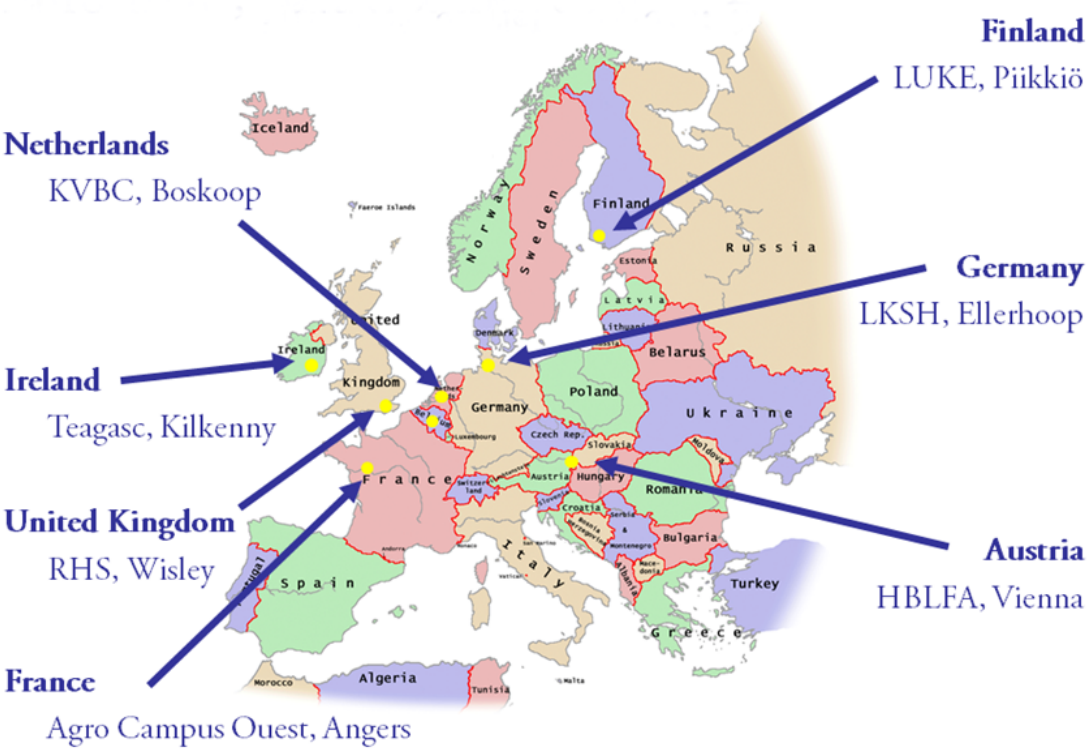

Figure 11. Current locations of Euro-trials (2017).

Negative hydrostatic pressure is an unnoticed but significant source of contamination in tissue culture©

N. Askari[1,a] and G.-J. De Klerk[2,b]

[1]Department of Plant Sciences, University of Jiroft, PO Box 364, Jiroft, Iran; [2]Wageningen UR, Plant Breeding, Wageningen, The Netherlands.

INTRODUCTION

Plants are characterized by a negative hydrostatic pressure, brought about by transpiration and by capillary activity of xylem vessels (Taiz and Zeiger, 2010). Because of this, a stem that is being cut sucks up what is nearby. Often this is air but it may also be liquid. The diameter of the xylem vessels is 50-100 µm, so when the liquid contains bacteria (that are typically 0.5-5.0 µm), they will enter deeply into the tissue (Askari et al., 2014; De Klerk et al., 2014). To our knowledge, this alleged source of contamination has never been examined.

MATERIALS AND METHODS

Lily (*Lilium*) scales were detached from bulbs that were submerged in either water or 0.03% NaClO. It had been established before that 0.03% NaClO does kill all bacteria in liquid medium. After that, explants were cut from the scales and cultured for 12 weeks under standard conditions to regenerate bulblets (Figure 1; Aguettaz et al., 1990). Contamination was scored weekly: after 5 weeks hardly any additional contamination was observed.

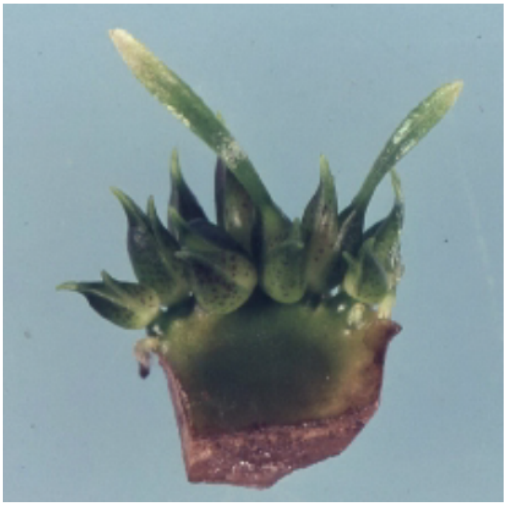

Figure 1. Bulblets regenerating from lily scale explants.

RESULTS

Detaching scales from bulbs that were submerged in a solution of acid fuchsin showed that the scales did suck up neighboring liquid (Figure 2). Detaching scales from bulbs submerged in sterilising liquid (0.03% NaClO) strongly reduced contamination (Figure 3). This shows that sucking up of liquid is a source of contamination. NaClO had no effect on the regeneration percentage and the number of regenerated bulblets but the weight of the regenerate bulblets was ca. 20% higher (Figure 4).

[a]E-mail: na.askari@yahoo.com
[b]E-mail: geertjan.deklerk@wur.nl

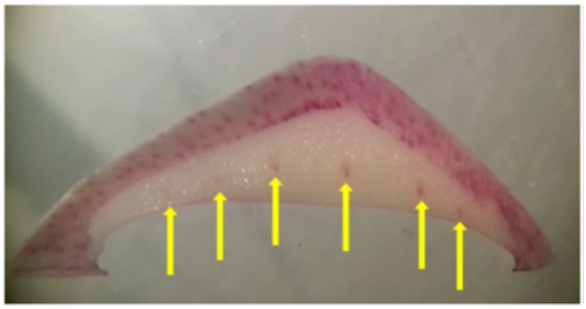

Figure 2. When scales were detached from bulbs submerged in a solution of acid fuchsine, the dye penetrated within seconds for ca. 1 cm into the scale. This demonstrates the occurrence of negative hydrostatic pressure in lily scales.

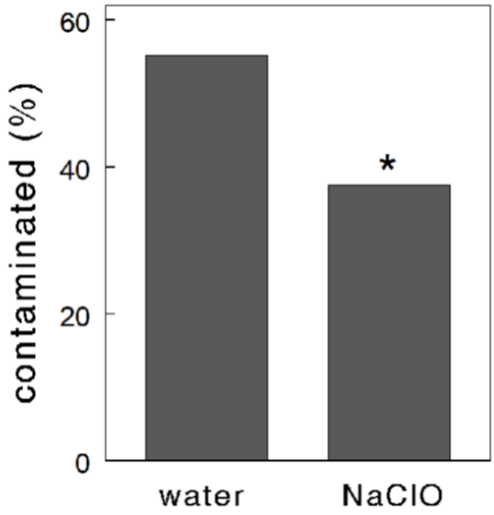

Figure 3. When scales were detached from bulbs submerged in 0.03% NaClO instead of water, contamination was strongly reduced.

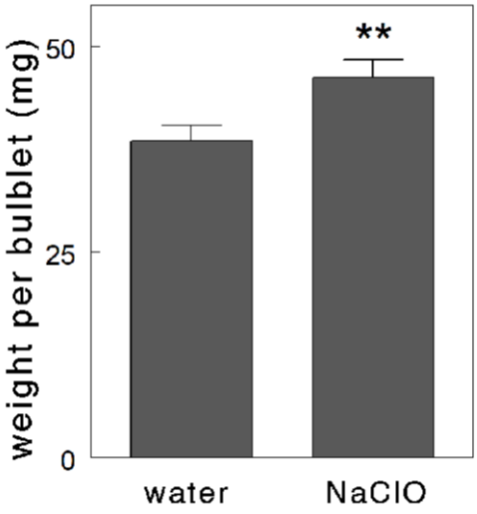

Figure 4. The bulblets regenerated from scale segments cut from scales that had been detached when submerged in 0.03% NaClO, had a significantly higher weight.

DISCUSSION AND CONCLUSION

In conclusion, the negative hydrostatic pressure is a major source of contamination. This problem can be easily overcome by detaching the scale from bulbs submerged in 0.03% NaClO. It should be noted that microorganisms are sucked up deep into the tissue so that they escape from the disinfectant during surface sterilization. It should also be noted that the extent of contamination depends on the presence of liquid at the cut surface and will be low when the explant is relatively dry. The same mode of contamination will occur in all plants and also when preparing conventional cuttings.

ACKNOWLEDGEMENTS

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Keeping nutrients in their place: irrigation management to enhance nutrient retention in container production©

R.T. Fernandez[a]

Department of Horticulture, Michigan State University, East Lansing, Michigan 48824-1325, USA.

Irrigation is essential for container production and is typically applied daily during the peak growing season. Under-irrigating plants can result in reduced growth, a longer production period, increased pest pressure on weakened plants, and plant death from desiccation. Since the visible symptoms of under-irrigating are very apparent, irrigators tend to err on the side of applying too much irrigation rather than risk the consequences of under-irrigating. However, there are consequences of over-irrigating that are as deleterious as under-irrigating even though the connection is often unnoticed. Over-irrigation can cause reduced growth, a longer production period, increased pest pressure due to a more favorable environment, and poor plant quality. Over-irrigation in combination with heavy fertilization can cause overly vigorous plants, also reducing plant quality and often resulting in higher pest pressure on the lush growth. Scheduling irrigation to avoid both over- and under-irrigation will improve productivity.

While the problems due to under-irrigating are a result of a lack of adequate water availability for plant uptake, over-irrigation can cause this and other problems. Over-irrigation can cause a lack of water uptake in plants due to anaerobic conditions resulting in loss of proper root function, although this is rare since most container substrates have large pores and drain/aerate quickly. More commonly over-irrigation leaches nutrients from containers thus reducing plant nutrition, delaying flowering and reducing plant growth and quality. If irrigation water has alkalinity issues, as many water sources do, over-irrigating can further exacerbate nutrition problems by increasing substrate pH above the proper range causing some nutrients to be unavailable for plant uptake. Over-irrigation combined with heavy fertilization to counteract high leaching leads to even greater problems. Leached nutrients are not only a waste of money but can result in significant environmental problems that increase the probability of regulatory action. Eutrophication is a proliferation of biological organisms in aquatic systems due to excess nutrients, particularly phosphorus and nitrogen, that can cause serious economic and environmental damage. For example toxic algal blooms have affected the drinking water of nearly half a million people who rely on Lake Erie for their water source off and on over the past decade.

Over-irrigation wastes water, often relatively high quality water. Water is highly undervalued in most areas of the U.S. but that is quickly changing. Although some areas of the U.S. pay a substantial price for irrigation water, the cost of water for most irrigators is the cost to pump it from its source. This is another factor that makes it easy to over-irrigate, however, there are hidden costs to water. Over-irrigation can increase fertilizer costs, although this is often minimal. Most importantly over-irrigation can result in a longer production cycle and all of the costs associated with growing the same crop over a longer period such as more labor, more pesticides, more fertilizer, land costs (fewer crop turns per year), interest, longer return on investment, more water and others.

Some important considerations to keep in mind when implementing leaner irrigation practices are the source water quality (especially soluble salts and alkalinity), substrate properties, and local rainfall patterns. Monitoring of substrate electrical conductivity (EC), for soluble salts, and pH, as an indicator of the effect of water alkalinity, using methods such as the Pour-Thru method (Link 1), should be routine and are essential when using lean irrigation practices. Water with high soluble salts may require periodic leaching if leachate soluble salt levels exceed recommended values of 0.5 to 1.5 dSiemens m^{-1} (mmhos cm^{-1}). If

[a]E-mail: fernan15@msu.edu

leachate soluble salts are consistently high and water does not have high soluble salts it is possible that the fertilizer rate is too high, consider saving some money by backing down on fertilizer rates. Water with high alkalinity will slowly increase the pH of container substrates, possibly above recommended ranges of pH 4.7 to 6.5 depending on the crop and substrate, resulting in the need to apply sulfur compounds or acid-forming fertilizers to reduce pH. In this case irrigating less reduces the problem.

When deciding how much irrigation water to apply, it is important to understand how much water a container can hold. Some terms to know when determining this are:

- Container capacity: the maximum amount of water a container substrate will hold after gravitational drainage.
  - Typically 45-60%
- Unavailable water: water that is tightly bound to the substrate and cannot be extracted by a plant.
  - Typically 25-35%
- Available water: the amount of water that can be extracted by a plant.
  - = Container capacity – Unavailable Water
- Readily available water: the amount of water that can be easily extracted by a plant.
  - Typically 25-35% of available water
- Permanent wilting point: when the plant has extracted all of the available water and is not able to regain turgor.

To calculate how much water a container can hold is pretty straightforward if you know the actual volume (not trade size) of the empty container (usually provided by the manufacturer), the percent moisture at container capacity and the percent unavailable water. The latter two values can be provided by a good substrate supplier or from a substrate analysis by a substrate/soil testing lab. The available water is the difference between these two percentages. It is important to know that as the percent substrate moisture content decreases below container capacity, it becomes more difficult for the plant to take up the remaining water to a point (unavailable water) where the plant can no longer extract moisture. Moisture content closer to container capacity means the plant is more easily able to extract water. Readily available water is somewhere above unavailable water but where depends on plant species and substrate properties. Fortunately, we don't even want to let water get to the end of readily available water. A good target is to irrigate somewhere between 5 and 10% below container capacity.

The amount of irrigation needed to replace available water and for various container sizes for a container substrate with a high container capacity is shown in Table 1. In this example, container capacity is 65% substrate volumetric moisture content (SVMC) and unavailable water is at 25% SVMC making available water of 35%. SVMC is just the volume of water in a substrate divided by the total volume occupied by the substrate (including solids, air and liquids). Rarely do we allow plants to get to the point where all of the available water is depleted, when this happens it is usually the result of applicator error. Obviously irrigating to replace all of the available water is excessive, even the most extravagant irrigator will question irrigating #1 containers with 1.6 acre-inch of water.

Since volumetric water content is based on the percent of the total volume of the container, it is does not matter what the available water content is when determining irrigation rates if we base our calculations on the amount of water depleted (used by the plant or evaporated). For example, when you go from container capacity (65% SVMC in the previous example) to 55% SVMC, 10% SVMC lost, this is calculated as 10% times the total container volume not 10% times the available water. Calculating any % SVMC loss is in relation to the container volume, not the % available water, so it is based on container size, not the substrate. Knowing the % available water is important because it lets you know the maximum amount of water the plant can extract before the permanent wilting point and the maximum amount at the extreme you would ever apply to a container.

Table 1. Determining the maximum amount of irrigation can be applied to replace all available water and 10% depletion below container capacity before leaching occurs based on container size for a substrate with 65% volumetric substrate moisture content (SVMC) at container capacity with 35% available water. Calculations based on 100% land available per acre using overhead irrigation with 100% distribution uniformity. Values will be different for individual plant irrigation (drip or spray stake).

Trade container size[1]	Container diameter (inch)[1]	Container volume (gallon)[1]	Volume 35% available water (gallons container^{-1})[2]	Irrigation to replace 35% available water (acre-in)[3]	Irrigation to replace 35% available water (gallons acre^{-1})[4]	Irrigation to replace 10% (acre-in)[5]	Irrigation to replace 10% (gallons acre^{-1})[4]	Irrigation to replace 5% (acre-in)[6]	Irrigation to replace 5% (gallons acre^{-1})[4]
1	8	1	0.35	1.6	43,676	0.46	12,479	0.23	6,239
3	11	3	1.05	2.6	69,304	0.73	19,801	0.36	9,901
5	11.875	3.7	1.30	2.7	93,343	0.77	20,955	0.39	10,478
7	15	7.5	2.63	3.4	93,176	0.98	26,622	0.49	13,311
10	16.5	10.3	3.61	3.9	105,753	1.11	30,215	0.56	15,108
15	18.375	13.5	4.73	4.1	111,764	1.18	31,933	0.59	15,966

[1]Values obtained from manufacturer web site- varies by manufacturer and container.

[2]Volume available water = container volume × % available water (35%).

[3]Irrigation to replace available water (acre-inch) = gallons available water × 231 (convert gallons to cubic inches) / (π r^2).

[4]Multiply by 27,154 to convert acre-inch to gallons.

[5]Irrigation to replace 10% depletion (acre-inch) = container volume x 10% × 231 / (π r^2).

[6]Irrigation to replace 5% depletion (acre-inch) = container volume x 5% × 231 / (π r^2).

A start on determining how much irrigation to apply can be made using the same information. A commonly reported irrigation practice is to irrigate #3 containers with 0.75 acre-inch per day during the peak growing season. This ends up being the amount to irrigate when 10% of the water is lost from a #3 container (Table 1). This may seem like a good rate and falls within the above mentioned 5-10% depletion, but this still has not taken plant water use and evaporation into consideration. A better understanding of plant daily water use will allow further refinement in irrigation scheduling.

Scheduling irrigation based on leaching fraction is a practice that has been around for a long time. With leaching fraction we are basically determining how much water was used over a certain period plus a percentage above that to cause a certain amount of leaching. To determine leaching fraction:

1) Just before a normally scheduled irrigation event place 5 to 10 potted plants each into a larger container, such as a bucket, that fits tightly around the pot so that the only water that can enter the bucket has to go through the substrate.
2) Make sure there is a large enough gap between the bottom of the bucket and the pot so that water is not reabsorbed by the substrate through capillary action.
3) Do the same thing except with the same size but empty pot, no plant and no substrate.
4) Run your irrigation system for the normal period.
5) Measure the amount of water collected in each bucket.
6) Average the amount collected in the buckets with plants and the average collected in the buckets without plants, divide the average with plants by the average without plants, multiply by 100 and that is your leaching fraction (Table 2).

Table 2. Leaching fraction is determined by measuring the water leached from container plants and water collected from the same size container without a plant during a normal irrigation period. Average the water collected from the container plants and divide by the average collected without a plant, multiply by 100 to get the leaching fraction.

Container #	1	2	3	4	5	6	7	8	9	10	Avg.
Plant collected (mL)	83	96	98	93	84	91	74	87	72	69	85
Empty collected (mL)	891	866	841	877	804	856	821	902	883	832	857
Leaching fraction (%)	9	12	9	10	8	11	8	10	11	11	10

If the leaching fraction is too high, reduce the time of application and retest at the next irrigation period. Increase the application time if the leaching fraction is too low.

Most recommendations are to target a leaching fraction of 10 to 20%, however, this is based primarily on greenhouse crops. For nursery production, at least in the eastern U.S., leaching fractions should be less than 10%. The reason for the difference is that plants in nursery production periodically receive rain and this will often leach out salts enough to keep EC at acceptable levels, this obviously cannot happen in a greenhouse. Since part of a leaner irrigation program includes monitoring EC regularly, leaching fraction can be increased periodically if EC begins to rise too high and then returned to a lower level. There is no need to continuously leach salts (fertilizers) from nursery crops unless there is a problem with high salts in the irrigation water. Again, if leachate EC is consistently high and the levels of soluble salts in the irrigation water are low, the fertilizer rate may be too high resulting in the need to leach out the fertilizer you paid for. In our research nursery we have been irrigating at zero leaching fraction for years and have not had problems with soluble salts building up even during 2007, which was a very dry summer in Michigan with only 11 inches of rain during our growing period. Nurseries in more arid regions and those with high soluble salts in their irrigation water considering irrigating at low leaching fractions must

monitor leachate EC at least monthly to make sure salts are not building up in container substrates.

There are other ways to determine irrigation schedules including evapotranspiration models, plant-based measurements and soil/substrate moisture determination. Evapotranspiration models are based on weather conditions and a crop factor (crop coefficient) to determine how much water is lost through evaporation and transpiration over a period of time. These have been very effective for crop production where there is little diversity in the type of plant grown and crop coefficients can be determined for a limited number of plant species. Unfortunately the great diversity of plants grown at a typical nursery makes it difficult to use evapotranspiration models. Plant-based measurements give a direct indication of the plant water status. These measurements are often tedious and require trained technicians and relatively expensive equipment and are rarely used in production agriculture. Some soil/substrate moisture sensors have been used for decades in field production. Some of them, such as tensiometers, are inexpensive and accurate. Unfortunately tensiometers are not practical for nursery substrates. Sensors using time domain reflectometry or capacitance are becoming common for measuring soil/substrate moisture in commercial nurseries.

We have used both types of sensors to determine SVMC in our research projects. Currently we are using capacitance sensors due to the lower cost. We determine our irrigation schedule daily by measuring the SVMC 30 to 45 minutes following irrigation to determine container capacity, measure again just before the next irrigation period, calculate the difference and use that to determine how much irrigation to apply to replace what was used. This is done through a datalogger/controller so all of these measurements and calculations are done in milliseconds. This type of control is not limited to a small research nursery. Wireless sensor networks have been developed and effectively deployed to use sensors to monitor and control irrigation in commercial nurseries (Link 2). Irrigation can be scheduled to apply the amount used by a crop over a period of time, such as daily as we do in our research nursery, or it can be scheduled to maintain SVMC above a certain set-point. For set-point control, once you know container capacity you can determine the % water depletion to allow (between 5-10%) and use that as the set-point. To determine container capacity, irrigate so that leaching occurs, wait 30 to 45 minutes, record the SVMC at this time as the container capacity. Subtract the % water depletion desired from the container capacity and use that as the low set-point, container capacity will be the high set-point. The system can be programed to turn irrigation on once the low set-point is reached and off just before (it will take some time for the irrigation water to move to the sensor area) the high set-point is reached.

We have done research on scheduling irrigation based on plant water use for many years (Links 3, 4, 5). By knowing the plant daily water use, we can begin to create groupings of plants with similar water use in order to organize them into similar irrigation blocks. A potential grouping based on plant daily (averaged over the season) irrigation requirements for plants grown in #3 containers at our research nursery is shown in Figure 1. Since local and daily climatic conditions will affect water use, the amount of irrigation to apply will vary depending on time of year and location but the relative water use should be similar.

Daily water use for plants grown in #3 containers exceeded 10% SVMC water use (0.73 acre-inch irrigation to replace) for only 1 out of 37 species: *Buddleja davidii* averaged 0.95 acre-inch of water use per day (Figure 1). This was also greater than our control irrigation rate of 0.75 acre-inch, another important reason to know plant water use- you could possibly be under-irrigating. Most plants (25 out of 37) (see Table 3 for list of plants studied) evapotranspired less than 5% SVMC (0.44 acre-inch for a #3 container). Irrigating to replace exactly the amount of water used daily for each crop is impractical but grouping plants with similar water requirements will allow more efficient irrigation scheduling.

Irrigating with low to zero leaching not only reduces the amount of water used for irrigation but reduces the amount of runoff created. In our studies where we've use 0.75 acre-inch as our standard control irrigation rate and zero or deficit irrigation as treatments, depending on species we have been able to reduce the amount of irrigation applied by 30 to

70%, the amount of runoff water generated by 30 to 85% and the amount of nitrate and phosphate in runoff by 30 to 50%. Out of all of the plants we've used, only 3 species had lower growth compared to the control, 4 species had greater growth, and there was no difference for the rest. We did find reduced foliar nutrient levels for several plants irrigated with the control rate compared to the other treatments, indicating that we were leaching fertilizers out of the containers before the plants could acquire them. To attain results as high as this might be difficult for a commercial nursery but substantial reductions in water use, runoff generation and nutrient loss could certainly be attained.

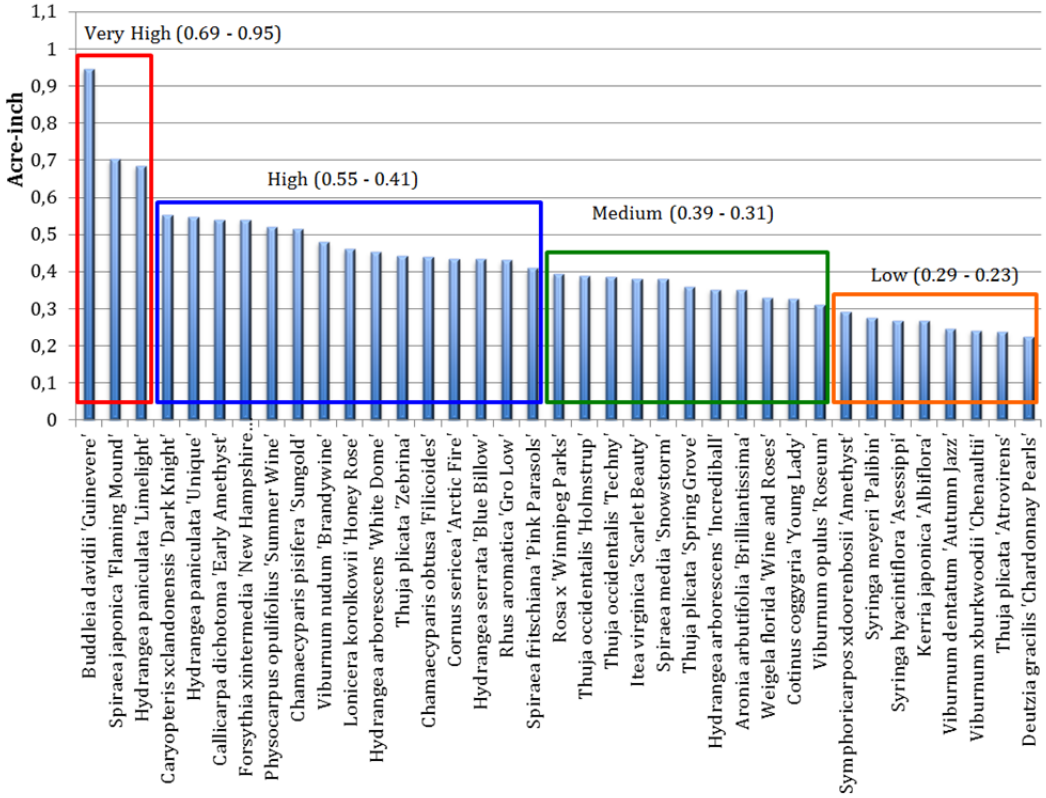

Figure 1. The average plant daily water use in acre-inches averaged over one growing season for 37 taxa of plants. Possible groupings of plants based on relative water use are shown by the different colored boxes. Water use will vary with climatic conditions and location but relative performance of species should be similar.

Water does cost money but the cost per gallon can be negligible to quite expensive depending on where a nursery is located. The cost of water for nurseries in most of the eastern U.S. is the pumping cost. At our research nursery it costs us $0.032 to grow a plant in a #3 container for one season. By reducing our water use by 30 to 70%, as we've shown we can do in our research, we save $0.009 to $0.022 per plant. We can also save approximately $0.005 in fertilizer by reducing leaching. That comes to $0.014 to $0.023 per plant or approximately $150 to $240 per acre. Yes, water itself is cheap, at least the way it is currently valued. However, the cost of improperly using water can be very high, especially for problem crops. Link #6 is to an excellent article that describes how a large commercial nursery saved $1 per square foot of production on a problem crop when they used sensor-based irrigation compared to their normal management practices. When they reduced the amount of water applied they decreased the time it took to produce the crop by an average of 6 months, which reduced all of those associated costs such as labor, fertilizer and pest management. They also reduced losses from the normal range of 10-30% to none. So water may be cheap but not the consequences of misuse.

Table 3. Alphabetical list of plants studied in daily water use experiments shown in Figure 1. Plants were grown in #3 containers in an 85% pine bark to 15% sphagnum peat (by volume) substrate) at the Michigan State University Horticulture Teaching and Research Center in Holt, Michigan.

Plant	Water use group
Aronia arbutifolia 'Brilliantissima'	Medium
Buddleia davidii 'Guinevere'	Very high
Callicarpa dichotoma 'Early Amethyst'	High
Caryopteris × clandonensis 'Dark Knight'	High
Chamaecyparis obtusa 'Filicoides'	High
Chamaecyparis pisifera 'Sungold'	High
Cornus sericea 'Farrow' (Arctic Fire® red twig dogwood)	High
Cotinus coggygria 'Young Lady'	Medium
Deutzia gracilis 'Duncan' (Chardonnay Pearls® deutzia)	Low
Forsythia × *intermedia* 'New Hampshire Gold'	High
Hydrangea arborescens 'Abetwo' (Incrediball® smooth hydrangea)	Medium
Hydrangea arborescens 'Dardom' (White Dome® hydrangea)	High
Hydrangea macrophylla subsp. serrata 'Blue Billow'	High
Hydrangea paniculata 'Limelight'	Very high
Hydrangea paniculata 'Unique'	High
Itea virginica 'Morton' (Scarlet Beauty™ Virginia sweetspire)	Medium
Kerria japonica 'Albiflora'	Low
Lonicera korolkowii	High
Physocarpus opulifolius 'Seward' (Summer Wine® ninebark)	High
Rhus aromatic 'Gro-Low'	High
Rosa 'Winnipeg Parks'	Medium
Spiraea fritschiana 'Wilma' (Pink Parasols® spirea)	High
Spiraea japonica 'Flaming Mound'	Very high
Spiraea media 'Darsnorm' (Snow Storm™ spirea)	Medium
Symphoricarpos × *doorenbosii* 'Kordes' (Amethyst™ coral berry)	Low
Syringa meyeri 'Palibin'	Low
Syringa × hyacinthiflora 'Asessippi'	Low
Thuja occidentalis 'Holmstrup'	Medium
Thuja occidentalis 'Techny'	Medium
Thuja plicata 'Atrovirens'	Low
Thuja plicata 'Grovepli' (Spring Grove® arborvitae)	Medium
Thuja plicata 'Zebrina'	High
Viburnum × burkwoodii 'Chenaultii'	Low
Viburnum dentatum 'Ralph Senior' (Autumn Jazz® arrowwood viburnum)	Low
Viburnum nudum 'Bulk' (Brandywine™ withered viburnum)	High
Viburnum opulus 'Roseum'	Medium
Weigela florida 'Alexandra' (Wine and Roses® weigela)	Medium

In summary, when scheduling is done properly it can result in more efficient water use, nutrients retained where they are available for plant uptake, reduced problems with alkaline water, reduced plant losses, improved plant growth and quality, shortened production cycle, less runoff generated and less off-site movement of water and nutrients. Below are a list of links referred to in the article along with a few more that should be of interest to anyone wanting to improve their irrigation and water management practices.

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Additional reading

http://msue.anr.msu.edu/uploads/235/67987/resources/6-4FactSheetTemplateOverhead_Sprinkler. pdf

http://msue.anr.msu.edu/uploads/files/6-28FactSheet_WaterApplicationTOM.pdf

https://content.ces.ncsu.edu/using-the-pourthru-procedure-for-checking-ec-and-ph-for-nursery-crops

https://www.researchgate.net/publication/228506613_Water_Conservation_Growth_and_Water_Use_Efficiency_of_Container-grown_Woody_Ornamentals_Irrigated_Based_on_Daily_Water_Use

https://www.researchgate.net/publication/231520634_Container-grown_Ornamental_Plant_Growth_and_Water_Runoff_Nutrient_Content_and_Volume_Under_Four_Irrigation_Treatments

https://www.researchgate.net/publication/259674301_Implementation_of_Wireless_Sensor_Networks_for_Irrigation_Control_in_Three_Container_Nurseries

https://www.researchgate.net/publication/283703373_Irrigating_Based_on_Daily_Water_Use_Reduces_Nursery_Runoff_Volume_and_Nutrient_Load_Without_Reducing_Growth_of_Four_Conifers

http://www.nurserymag.com/article/nm0612-precision-irrigation-benefits/

http://www.watereducationalliance.org/

Green roofs: plant production and installation methods©

D.B. Rowe[a]

Department of Horticulture, Michigan State University, East Lansing, Michigan 48824, USA.

INTRODUCTION

Green roofs involve growing plants on rooftops, thus replacing the vegetated footprint that was destroyed when the building was constructed. They can be categorized as 'extensive' or 'intensive' systems depending on the plant material and planned usage for the roof area (Dunnett and Kingsbury, 2004; Getter and Rowe, 2006).

Extensive green roofs typically are not accessible to the public and may not even be visible. Because of their shallower media depth [<15 cm (6 in)], plant species are limited to herbs, grasses, mosses, and drought tolerant succulents such as *Sedum.* In addition, they usually require less maintenance than intensive green roofs and can be built on slopes. In contrast, intensive roofs are designed to be similar to landscaping found at natural ground level for park-like settings that are usually open to the public. They typically utilize a wide range of plant species that may include trees and shrubs, require deeper media layers [usually >15 cm (6 in)], require more maintenance, and are generally limited to flat roofs. Shallow extensive roofs are much more common than the deeper intensive roofs due to costs and weight restrictions (Figure 1).

Figure 1. A: An intensive green roof at the Schlossle Galerie in Pforzheim, Germany. B: Portion of a 10.4 acre extensive green roof on a truck assembly plant at Ford Motor Company in Dearborn, Michigan.

Factors to consider when selecting plants include design intent, aesthetic appeal, environmental conditions, and media composition and depth that is available for planting (Getter and Rowe, 2006). A wide array of taxa are potential choices for intensive roofs because of deeper media depths and the likelihood of available supplemental irrigation. In contrast, drought tolerance is one of the most limiting factors on extensive green roof systems given their shallow media depths and usual reliance on natural precipitation events to sustain plant life.

BENEFITS

Prior to human disturbance, most rainwater falling on land infiltrated into the ground or was returned to the atmosphere via evapotranspiration. However, as humans continue to build roads, parking lots, buildings, and other impervious surfaces that replace forests and agricultural fields, the necessity to recover green space is becoming increasingly critical to

[a]E-mail: rowed@msu.edu

maintain environmental quality. In the USA it is estimated that 10% of residential developments and 71-95% of industrial areas and shopping centers are covered with impervious surfaces and these percentages keep increasing.

Green roofs can help alleviate this problem. Establishing plant material on rooftops provide numerous environmental, ecological, and economic benefits (Getter and Rowe, 2006; Oberndorfer et al., 2007). They reduce stormwater runoff, conserve energy in individual buildings, mitigate the urban heat island on a community scale, sequester carbon (Getter et al., 2009), increase the longevity of roofing membranes, and can be utilized to grow locally produced food (Czerniel Berndtsson, 2010; Eksi et al., 2017; Getter et al., 2009; Whittinghill and Rowe, 2012). They also can reduce air and noise pollution, increase biodiversity in urban areas, provide habitat for wildlife, and result in a more aesthetically pleasing environment in which to work and live while improving human health (Eakin et al., 2015; Rowe, 2011).

Probably the single greatest ecosystem service that green roofs provide is storm-water management. Because impervious surfaces do not absorb precipitation, this water flows off almost instantaneously, thus increasing the chances for flooding downstream and the possibility of combined sewer overflows as the volume of water overwhelms the carrying capacities of streams and municipal sewer systems. In New York City, about half of all rainfall events result in raw sewage entering the East or Hudson Rivers. In addition, impervious surfaces collect pollutants such as oil, heavy metals, salts, pesticides, and animal wastes that may wash into waterways.

In a green roof system, much of the precipitation is captured in the media or vegetation and will eventually evaporate from the soil surface or will be released back into the atmosphere by evapotranspiration. Green roofs reduce the total amount of runoff, but more importantly, they reduce the peak runoff that may exceed the capacity of a municipal storm-water system. Runoff is delayed because it takes time for the media to become saturated and for the water to drain through the media, thus allowing the roof to process runoff for a longer time at a lower flow rate. Of course, water retention depends on factors such as media depth, composition, and plant species, as well as weather factors such as intensity and duration of rainfall.

GREEN ROOF PRODUCTION AND INSTALLATION METHODS

There are three main installation methods for green roofs: conventional built-up system, modules, and pre-vegetated mats. Each has its advantages and disadvantages (Figure 2).

The usual components of a conventional built-up green roof include a root barrier that is placed over the waterproofing membrane, a drainage layer to remove excess water as it drains through the media, a filter fabric to keep media from migrating into the drainage layer, growing media, and plants. Plants can be established directly on the green roof media by broadcasting seed, spreading cuttings if the roof is planted with sedum, and by planting plugs or containers directly on the roof. Installing plant material on an intensive roof is not much different than planting at ground level. However, the logistics of getting media, plants, and other materials to the roof is much more complicated. There is also the challenge of establishing the plants on site to reach 100% plant coverage. Supplemental irrigation, weeding, and overall plant care are required before the roof looks 'finished'. Plant species, media depth, and availability of water are all factors in determining the appropriate planting density of each species to achieve optimal green roof coverage in the desired timeframe (Rowe et al., 2012). Another option is spontaneous colonization where growing media is installed and one waits for plants to colonize the roof. Although, this method is less expensive and may ensure that local species will result, it does not guarantee that these species are actually native to the area. Also, the visual appeal may be questionable to some.

Figure 2. A. Conventional built-up green roof on the Molecular Plant Sciences Bldg. at Michigan State University in East Lansing, Michigan. B. Module green roof being installed on the 4H Children's Garden outdoor classroom at Michigan State University in East Lansing, Michigan. C. Pre-vegetated mats being installed on a private residence in Mason, Michigan.

Alternatively, vegetation can be pre-grown at ground level in modules or trays and then placed on the roof. Various types of modules are on the market and may be composed of plastic or biodegradable materials such as coconut coir. It is much easier to establish plants and reach 100% coverage in a nursery setting than on a roof because nurseryman are skilled in growing plants, whereas roofers or other building maintenance people may lack the necessary knowledge or interest. Overall, modules require less maintenance in terms of weeding, watering, etc. while the roof is being established. A large majority of this work takes place in the nursery rather than on the roof. Also, one of the major advantages of modules is the immediate impact of an instantly green roof when the modules are placed. Sometimes, plugs are planted just prior to roof installation so they are not completely established when shipped. In this case the customer does not receive the immediate green roof, but labor costs are usually less at the nursery than it is to hire people to plant on the roof. Modules made of biodegradable materials such as coconut coir may be more earth friendly than plastic, but if they remain in inventory too long, the container decomposes and the modules may fall apart when moved.

In regard to pre-vegetated mats, similar to modules, the plant material is grown in a nursery field prior to placement on the roof. It is grown and harvested similar to the production of sod for a turf lawn. When harvested it may be rolled up or cut into pieces and stacked on a pallet for shipping. Unlike turf sod, the special green roof growing media is placed on a carrier (sometimes a plastic or nylon mesh) that was placed on the ground. The

final product is not cut from the native soil. Once placed on the roof, time and care is required for the roots to grow into the medium below. Both modules and pre-vegetated mats are more or less limited to extensive green roofs. Deeper media makes them too heavy and difficult to lift and move efficiently. Larger plant material such as herbaceous perennials and grasses, shrubs, or even trees require a deeper media depth and it is nearly impossible to roll up a pre-vegetated mat that is thick and filled with taller plants.

Regardless of installation method, supplemental irrigation may be required immediately after planting and the frequency of watering during the first few weeks of establishment will depend on weather conditions. The need for long-term irrigation depends on climate, plant selection, media composition and depth, and desired aesthetic quality (Monterusso et al., 2005). Once vegetation has been established, a periodic roof inspection is recommended to determine the need for fertilization, weeding of undesirable species, infilling bare spots (with cuttings, plugs, or seeds), replacing eroded media, pruning vegetation back from building structures, and clearing plant debris away from roof drains.

CONCLUSIONS

Green roofs are one tool that can replace lost green space due to human development and help provide numerous environmental, ecological, and economic benefits. There are various types and construction methods, but among other benefits, they all offer a potential alternative to spending millions of dollars to renovate outdated stormwater infrastructure and to power air conditioners. Furthermore, the construction and maintenance of green roofs provide business opportunities for nurseries, landscape contractors, landscape architects, irrigation specialists, and other green industry members while addressing the issues of environmental stewardship.

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Marketing the ecosystem services provided by food plants for pollinators©

D. Smitley[a]

Department of Entomology, Michigan State University, East Lansing, Michigan 48824, USA.

The recent focus on protecting bees and butterflies has created some pest management headaches for greenhouse and nursery growers. Despite the fact that production practices used when growing plants for garden center sales has very little to do with the decline of honey bees or monarch butterflies, much public attention has been focused on them. This has led to a few of the major retail chain stores putting some restrictions on their growers: banning the use of neonicotinoid insecticides, or requiring a label in each pot saying that one was used. Also, for plants that are either super-attractive to bees (Figure 1) (like linden trees, sedum, panicle hydrangea, etc.), or for plants used as food for caterpillars (like milkweed being sold for monarch caterpillars and butterflies), systemic insecticides should not be used at all, and growers should avoid insecticide residue on flowers.

Figure 1. A honey bee (*Apis mellifera*) and a small carpenter bee (probably *Ceratina mikmaqi*- male) on milkweed flowers.

In addition to increasing the complexity of pest management efforts, increased awareness of the importance of pollinators has also created some marketing opportunities for growers. Many of the annual flowers, perennials and shrubs grown for garden centers are highly attractive to bees, butterflies, and many important predators and parasitoids that keep pests under control. A relatively new term appearing more frequently in the press the last 5 years is “Ecosystem Services”. Ecosystem services are the benefits people obtain from the land, water, plants and animals in natural ecosystems where they live or visit. The term has been used frequently to describe the benefits to mankind obtained from bees that pollinate flowers needed to produce fruit and nuts. But it can also be used to describe any natural benefit, like water for irrigation, natural beauty, and the cooling effect of trees on local climates. The ecosystem services provided by flowering plants purchased in garden centers include providing food for pollinators (mostly bees and butterflies), and providing food for many types of important predators and parasitoids that keep plant pests under natural control without the use of pesticides, or with selective use of pesticides to preserve natural enemies. For more information on how to manage major plant pests while also

[a]E-mail: smitley@msu.edu

preserving and enhancing pollinators, see the new bulletin: Protecting and Enhancing Pollinators in Urban Landscapes, available for free on-line (http://msue.anr.msu.edu/resources/how_to_protect_and_increase_pollinators_in_your_landscape).

Some growers have started marketing the benefits of patented flower types that are beneficial to pollinators, with creative names like BeeBright™ Pentas, and BeeDance™ Bidens (*Bidens* 'Sunbidevb 2' Beedance® Red Stripe™ biden) (Figure 2).

Figure 2. A: BeeBright® penta from Syngenta Flowers, and B: Beedance® Red Stripe™ biden from Suntory.

So far I have not seen any marketing of how natural pest control will be boosted by adding a sequence of flowering plants to the garden that will bloom throughout the year. This is just as great or even a greater benefit than providing food for pollinators. Here are a few resources for finding out which plant types are highly attractive to pollinators and other beneficial insects. Flowers that provide nectar and pollen for pollinators are also very good for predators and parasitoids. The following resources may be helpful for learning about which flower types are the best for pollinators and other beneficial insects.

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Lighting plants with LEDs: a panel discussion©

D. Koschmann[a]

Walters Gardens, 1992 96th Avenue, Zeeland, Michigan 49464, USA.

INTRODUCTION: WHY LED LIGHTS AT WALTERS GARDENS?

Day length changes and light intensity fluctuations can be challenging for growers, especially in the winter months in West Michigan. This is what led Walters Gardens to consider LED lights as a source of supplemental lighting to help improve plant quality and conserve energy.

Currently, Walters Gardens has about 12 acres of greenhouse space. About 2.5 acres of this area have high pressure sodium (HPS) lights. We had observed positive responses with HPS lights in items that we grow; however, we noticed the need to decrease our energy consumption and were intrigued by potential benefits LEDs might have on overall plant quality. Research shows that LEDs have the potential to be more energy efficient, last longer, and provide accurate wavelength specificity that can remove wavelength emissions that are not useful for plants (Randall and Lopez, 2013). Considering findings such as this, in August 2014, Walters Gardens began discussions with Philips about an alternative light source to HPS light fixtures that could enhance the quality of our perennial liner production while consuming less energy.

MATERIAL AND METHODS

LED cost analysis

The cost of the lighting units and the installation can scare a lot of growers away from installing LED lights. The light fixtures we chose to work with were the Philips GreenPower LED top lighting. We also questioned how much energy we could save with LED lights when compared to high pressure sodium lights. When looking into cost of installation, our CFO considered annual hours the lights would be operating, fixture costs, and any additional installation costs. He also looked into rebates that could help fund the cost of the project. From there, he was able to determine our return on investment. Since this would be a new installation, one important unknown to us was the longevity of the fixtures. Another important comparison to make when considering an installation is to make sure to compare LEDs and HPS at the micromole level. Are you achieving the intensity you want? We chose to pursue 80 µmol with our LED fixtures. Finally, another consideration is the amount of electricity that HPS lights convert into heat that can be useful for growers during the cold winter months. Research has shown that plants are often 2 to 3°F warmer under HPS lamps than LEDs, so there is the possibility that growers may have to increase heat when growing under LEDs than HPS lamps (Runkle, 2017). Below is a breakdown that helped us make the decision to move forward from a financial standpoint (Table 1).

MATERIAL AND METHODS

Trial department installation

After making the decision to install Philips LEDs in August 2014, we decided to install the lights in our trial department. By week two, we began experimenting with a light spectrum of DR/B MB and a light level targeting 80 µmol of light (Philips and Walters Gardens Case Study, 2015). Recent research at Michigan State University and Purdue University shows that a daily light integral of between 10 to 12 moles is necessary to produce high-quality plant plugs (Randall and Lopez, 2013). Based on this information, we decided to run these lights for 16 continuous hours and at an 80 µmol level. We knew we would be adding about 4.6 moles per day when running the lights this way during the winter

[a]E-mail: dek@waltersgardens.com

months. Our trial department decided to focus on items like *Dianthus*, *Hibiscus*, *Lavandula*, *Agastache*, *Sedum*, and *Coreopsis*, to name a few. We looked at items that we were traditionally growing in the dark winter months and that were popular items for us. With the toplighting trial, our trial department noticed *Hibiscus* (Figure 1) and *Dianthus* (Figure 2)finishing 10-14 days quicker, more lateral branching in *Lavandula* and *Sedum*, better rooting and more compact growth in *Agastache* (Figure 3), *Leucanthemum*, and *Gypsophila* (Philips and Walters Gardens case study, 2015). Below are some photos highlighting the results of this trial.

Table 1. Walters Gardens Inc., ROI / breakeven analysis, complete I4 only.

Description	HPS 1000W Lithonia	HPS 1000W Double End	LED 200W DR/W MB	Comments
Number of fixtures	44	48	114	
Energy consumption (Watts)	1085	1108	200	1000 W light (tested by Ken Austof 10/18/16)
Demand (KW)	47.74	53.18	22.80	
Annual energy consumption (kWh)	99,203.72	110,516.35	47,378.40	
Annual energy cost	$11,904.45	$13,261.96	$5,685.41	
Annual hours in operation	2078	2078	2078	Nov - 13/Dec - 16/Jan - 16/ Feb - 16/Mar - 8
Cost/kWh	0.12	0.12	0.12	Blended rate for peak use based on analysis from Midwest Energy
Fixture cost		$315.00	$395.75	per quotes
Accessories cost		$4.00	$30.73	per quotes
Total fixture cost	$0.00	$15,312.00	$48,618.15	
Potential rebate			$8,729.00	Consumers rebate is 0.35/W saved over a year or $350 per kW
Net project cost for fixtures	$0.00	$15,312.00	$39,889.15	
Break even years			3.24	Years to payback extra cost for an LED install vs. HPS DE
ROI years			5.26	Years to payback total cost for an LED install vs. HPS DE

Figure 1. *Hibiscus* 'Cranberry Crush'. Left: LED 16 h continuous; Middle: LED 16 h; Right: high pressure sodium (HPS) 16 h. Plants under LED 16-h continuous lighting are taller with larger leaves than the other two greatments. From Round 2 of LED trials/photo taken 22 Feb. 2017.

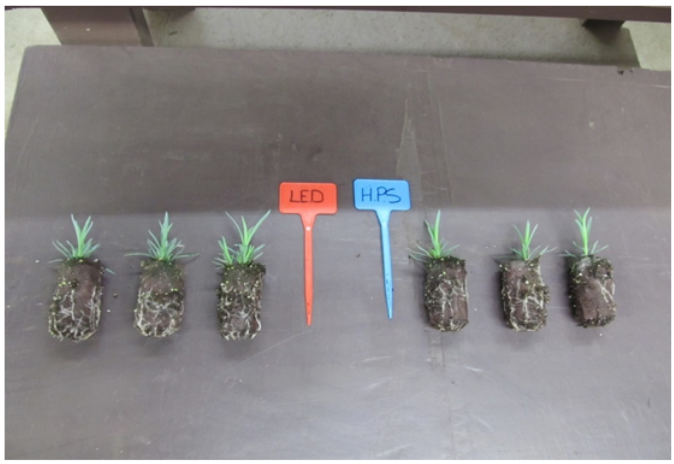

Figure 2. *Dianthus* LED on left and right is high pressure sodium (HPS).

Figure 3. *Agastache* left is high pressure sodium (HPS) and LED on right.

SUMMARY: PRODUCTION INSTALLATION

After seeing success in the trial department in the winter of 2015, we decided to install LED lights in our production area. The purplish cast created by the DR/B MB fixtures in our trial department led us to try adding white into the spectrum. With sorting staff, growing, and plant health employees needing to work under the lights, we wanted to make them as comfortable as possible. We decided to add 15% white to these fixtures and adjust to 75% deep red and 10% blue/medium blue and continue to target 80 µmol. What we learned is that one important factor to consider is that after a lighting system is installed; check that the light intensity delivers what you purchased. Also, when considering the location for the production installation, we considered how we currently were operating the lights during the early fall through late spring months.

We have seen good responses from items like *Sedum* when we grow them under 13-h HPS lights, and there are items like our warm season grasses, *Hibiscus*, and *Lagerstroemia* that we like to grow in 16-h light sections. We have also been looking at *Echinacea* and its light requirement needs during the dark months in West Michigan. With *Echinacea*, we compared 13-h lights, 17-h lights, and 24-h lights. Ultimately we decided to install the lights in an area that we would light for 16 h, since a large portion of our items under lights fell in this category. We decided to use the LED lights in a production area which entailed 10,000 sq ft of growing space. Our target for the fixtures was 80 µmol. In the production area, LED lights and HPS lights are tied into our Priva computer system. We setup trial locations in three different spots; one spot running the LED lights 16 h continually, one LED location 16 h based off of outside light conditions, and one HPS location running 16 h and lights turning on and off based off of outside light conditions. Questions are often raised on when is a good starting point when running lights based off of light intensity; consider setting growing lights to turn on when light intensity outside is less than 200 µmol for a few minutes. You could then set the lamps to turn off when the outside light intensity exceeds a higher value, like when 400 µmol has been achieved for a few minutes (Runkle, 2013). We focused on having our environmental control system achieve similar settings to this in our greenhouses.

Production trials have shown similar results to those captured by our trial department for items including *Hibiscus* (Figure 1), *Amsonia* (Figure 4), *Agastache*, *Astilbe* (Figure 5), and *Ligularia*. Below are a few photos highlighting those results.

Figure 4. *Amsonia* 'Storm Cloud'. Left: LED 16 h continuous; Middle: LED 16 h; Right: high pressure sodium (HPS) 16 h. LED treatments have more compact growth than HPS. From Round 2 of LED trials/photo taken 22 Feb. 2017.

Figure 5. *Astilbe* 'Amber Moon'. Left: LED 16 h continuous; Middle: LED 16 h; Right: high pressure sodium (HPS) (control) 16 h. Color on HPS is very yellow. Color under LED treatments is more desirable. From Round 3 of LED trials/photo taken 15 March 2017.

CONCLUSION

Through our study and additional research, we have learned that when considering LED lights, your potential lighting supplier should be able to provide a map of intensity and uniformity of the lights, efficacy for your specific application, and cost associated with the installation. Look into potential options for energy rebates. Based on a proposed lighting plan, it is important that your current electrical supply needs allows for the use of supplemental lighting (Poel and Runkle, 2017). The installation of LEDs at Walters Gardens utilized 15 AMP circuits and not 20 AMP like we utilize in HPS.

After evaluating the cost of the fixtures and seeing the benefits of growing items under LED continuously for 16 hours at Walters Gardens, we want to expand on this program in the winter of 2017-2018. Goals we have for this year include: validating our prior results, testing new taxa, tracking the number of cuttings per sq ft from *Hibiscus*, tracking PGR usage, evaluating overall plant quality, and tracking finish times on a larger scale.

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Plant propagation for successful hydroponic production©

H.-J. Kim[a], T. Yang, M.-Y. Lin and P. Langenhoven

Department of Horticulture and Landscape Architecture, Purdue University, 625 Agriculture Mall Drive, West Lafayette, Indiana 47907, USA.

INTRODUCTION

Hydroponics is a plant cultivation system in nutrient solutions with or without the use of a growth medium. Using hydroponics systems, crops can be grown in places considered hostile for crop production such as deserts, the Arctic and even in space. Hydroponics is a sustainable option to produce crops, as it offers many advantages such as higher crop yields in a smaller space. Increased productivity and sustainability is achieved through more efficient use of water, fertilizers, and pesticides, and faster production cycles, year around production, and production at the point of sale. Hydroponic production normally starts from seed propagation. Establishing vigorous, heathy disease-free uniform plant material is a key step for the success of hydroponic crop production. Several unique challenges need to be considered for successful establishment of plant material, which include choice of crops and cultivars, type of propagation media, hydroponic water quality and nutrient management, and environment control and management. The objectives of this paper are to provide some general information regarding propagation practices for hydroponics, and specific goals and unique strategies for each process to establish stronger and healthier seedlings. These guidelines will provide more sustainable options and help improve production efficiency of hydroponic crop production systems. The paper will be organized into sections on: (a) types of hydroponic growing systems, (b) choice of crops and cultivars, (c) growing media, (d) hydroponic propagation methods, (e) propagation environment management, and (f) transplanting.

TYPES OF HYDROPONIC GROWING SYSTEMS

Hydroponic systems are commonly designed as open (drain to waste) or closed (recirculating) systems (Raviv and Lieth, 2008) (Table 1). In open systems, nutrient solution is applied to the plant growth medium and then drained to waste. Fresh nutrient solution is applied to plants with each irrigation, and therefore, open systems require more water and chemical fertilizers than closed systems. Untreated wastewater from open hydroponics systems poses detrimental effects to the environment. In closed systems, nutrient solution is collected in a nutrient reservoir after each irrigation, and recirculated through the system. The nutrient solution is reused by adding more water and nutrients instead of replacing the entire solution (Jensen, 1999; Nederhoff and Stanghellini, 2010). Due to this practice, closed systems use 20-40% less water and fertilizer than open systems, but consistent monitoring and maintenance of electrical conductivity (EC) is required. Eventually the nutrient solution will be replaced, partly due to the imbalance of mineral elements in recirculating water as plants uptake nutrients at differential rates. To maintain a near perfect nutrient balance is a challenge in the recirculating system, and requires chemical analysis and constant addition of minerals that are in high demand. Deteriorating water quality is another reason for replacing the nutrient solution. Reuse of the nutrient solution increase the risk of disease build-up. Organisms such as *Fusarium* or *Pythium* can have a devastating effect if the water is not properly processed.

Disposal of hydroponic wastewater is an important issue. Even the closed systems generate wastewater that contains significant amounts of environmental pollutants such as nitrogen and phosphorus. Common practice is that wastewaters are collected, diluted and applied to either community gardens or open spaces. Despite the environmental concerns

[a]E-mail: hyejikim@purdue.edu

related to the open hydroponics systems, open systems are more common compared to the closed systems in the USA. Closed hydroponics has gained great interest from producers and scientists in the last two decades (Neocleous and Savvas, 2016). Globally, more than two-third of hydroponic growers are using open systems while less than one-third of hydroponic systems are closed (Carruthers, 2007). Improved cultural practices are needed to overcome point source pollution while maintaining high quality and yield in hydroponic crop production.

Table 1. Type of hydroponic production systems.

System type		
Substrate-based system	Drip irrigation	Open or closed
	Ebb-and-flow	Open or closed
Water-based system	Nutrient film technique (NFT)	Closed
	Deep water culture	Closed
	Substrate culture	Open or closed
	Aeroponics	Closed

There are four growing systems used for hydroponic production: nutrient film technique (NFT), deep water culture (floating hydroponics), aeroponics, and substrate (media-based) culture (Resh, 2013). The choice of growing system depends on the duration of crop production. Short-term crops such as leafy vegetables and herbs can be commonly grown in a deep water, NFT or aeroponics culture system. However, long-term crops requiring more than a month for production require strong support of the plants, and therefore, substrate culture is a better choice. In substrate culture, suitable substrates should be chosen to provide good support for plants, sufficient air space, and good water holding capacity, with proper chemical properties (see Growing Media for detailed information).

Substrate-based system (aggregate system; media-based system)

A medium of choice can be an inert medium for conventional hydroponics or a medium containing organic components for organic hydroponics. There are numerous types of media used in substrate-based hydroponic systems (see Growing Media for detailed information). In this system, the nutrient solution is directly delivered to the plant roots using a drip irrigation system or ebb-and-flow system, which can be designed to be either open or closed. Trickle or drip irrigation is the most widely used type of hydroponic system in the USA.

Deep water culture system

In deep water culture systems, plants are inserted into small holes of a Styrofoam board placed on a rectangular tray or tank of reasonable depth filled with nutrient solution. The roots are constantly submerged in a nutrient solution. Plants are held by soilless cubes or a net pot filled with soilless substrate (e.g., aggregated clay, rockwool cubes). This system is commonly used for large-scale commercial production of leafy vegetables. This system is designed to be closed, and the nutrient solution is monitored, and adjusted. The depth of water can vary. A deep water system is common for greenhouse production, while a low-deep water system is a popular choice for indoor vertical faming.

Nutrient film technique (NFT)

In a NFT system, the plant's roots are exposed to ample oxygen and a thin film of nutrient solution. The PVC channel is angled at a 1% gradient, and is closed to exclude light and prevent evaporation. However, holes in the channel allow for plants to be planted. Nutrient solution is pumped to the higher side of each channel and flows by gravity through plant roots to catchment pipes and return back to a sump. The nutrient solution in the sump is monitored and replenished of salts and water before recycled. Some capillary materials

are used in the channel to help young plants to absorb water and nutrients, and promote root grow.

Aeroponics

In aeroponics, plants are inserted into the holes of Styrofoam board or other material, and their roots are suspended into a closed chamber or box kept in darkness, where high-pressure mist of nutrient solution is sprayed over roots periodically to provide a fully saturated humidity. The excess solution drains and recirculates through the system. The system is normally turned on for only a few seconds every few minutes, which keeps the roots moist while allowing them to be aerated. Some aeroponics uses the A-frame chamber system constructed using two Styrofoam or PVC boards.

CHOICE OF CROPS AND CULTIVARS

Plant varieties have been specifically developed for hydroponic production in controlled environments. The most popular crops grown in hydroponics are tomatoes (*Solanum lycopersicum*), cucumbers, lettuce, herbs, peppers and strawberries. All the varieties of tomatoes, cucumbers, and peppers are characterized by indeterminate growth, which means that the main stem continues to elongate indefinitely without being limited by a terminal flower structure. This "high wire or vine" growth habit help create unique form of plants to maximize crop production in a limited space.

GROWING MEDIA

There are many types of media and substrates for hydroponic propagation and production (Table 2). Media determines moisture retention, irrigation, cultural practices, production cost, and sustainability, and therefore, the choice of the growing media is critical. Soil is normally not used in conventional hydroponics, but it can be used in organic hydroponics. Media preferred for hydroponic plant propagation serve several purposes, including providing support, moisture, aeration and nutrition. The components of the medium, their particle size, and the degree of compaction are all characteristics that affect how well the medium provides for these functions. The ideal media for hydroponic propagation must also have a high moisture holding capacity, yet allow excess water to drain freely so that the seeds are not drowned in water. Roots may rot if the medium is poorly drained.

Table 2. Substrate and medium choice for hydroponic propagation.

	Substrates		Synthetic media
	Organic components	Mineral components	
Conventional hydroponics	Peat moss Coconut coir Sand Sawdust Rice hulls	Perlite Vermiculite	polymer bound plugs (e.g. peat pellets, coir pellets, composted organic material plugs, Oasis Horticubes, urethane foam plugs), rockwool cubes & blocks, coco coir cubes and blocks

One should consider compatibility with the production system. Commercial growers often use the "rockwool system" which consists of germination cubes, and blocks, which are placed onto slabs or bags. Such system can keep the work flow smooth and easy to handle.

The medium also should not be saline or contain toxic substances; should be capable of being sterilized; and be disease and insect free.

The above listed substrates can be used alone or in mixture with other substrates. In some regions of the world, media such as coconut coir, sand, sawdust, and volcanic rock are also common due to local availability. Synthetic medium is a popular choice for hydroponics. Particularly for growing row crops such as tomato, cucumber, and pepper, the most popular

growing media is rockwool followed by perlite as they are light-weighted, and easily handled and sterilized than many other types of aggregate materials. However, due to the disposal issue and increased environmental pressures on greenhouse operation, rockwool is being replaced by coconut coir in large hydroponic greenhouse operations as it being more sustainable choice of substrate.

HYDROPONIC PROPAGATION METHODS

Seed propagation

Most vegetable transplants are produced from seeds, and the choice of seed is one of the most important decisions a grower can make (Hartmann et al., 2011). Hybrid seeds are the common type of plant material to start with in commercial greenhouse hydroponic production. This is because plants derived from hybrid seeds will have the same characteristics and produce the same quality and yield. The seeds in the fruit from the hybrid plants will not produce the same plant as the hybrid seeds do. It is important to acquire seeds from the reliable commercial source to ensure the same plants of disease-free. The number of days to germination is crop specific. e.g., tomatoes about 5 to 6 days, lettuces about 7 to 10 days, and cucumbers about 14 days.

Vegetative cuttings are not desirable to establish transplants because virus disease from the mother plants can be transmitted to the cuttings. Purchasing hybrid seeds could be quite costly but the investment can be recovered from the economic return.

Seed germination trays

Seeds may be sown into molded plastic or Styrofoam plug trays or peat strips. The trays can be filled with germination mix, or other suitable substrates or media as listed in Table 2. Seedling plugs are the most popular choice for hydroponics. Seeds can be placed directly into the plugs, such as peat or coir pellets, rockwool cubes, or foam that are sized to fit the trays, and divided into small cubes. There are various sizes of plug trays and cubes on the market. The propagation medium should be thoroughly moistened before seeding. Some blocks are designed to nest small size plugs or cubes, and further placed onto a larger slab. Such system is effective in minimizing transplant shock. When sowing seeds, one seed per each cell or cube should be sown. Many commercial products such as rock wool and foam cubes, have a small hole in the top of each cube where a seed can be placed. The percentage germination should be considered and sown enough to meet the required number of seedlings. Depending on the types of seeds, seeds should be shown at proper depth, which can be found on the seed packet. General rule of thumb is to sow two to three times thicker than the seed diameter. Seeds of herbs and many leafy vegetables may be placed at the surface. Sprinkle a thin layer of vermiculite over the seeds to keep moisture for germination.

Vegetable grafting

Vegetable grafting is common method of growing most cultivars of tomatoes, peppers, and eggplants (Figure 1). This requires skills and specialized techniques (Caula and Trigiano, 2014). Fruiting scion varieties are often grafted onto a rootstock for disease resistance and more vigorous growth, providing greater yield potential and crop performance. The choice of rootstocks can be determined depending on the traits to introduce.

Splice grafting (also known as top grafting, tube grafting and slant-cut grafting) is the most widely used grafting technique for tomatoes (Figure 1A). Splice grafting is quicker and less complicated to do than cleft grafting because it only requires a single straight cut on both the root and shoot portions of a graft with a high success rate (95%). Splice grafting should be carried out when two to four true leaves are present on seedlings and the stems are 1.5 to 2 mm in diameter. For proper healing to take place, the vascular tissue in the rootstock and scion must align so that their tissues can easily grow together, forming a strong union for water and nutrient uptake. An essential component for grafting success is to use rootstock and scion plants that have similar stem diameters.

Grafting should take place when there is little water stress upon the plants. Early in

the morning or just after dark are excellent times to graft as transpiration has typically slowed to reduced levels. The grafting process should be carried out indoors or under some sort of shading device. Sanitation is extremely important during grafting. Wash with anti-microbial soap, use latex gloves, and use latex gloves and sterile tools to reduce the exposure of the plant to pathogenic bacteria, fungi and viruses.

Figure 1. A: Slice graft; B: a small-scale grafting system (tray, plastic dome, and grafted tomatoes in plugs); C: grafted tomato for hydroponics where a dome was removed for photo clarity.

PROPAGATION ENVIRONMENT MANAGEMENT

Depending on the type of crop, germination may occur within a week or two weeks of seeding. Seeds may require light for germination. Light environment should be adjusted depending on the crop. If the seeds require light, LED lights can be used to avoid heat-overloading to the seedlings. Radiant heat emitted from the light source can dry up the surface of substrates and restrict water for seed germination, leading to poor germination rate or poor-quality seedlings. Alternatively, the tray can be covered with a clear plastic dome, which can control water environment better. However, it should be removed when seedling emergence occurs. Once seedlings emerge, the seedling trays should be moved to the greenhouse environment to allow them gradually to acclimatize to the production environment. If germination is done in the greenhouse, avoid the use of plastic dome as it may trap high heat when direct sunlight hits the dome.

Source water in these systems primarily comes from municipalities. Water should be tested to ensure it is equal to or better quality than drinking water.

Environment conditions during seed germination

Seeds are often germinated in a germination room or chamber where high relative humidity and temperature is maintained to facilitate seed germination. If a germination room is not available, a germination system consisting of a plastic dome, tray and bottom heat, will serve the purpose for small scale seed germination. During seed germination, water should be applied from the bottom to moisten the medium where water can be taken up by capillary action of the substrate. Avoid overhead watering during seed germination as it may knock down seedlings, and avoid overwatering as it can cause damping-off disease. Ebb and flow systems are quite effective for large scale seed germination. Once the blocks are evenly moist, the tray is drained, which allows aeration of the roots. This process will need to be repeated often throughout the day. Supplemental light with LEDs for ~16 hours daily will help grow healthy seedlings during winter months, particularly in Northern latitudes.

Environment conditions after seedling emergence

Once seedlings emerge, the seedling trays should be moved to the greenhouse environment to allow them gradually to acclimatize to the production environment with optimum growth temperature, and light level. Overhead irrigation using mist is the most common method for seedling establishment. Overwatering will not only increase the risk of damping-off disease, but also encourage succulent growth of seedlings making them more

susceptible to disease and transplant stress. It should be also noted that encouraging root growth during seedling establishment is important because it helps minimize transplant shock and enhance crop performance in a hydroponic system. Establishing sturdy transplants with well-established roots is the major goal during this process.

Seedlings grown in a germination mix or substrates containing organic components may have sufficient nutrients available to support growth, and therefore, may not require any additional nutrients during seedling establishment except water. However, for seedlings grown in an inert medium need nutrient solution, diluted nutrient solution at an electrical conductivity (EC) of 0.5 mS cm^{-1} and a pH of 6 is recommended for seedling growth, as it supplements nutrient reserves depleted from the seeds. Once the early first-true-leaf emerges and the cotyledons expand, one should consider applying diluted nutrient solution with an EC ranging from 1.0 to 1.5 mS cm^{-1} (or mmho).

Established seedlings can be placed inside plastic containers called net pots or web pots, which are commonly used in deep-water or NFT hydroponic systems. The pots can be filled with either perlite, aggregated clay (clay pebbles), or rock wool.

Environment conditions for grafting-healing

Environment control is critical for grafting success (Figure 2). Newly grafted plants must be kept under high humidity (85 to 100%) and either low light (or heavy shade) or darkness to help ensure that the graft will take. High humidity decreases water loss from the grafted plants and increases success rate. A small-scale grafting-healing system (Figure 1B) can be set up using a plastic dome and a tray, or a transparent plastic box to maintain high humidity. Covered benches using a plastic covering with a misting system can be constructed in the greenhouse. After 3-4 days, a graft union is formed. Allow a couple of days to help a strong graft union is formed. During this time, humidity level is gradually decreased, and light level can be gradually increased to indoor environment or shaded condition. Once graft union is formed, grafted plants will resume taking up water through the roots. It is important to note that diluted nutrient solution should be added to the medium, particularly when an inert medium is used. The grafted plants should be protected from direct sunlight, low humidity or high temperature. They are gradually reacclimatized to a brighter and drier environment. After 7 days, plants can be moved into a normal production environment. Extra days of acclimation will allow the grafted plants to better perform during the transition period.

<table>
<tr><td>Major Event</td><td colspan="2">Scion seed sowing
Rootstock seed sowing</td><td>Grafting</td><td>Acclimation to indoor environment</td><td>Acclimation to production environment</td></tr>
<tr><td></td><td colspan="2">Germination chamber/greenhouse</td><td colspan="2">Healing chamber</td><td>Greenhouse</td></tr>
<tr><td>Environment control</td><td>2-5 days</td><td>≈10-14 days</td><td>3-4 days</td><td>3-4 days or longer</td><td>≈ 7 days</td></tr>
<tr><td>Humidity</td><td colspan="2" rowspan="3">Seed propagation environment</td><td>85-100%</td><td>Gradually decrease (≈ 60%)</td><td>Gradually decrease (40-60%)</td></tr>
<tr><td>Light intensity</td><td>Low light or heavy shade</td><td>Gradually increase</td><td>Gradually increase</td></tr>
<tr><td>Air temperature</td><td>25-30°C</td><td>Gradually decrease</td><td>–</td></tr>
</table>

Figure 2. Timeline and environmental control for grafting and healing.

TRANSPLANTING

Transplanting for leafy vegetables occurs in 2-3 weeks. Too early transplanting to hydroponic environment may delay initial growth of seedlings, while too late transplanting can also slow down plant growth due to root bound. Transplanting of fruit vegetables should be done once true leaves are unfolded. This could vary by vegetable crops, e.g. tomato in 2 to 3 weeks after sowing. Seedlings should be transferred into larger growing blocks or pots from the original seedling cubes, and then evenly spaced out to avoid mutual shading and promote better light interception to each plant. Slight water and nutrient stress may help establish stronger seedlings. The final growing media should be properly leached and moistened, and the production environment should be kept at a proper temperature before plants are moved to the production area. Plants should be irrigated with a half to full strength nutrient solution immediately after transplanting.

One of the advantages of hydroponics is higher planting density compared to conventional production systems. Planting density varies depending on the crop: fruiting vegetables, e.g. tomato and cucumber, 4-8 plants m^{-2} and leafy vegetables 20-25 plants m^{-2} (FAO, 2014). To increase planting density, two seedlings can be nestled in a slab or a pot. Alternatively, a growing point of a seedling can be removed and a double-headed plant can be induced. Removing a growing point may slightly delay plant growth; however, seed cost can be reduced compared to planting two seedlings in a given area. Greenhouse crops with indeterminate growth must be trained using support strings to help grow upright. Mature plants with normal fruit loads can weigh anywhere between 10 and 20 kg (22 and 44 pounds) for tomato. Therefore, the strings should be hung from the crop support of the greenhouse, with or without additional support using horizontal wires that run through the greenhouse.

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Grow your business©

D. Deppe[a]

Spring Meadow Nursery, Inc., 12601 120th Ave, Grand Haven, Michigan 49417, USA.

INTRODUCTION

Seek and share

I want to thank all of the IPPS members in the room today who took the time to come here and learn from one another. A strong association for plant propagators benefits everyone in our industry. Without IPPS, where would the industry be today? It's amazing to think of all the advancements that have taken place in plant propagation because of this organization. This network of peers allows us to share and learn from each other, and a strong education program helps all of us become better at our jobs.

The knowledge and skill we get through IPPS helps us create strong businesses that will continue to grow the industry, provide interesting plants for the landscape, and jobs for the future. I'm so thankful that the members in this room understand the value of coming together for these meetings. I have been a member of IPPS for over 40 years and stand by our motto, "to seek and share."

Many of you have been in this room before and look forward to this meeting each year; many of you are new to the organization and this might be your first meeting. New members bring energy into this room and into IPPS. Get to know a new person if you haven't already—we need the passion that new members bring, we need their excitement for learning. Everyone here has their own unique knowledge about how the plant business works and all of us can learn something from one another. Let's help each other as we learn how to move this industry forward.

You know I love these meetings—it's a time to meet good friends, review the season, and learn more about how to build a successful business.

Think about your business

The focus of this session and in a way, maybe every session, is to think about business.

It's a time to think about the future, about profitability, and the margin we make on our products. Without profitability, this industry will continue to shrink. A lot of us do a disservice to ourselves and our businesses by not daring to be profitable—by thinking we can't raise our prices, or demand what our products and knowledge are actually worth.

At Spring Meadow Nursery, we think about business constantly. Our goal is to double our business every 5 years. So we make a plan of how we're going to get there, and we adjust our plan to make sure it's keeping us on the right path. We are always focused on improving everything we do in pursuit of this goal and beyond, even where we will be ten years from now. While it is a cliché, "innovate or die" is how we run Spring Meadow Nursery, and it's relevant to everyone in the plant business.

Are you actively working on a plan to make your business more profitable? Have you even thought about it? Creating a plan is the first step toward growing your business. I think everyone in this room can double their businesses in the next 5 years if they have a plan to do it.

I started Spring Meadow Nursery as a shrub liner supplier 35 years ago. Like everyone here, I had some things to learn along the way. That's called the school of hard knocks, which I can say I've attended in addition to Michigan State University. After I graduated, I worked at Zelenka Nursery for 11 years as a senior manager over multiple propagation departments, until I lost my job in the 1982 economic downturn.

[a]E-mail: dale@springmeadownursery.com

BE DIFFERENT/ADD VALUE

When I started Spring Meadow Nursery, I thought that competition meant selling plants at a cheaper price than the other liner nurseries and that growing my business meant just selling more plants. So I worked harder and longer and tried to do it cheaper, and even though I sold my inventory, money was still pretty scarce. This all changed once I understood that I needed to be different from everyone else, not just copy what others were doing and hope for better.

So Spring Meadow Nursery started growing different plants than our competitors. We introduced new and unusual plants that allowed us to set our own prices instead of following others down the low price rat hole. We found plants that created excitement in the market—plants that people wanted to talk about, which led to garden centers selling them quicker and at higher prices.

We sought out flowering shrubs that had bigger flowers, better color, and bloomed longer. We focused on smaller plants that offered interesting solutions for the landscape, and plants with attractive foliage that looked good all season. Good, garden-tested plants with fragrance and impulse appeal at the garden center that looked more like perennials than what people, at the time, thought of as shrubs. We've often used the tag line, "changing the way you think about flowering shrubs." If we can change the perception of a plant's value, we can change this business forever.

After a few years, it was clear that selling new plants at higher prices was not only more profitable for us but added value for our customers as well. And when your customers win, you win.

Selling generic plants at cheaper prices was not the right answer for us. We weren't able to make the generic plant business profitable. Selling more for less was just not an option. This all seems simple enough in retrospect, but often we fail to understand that we must add value to our products, and how to do that. Adding value is about making sure everyone in the supply chain benefits, which means everyone has to make little more profit on each plant. To this day, we're always eliminating low margin plants.

STRATEGIC RELATIONSHIPS

Back when branding was just beginning to emerge in the nursery industry, we at Spring Meadow Nursery knew we had to embrace this new opportunity. If we didn't move forward with branding, where would we be in 10 years? Remember that "innovate or die" rule I mentioned earlier?

So we started our own brand called ColorChoice® Flowering Shrubs and introduced our new plants under this name. We then showcased ColorChoice® plants to our customers and to retailers, which increased our margins, and we used those profits to build our brand and our business even stronger.

In 2003, we began discussions with Proven Winners® and soon joined them with the exclusive right to manage all woody plants under Proven Winners® in North America. We moved from being a wholesale, B-to-B brand to being a retail, B-to-C brand. This was huge for us. It changed us as a company. It changed how we think about the power of marketing and branding. It brought us new customers and new markets for proprietary branded flowering shrubs.

It also changed plant branding. Proven Winners® is the number one plant brand in North America, selling well over 100 million plants a year. Proven Winners is not a nursery. It is a cooperative. When we joined the brand, we joined together with the other companies that make up Proven Winners®. None of us could have created Proven Winners® on our own, but by combining annuals, shrubs, and perennials under one recognizable brand, the marketing becomes more effective. Every plant sold under the brand contributes to the marketing fund, which helps grow our business and increase demand for our products. That's why consumer recognition of the Proven Winners® brand grows every day.

Today, we introduce plants into the market from independent breeders worldwide and also breed plants internally at Spring Meadow Nursery. We now own or manage patents on over 300 flowering shrubs, and Proven Winners® ColorChoice® plants are in almost every

garden center in North America.

Strategic partnerships like this are a crucial part of growing your business. Ask yourself, how can I join together with others to make all of us stronger and improve our chances of success? Where can we improve the supply chain to include our products? Questions like these help you develop your plan to grow your business.

PLAN FOR LONG TERM SUCCESS

Growing your business doesn't mean just making it physically bigger, but also better and more profitable. The reality is that opportunity for higher profit is everywhere: you can reduce your labor costs by being more efficient in the way your staff does things. You can raise the quality of your product. You can look for new markets so you can sell higher volume.

One of the easiest ways to become more profitable without adding staff or space is by increasing margin. Everyone in the supply chain is searching for margin. Basically, this industry needs a solution to the historical low profit issue. Higher margin plants are a big part of the solution. I am telling you to raise your prices. When? Every year. After all, your supply costs go up every year, don't they? So every year you don't raise your prices, you're becoming less profitable.

Don't be afraid to raise prices, especially on higher value plants. It doesn't have to be a huge increase, just 10¢ a year can keep you profitable. New plants are the perfect opportunity to raise prices year after year. After all, no one knows what they should cost, so it creates its own market. New plants help us compete and increase margin. Everyone always asks "what's new?" and then, "where can I get it?"

If you struggle with price increases, think about what kind of people you need in your sales department. Most sales people in this industry are focused on customer service and seldom understand how to help your customers grow their business by selling solutions as well as products. When you finally make the decision to upgrade your sales team, you will wonder what took you so long.

SUCCESSFUL DECISION MAKING HAS A STARTING POINT: MAKE A PLAN

This is all really basic information, increasing margin and profits. But without a plan, it's easy to forget the basics. I firmly believe each of us needs a plan in place to be successful. I'm not talking about a plan to do the same thing as last year. I'm talking about raising the bar for next year and never being content with the status quo. That's how a successful business works long-term.

Remember that "innovate or die" rule I mentioned earlier? Business naturally resists innovation, but this sets us up for failure. Plan to innovate and do the uncomfortable.

We are all in this quest for success, for profitability. It's not just about financial success, but also about being better and surviving for another year as a business. It's about the future of our teams and their families. It's about doing our best every day. If you're not profitable, life is pretty tough and it's hard to get ahead. Even when you plan for the long term, you still need to make the right decisions every day to improve your business.

Decision making is hard. We're all afraid of making the wrong decisions, because we know our success or failure is tied to the decisions we make. I'm sure everyone here knows of nursery failures caused by poor decisions. Sometimes, we struggle and keep delaying the process because we are worried about the unknown or because we are worried about the competition. Since we need to make decisions every day, how do we make the right ones? I say look to your long-term plan. As you know, short term and long term thinking are different from each other—short term fixes may not be the best choice for your long term plan. When we're making decisions, we seldom think about how they may impact us 5 or 10 years from now. But these daily decisions are what drive growth and change over time, both in your business and personal life.

Looking back in life, each of us can see how our personal success has a starting point, whether it is accepting the influence of a parent or mentor, deciding to go one way or the other in a degree or job, early investing in a mutual fund, or spending time with your family

to strengthen those relationships. Successful business has a starting point as well: find a need in the market and fulfill it better than anyone else. Do it profitably so you can invest in your business for the future. Think long term. Stick to your plan and build your business piece-by-piece. Hire the right people that can move the business forward.

I know business is constantly changing as it goes along. At Spring Meadow Nursery, we are always sorting out the decisions we made and looking to our plan for guidance. We measure the success of our decisions against our core principles. The long term core principles at Spring Meadow Nursery are pretty simple, big-picture stuff:

1. Take care of the plants, and they will take care of you.
2. Invest in people and let them do their job.
3. Work on your business, not in your business—limit daily grind stuff and work on the future plan.
4. Improve your quality every year in everything you do.
5. Invest in your business for the long term.
6. Move the needle every day—we measure everyday almost everything we do.
7. Lead the industry—early innovators make money, others have to pay to catch up.

I encourage you to go home, make a plan, and put it into practice. What can you do right now in your business to get you closer to your long term goals?

The choices you make every day are opportunities to improve your business and your business plan. When decisions or challenges come along, look to your plan, and then measure against your core principles. Get in the habit of making decisions that move your business forward!

When I look back at Spring Meadow Nursery's history, I'm so thankful for the strong business principles in place, for the unbelievable people that have joined us in moving the industry forward, for game-changing new plants that have increased margin and profit, and for the passion that drives us every day to be better at what we do.

WHY WE ARE HERE TODAY

So why are we all here today? We are here to celebrate 2017—to be thankful—to be happy—to see our friends. We are here to work on our plan—review it—adjust it—add value to it—and grow our business. There is unbelievable opportunity ahead in 2018 and beyond, and there is great wisdom in this room. Let's put it to work.

Production cycles at Sheridan Nurseries©

B. Brusse[a]

Sheridan Nurseries, 12266 10th Line, RR#4, Georgetown, Ontario L7G 4S7, Canada.

SHERIDAN NURSERIES

Sheridan Nurseries was established 1913 and is located in Georgetown, Ontario, operating 8 Garden centers in the Greater Toronto area and two growing farms totaling 900 acres (Figure 1). We are growing 1200 cultivars of hardy nursery stock and perennials, and propagating over 2 million plants per year with 5 million plants total in production.

Figure 1. Main growing farm in Georgetown, Ontario, Canada.

PRODUCTION PLANNING

Production planning should be fairly simple, right?

1) Ask sales, how many plants do you need ready? When do you want them ready?
2) Work backwards—how long does it take to grow each stage (Figure 2) and start propagating.
3) Wait 1-7 years for the plants to grow.
4) Sell all the plants.

Figure 2. Example of production stages for *Buxus* 'Green Velvet'.

[a]E-mail: bbrusse@sheridannurseries.com

But then, there are a few things that complicate the process:

- We grow 1200 cultivars, in 2000 SKUs (different sizes).
- Often use one size to make another (shift up), and may sell off a portion of the smaller size at each stage.
- Different liner plant size, can vary by year and growing time, depending on supplier and weather so sometimes the plants are ready faster, or slower than we planned, or some die or are unsuitable for sale.
- And sometimes they are all beautiful and ready on time but market conditions have changed and they don't sell.

So they end up on the scrap pile which is a very expensive loss for the business.

BUSINESS NEEDS

Our challenge is to run a sustainable business that earns enough profit each year to invest in our facilities, provide an environment for staff to grow their skills and reward owners for their investment. To do this we need to set targets:

Yield: 94% of each crop we pot to sell at normal price (does not include sales at a large discount, scrap, or shrink), includes 3% growing loss and 3% sales loss.

Gross margin: 35%+ gross margin at 1-2 year crop cycle. This farm margin then covers shipping, sales, and head office functions, with profit left over.

Tools available

To help with production planning there are several tools available:

- Experience of staff and colleagues. How long does this plant take to grow? What if we change one aspect? etc.
- Historical data in database and spreadsheets you have already or can start tracking.
- Time need to set aside enough time to analyse each plant.
- Know your crops, make sure to include staff that have experience growing and selling particular crops over several years/business cycles.

FIVE STEPS TO FORECAST AND PLAN

Each company will have their own way to forecast and plan how many plants to grow in a given year. This is how it is done at Sheridan:

1) Forecast demand
2) Inventory/orders forecast
3) Want number
4) Liner size and growing time
5) Review and stay nimble

To help explain the process we'll look at one plant as an example: *Hydrangea arborescens* 'Annabelle' #5 container. Here are the main steps to produce this plant. Summer softwood cuttings are taken from existing stock and rooted into 2-in. plug.

- Year 1: spring plant 2-in. plug into 3 row field beds, grow for 2 years.
- Year 3: spring dig bare root plants from field and grade to size; spring pot bare-root liners into #5 containers. If not enough plants available then can bump our own #2 container or buy in #2 or bare root to make up difference. Summer, plants are ready and start selling. Approximately 50% sell in bloom.
- Year 4: leftover 50% of crop sells during spring and early summer until new crop is ready.

Forecast demand

Forecasting demand requires good sales history data, knowledge of previous inventory, how your customers and competitors are likely to change and some 'gut feel'. We hold a 3-day meeting each winter to review every plant and SKU we grow. Make sure to have:

- Previous sales quantity and price over last 3 years.
- Main customers, price trend, gross margin.
- What quantity is presold (you already know who is going to buy it).

- Mass merchants account requirements.
- Brands—new plants coming, possible cannibalism with established cultivars. An example of new plants that may compete with *H. arborescens* 'Annabelle' (Table 1).

For our example, we decide the future sales number for *H. arborescens* 'Annabelle' in #5 container is 1,000 year^{-1}.

Table 1. Plants that may compete with *Hydrangea arborescens* 'Annabelle'.

Hydrangea arborescens NCHA4', Incrediball® Blush
H. arborescens 'Abetwo', Incrediball® smooth hydrangea
H. arborescens 'NCHA8', Invincibelle Limetta® smooth hydrangea
H. arborescens 'NCHA5', Invincibelle Wee White® smooth hydrangea
H. arborescens 'NCHA7', Invincibelle Mini Mauvette® smooth hydrangea
H. arborescens 'NCHA3', Invincibelle Ruby® smooth hydrangea
H. arborescens 'NCHA2', Invincibelle® Spirit II smooth hydrangea
H. arborescens 'SMNHALR', Lime Rickey® smooth hydrangea

Inventory/orders/forecast

Therefore our job at Container Farm is to have 1,000 available for sale each year. Now we need to look at:

- Inventory that is ready now.
- Current orders, so how many are available.
- Next crop coming on, how many and when ready.
- Crop time to finish, timing of the selling season.

From Table 2 for #5 container we see:

- Inventory = 888 in # 5 container.
- Current orders available Jan 2018 = 459.
- Next crop coming on = 0 till July 15 new crop, not shown in table; July 15 is when the newly potted crop we are calculating will be saleable.
- Selling season to July 15 in 2017 = 639; other records show that we can sell an additional 639 plants by July 15.
- 639 – 459 = -180 sold out!
- Before July 15, 2018 we'll be sold out.

So the forecast demand sales number = 1,000 and inventory/sales shows we'll be short 180 units.

Table 2. Inventory and sales: shortage calculation.

			Inventory			Inventory		Full year sales		
		List price	Avail. now to Jan 2, 2018			Avail. between Jan 3, 2018 and Jun 5, 2018		2017 to date (Qty)	2016 (Qty)	2015 (Qty)
Botanical	Size	2017	In stock	Orders	Avail.	June 2018	Orders			
Hydrangea arborescens 'Annabelle'	# 2 CG	$13.50	2,532	513	2,019	5,208	1,139	4,612	5,364	3,927
Hydrangea arborescens 'Annabelle'	# 5 CG	$24.50	888	429	459	0	0	1,026	884	918

Want number

The Want number is how many do we pot in 2018. Working backwards from ready date and scheduling to forecast sales. Build an Excel® template so we can see quantities selling and being produced:

- Want number = how many do we pot in 2018?

• Need 180 before July 15, round up to 200.
• 1,000 for rest of 2018 and Spring 2019.
• Want number = 1,200 (need to pot 1,200 in Spring 2018).

What liners are available to meet the potting target of 1200? There are 500 from self-produced (GW), bump, or buy in? Are there any of our own #2 available to bump up? There are 2,019 available (Table 3) which we will sell by June and then 5,208 for the next crop cycle. The sales target for #2 container size is 5,000 and with orders against the June crop of 1,139 already we forecast to sell the whole crop, so none are available for bump.

Table 3. Potting plan.

Product	Gallon	Projection 2018	Want 2018	Incoming	Supplier	Note	Bump
Hydrangea arborescens 'Annabelle'	5	1,000	1,200	500+700	GW/buy	No #2 avail. for bump	

Liner size and growing time

We need to find 700 more liners to add to the 500 self-produced to meet our Want number potting target of 1,200 units. At this point we may walk own liner crops again to check on size, variability, and double check the counts. Options for liners to put in the #5 container:

• Bare root is available at a cost of $5.06 landed.
• Buy in #1 or #2 size to shift up.
• What is the margin if we buy in?
• Will the buy in meet our 35% target?

At this point we often work with our supplier partners (Figure 2) who can recommend what liner to finish in a certain time and cost.

Figure 2. Shipment of potted liners arriving from supplier (Spring Meadow Nursery).

Review and stay nimble

Let's review the margin if we use the bare-root liners from above. Once your production costs are known, a simple spreadsheet can be created to plug in list price, liner cost, growing time to show forecast margin (Table 4). In this case the bare-root liner at $5.06 landed gives us 39% margin, so meets the 35% minimum target.

Table 4. Margin/cost template.

List	Net sell	Gross margin	Total cost	Liner	Factor	Liner landed	Pot	Grow	Grow years	Net grow	Yield	Assembly/ tag
24.50	19.60	39%	11.88	4.60	1.10	5.06	2.01	3.37	1.00	3.37	0.97	1.12

Our decision is to pot the 1,200 *H. arborescens* 'Annabelle' #5 from 500 of our own liners and 700 bought in as bare-root liners. We also need to review in the coming winter:

- Want number again before potting. If bookings are way up, we may want to increase potting number.
- Hold at 1,000 units to plant in bed liners in 2018 to pot up in 2020?
- Hold at 1,000 units to propagate in 2018, to plant out in 2019 and pot up in 2021?

There are always ways to improve the production planning method. At Sheridan Nurseries we are still working on:

- Improving ways to monitor so we know earlier when a crop is not selling on plan—adapt selling plan, potential future surplus.
- Check monthly what is booking/selling way more or less than same point last year. Can we increase production?
- Improving forecasting for new cultivar demand.
- Shorter crop cycles, eliminating steps so that in production we can react sooner to market/demand changes.

Midwest groundcovers lean flow journey with Flow Vision©

M. Fredrickson[a]

Midwest Groundcovers, PO Box 748, St. Charles, Illinois 60174, USA.

Midwest Groundcovers is a wholesale nursery based out of St. Charles, Illinois that focuses on growing a wide range of products in five production nurseries in Illinois and Michigan. Due to concerns of decreasing labor availability, increasing labor costs, and increasing transportation costs; along with the desire to increase the capacity of order fulfillment, increase transportation capacities, and to eliminate all non-value added work, we explored how Flow Vision could help us to streamline processes to ease these concerns and to increase our overall profitability.

Midwest Groundcovers began working with Flow Vision in June of 2015. During the first assessment, Flow Vision identified five areas for Lean Flow redesigns. Distribution and shipping, the customer pick-up area, propagation, lean materials strategies, and cart optimization, possibly with Lean Flow's RIO software.

Because Midwest Groundcovers is spread out between five locations in two states, we decided to redesign our distribution and shipping processes and to implement a cart optimization program. We chose this process because all five locations would be equally impacted with the implementation. All company departments and employees would be equally involved because shipping and distribution is our most standardized process. Shipping capacities had been our greatest limitation on company growth and it would bring forth the greatest benefits to our customers. Another goal was to lower employee stress during the busy shipping season. And last it would bring Midwest Groundcovers the quickest return on investment. Although we had many good reasons to focus on distribution and shipping, we also found out that we chose the most difficult project to start with.

Midwest Groundcovers' shipping department is based out of the St. Charles, Illinois location. Before the Lean Flow implementation, inventories of all salable products from the outlying nurseries would be warehoused in the St. Charles nursery in what we call the holding area. Plants would be picked from this inventory to fill orders. We would transfer inventory from production nurseries to replenish the holding area based on predetermined minimum and maximum inventory set points. All orders were picked individually and all the plant material would end back at the shipping dock where it first arrived.

The first part of the redesign process was for us to map out our desired order pulling process. We did this by creating flow charts to indicate what everyone needed to be doing. This process needed to be mapped from the time that the sales department took the order to the time the order landed at the customers. Through this process we wanted to continue to guarantee customers that we would be able to deliver their order within 36 h. For this new process to work, we also determined that we needed to have firm order cut off times.

We implemented what Flow Vision calls a "pre-staged order" or what we are calling at Midwest Groundcovers a "Moving Supermarket". With the new process, all plant material is bulk pulled from the production nurseries (Figure 1). For example, with the old process, if there were 10 orders that each contained five flats of *Pachysandra*, 10 order pullers would go to the pachysandra house to each pick five flats. Now one order puller goes to the pachysandra house one time and picks 50 flats. All material for our shipping orders now stays on the shipping dock. All shipping carts are staged by truckload in a predetermined location. Paperwork is distributed to show the shipping employees how to load the carts so that they do not have to figure out how to load the carts. The transfer carts of bulk pulled material are moved through the dock and their plants are offloaded onto the pre-staged shipping carts. Bottle necks have been removed as workers can continue to load carts and do

[a]E-mail: mfredrickson@midwestgroundcovers.com

not have to wait to receive their next order, order pickers do not waste time driving through the nursery, or wait for their turn to get onto the dock.

Figure 1. Bulk pulled plant material from the production nurseries.

Changes made to the order picking process in remote production nurseries also helped. All order picking paperwork was changed so that it is now printed out in geographic order of the nursery, not in alphabetical order. There is also paperwork for all internal transfer loads to show workers how to load the carts. This has maximized our internal shipping capacity by making sure that all carts are filled to capacity. In order for this to work, our inventory department must now make sure that all salable plant heights are accurate in our ERP system so that our cart optimizer works properly. We have also seen a positive result of this with our sales team as they now always have accurate plant heights to use when selling.

Our Lean Flow implementation also forced us to evaluate how we label our plants. Because we warehoused our salable plants in the holding area before Lean Flow, we did not need to label plants until they were picked for an order; we also gave our customers six label options that would be attached when the order was picked. We now label all material in the production nursery at the time it is picked and have also reduced label options to only two. This initial change has saved us 62% on label stock and printer toner alone from the year prior. We also need less time and labor to prepare plant labels with the new process.

Since our implementation, we have increased our shipping capacity thresholds by 30%. Midwest hit a record for the amount of material shipped in one day only four weeks after our implementation. We have also decreased our holding area nursery by 33% and

converted this space into production space, increased the amount of cross-docked material by 40%, and improved product quality due to less transportation damage and decline from being in a holding area.

As it is easy to point out the successes of our Lean Flow implementation, there have also been many difficulties with this implementation. We went live on 20 April 2017. This timing was good to make sure that we couldn't back out, however we needed to learn and train new processes to our employees going into the busiest time of the year. We had to undergo very difficult computer programming to our ERP system and we were unable to get it complete in time. This caused two weeks of chaos until the program finished. Because this implementation involved changes to processes that worked very well in the past, it was difficult getting all employees engaged and involved and we had to constantly remind them that the old process wasn't bad, but that we had outgrown it. Managers and supervisors needed to give support and to show the results and improvements of the process change. Our next challenge is how to better redistribute employees and resources when the work is completed quicker than before.

Overall, Midwest Groundcovers is pleased with the results of our first Flow Vision process redesign. We now consider lean a part of our culture. It is a new way of working and we are constantly improving our processes. We are constantly reviewing our results and celebrating our accomplishments.

The rooting response of evergreen and deciduous cuttings to foliar applications of the rooting hormone indole-3-butyric acid©

A. Phillips[a]

Spring Meadow Nursery, 12601 120th Avenue, Grand Haven, Michigan, 49417, USA.

Abstract

This study sought to answer the question of whether a foliar application of indole-3-butyric acid (Hortus IBA Water Soluble Salts) could replace a basal treatment of indole-3-butyric acid plus 1-naphthaleneacetic acid (Dip 'n Grow), in the production of evergreen and deciduous rooted cuttings, without a loss of plant quality or rooting percentage. The evergreen cuttings were given three treatments, including a basal quick dip of Dip 'N Grow (IBA/NAA) with concentrations ranging from 1000-7500 ppm, a foliar spray of Hortus IBA Water Soluble Salts (IBA) at half the concentration of the basal quick dip, and a second identical foliar spray one week later. The deciduous cuttings were also given three treatments, including a basal quick dip of Dip 'N Grow (IBA/NAA) with a concentration of 500 ppm, a foliar spray of Hortus IBA Water Soluble Salts (IBA) of 500 ppm, and a control with no hormone treatment. Evergreen rooted cuttings were evaluated half way through, and at the end of the production cycle, while the deciduous rooted cuttings were evaluated only at the end of the production cycle. Both groups of cuttings were evaluated using a quantative 0-5 scale, 0 being necrotic and 5 being fully rooted. Results were compared by using RStudio statistical program, including the one-way ANOVA test and the Tukey HSD test, both at the 0.05 level. Results showed that rooting scores of broad leaved evergreens with a foliar treatment were less than those of the basal quick dip treatment, rooting scores of needle leaved evergreens with a foliar treatment were not significantly different than those of the basal quick dip treatment, while rooting scores of scale leaved evergreens with a foliar treatment were greater than those of the basal quick dip treatment. Most deciduous taxa were not significantly different when comparing foliar and basal quick dip treatments. Both evergreen and deciduous taxa that were significantly improved, or not significantly different when comparing foliar and basal quick dip treatments could be produced by using a foliar treatment without loss of plant quality or rooting percentage.

INTRODUCTION

There are multiple methods for applying rooting hormone on cuttings in order to encourage root growth. One method is a basal quick dip, which involves dipping the stem of the cutting into concentrated hormone for a few seconds and then sticking into media. Another method is spraying rooting hormone onto the leaves of the cutting to the point of dripping after they are stuck into media and placed in a controlled environment (Kroin, 2011). The basal quick dip method is the standard practice at Spring Meadow Nursery, in Grand Haven, Michigan.

Spring Meadow Nursery recently purchased four ISO Group (www.isogroep machinebouw.nl) sticking machine robots (Figure 1). The basal quick dip method of hormone application was used before the cuttings were placed in the machine. This caused the cuttings to stick together and prevented the cameras from recognizing the cuttings, which resulted in decreased productivity. These issues led to trials of foliar applications of rooting hormone on evergreen and deciduous cuttings, after they were stuck in media and placed in the greenhouse. This study was designed to determine whether a foliar treatment

[a]E-mail: aren@springmeadownursery.com

of auxin can replace the standard basal quick dip treatment, without reducing the quality and percentage of rooted cuttings.

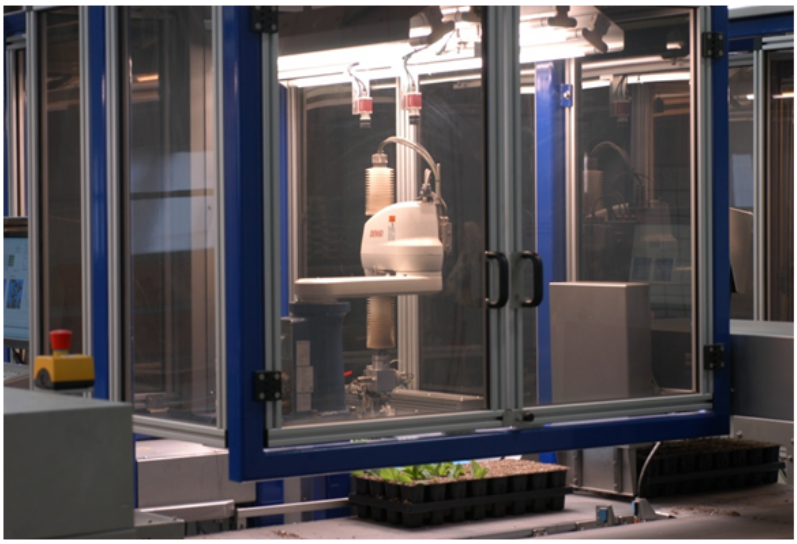

Figure 1. ISO Group sticking machine robot.

MATERIALS AND METHODS

Experiment 1: rooting response of evergreen cuttings to foliar or basal applications of IBA

Evergreen cuttings were taken from field-grown stock plants at Spring Meadow Nursery, in Grand Haven, Michigan from mid-October through December of 2016. Seventeen taxa from eight genera were used in the study (Table 1), including *Buxus microphylla* var. *japonica* 'Winter Gem'; *Buxus* 'Green Velvet'; *Cephalotaxus harringtonia* 'Duke Gardens' and 'Fritz Huber'; *Chamaecyparis pisifera* 'Gold Mop' and 'Dow Whiting', Soft Serve® false cypress; *Ilex crenata* 'ANNYS1', Brass Buckle® Japanese holly and 'FarrowSK6', Patti O® Japanese holly; *Ilex glabra* 'Compacta'; *Ilex* × *meserveae* 'Hachfee', Castle Spire® blue holly; *Juniperus horizontalis* Good Vibrations® Gold; *J. squamata* 'Blue Star'; *Microbiota decussate*; *Taxus* × *media* 'Densiformis'; and *Thuja occidentalis* 'Congabe', Fire Chief™ arborvitae; *T. occidentalis* 'Nigra Dark Green' and 'SMTOYB', Polar Gold™ arborvitae. All cuttings measured between 2 and 3 in. and were handled in bundles of 25-50 cuttings, depending on the size of the cutting. Cuttings were stored in plastic containers overnight in a walk-in cooler set at 7.2°C (45°F). Per standard protocol, *Ilex* cuttings were treated with EthylBloc™ ethylene inhibitor in air-tight containers overnight and stuck the next day.

The experiment included three treatment groups: a basal quick dip, a foliar treatment applied once and a foliar treatment applied twice with treatments separated by one week. All foliar treatments were applied at 50% of the concentration of the standard treatment (Blythe et al., 2004). Each treatment group had two 72-cell trays (144 cuttings) per treatment, per evaluation round. Treatment groups were labeled and placed within the commercial production group.

The basal quick dip treatment varied from 1000 ppm to 7500 ppm Dip 'n Grow (indole-3-butyric acid plus 1-naphthaleneacetic acid), depending on taxon, and was based on standard production protocol (Table 1). Bundles were treated using the basal quick dip method (stems were dipped into the hormone for two seconds and directly stuck into the media). The cuttings were stuck into 72-cell trays containing soilless media (50% decomposed pine bark by volume, 50% perlite and 3.5 pounds per cubic yard limestone).

Table 1. List of evergreen taxa, hormone concentration of treatments, and timing of evaluations. The basal quick dip hormone concentration was based on standard protocol at Spring Meadow Nursery. The foliar hormone concentration was half the basal quick dip concentration. Round 1 rooting evaluations took place when the roots of the commercial production cuttings filled the cell half way. Round 2 rooting evaluations took place when the commercial production cuttings were rooted well enough to be transplanted to the finished size. The time was measured in weeks from sticking in order to normalize elapsed time, since the cuttings were stuck in different production weeks, depending on taxon.

Plant	Hormone (ppm)		Number of weeks from sticking	
	Basal quick dip	Foliar	Evaluation round 1	Evaluation round 2
Buxus microphylla var. *japonica* 'Winter Gem'	1000	500	16	33
Buxus 'Green Velvet'	1500	750	16	28
Cephalotaxus harringtonia 'Duke Gardens'	5000	2500	20	26
C. harringtonia 'Fritz Huber'	7500	3750	22	27
Chamaecyparis pisifera 'Gold Mop'	3000	1500	24	31
C. pisifera Soft Serve® false cypress	3000	1500	16	22
Ilex crenata 'ANNYS1', Brass Buckle® Japanese holly	1000	500	11	33
I. crenata 'FarrowSK6', Patti O® Japanese holly	1000	500	14	24
I. glabra 'Compacta'	1500	750	12	32
I. × *meserveae* 'Hachfee', Castle Spire® blue holly	1000	500	8	25
Juniperus horizontalis 'Hegedus', Good Vibrations® Gold	3000	1500	18	22
J. squamata 'Blue Star'	5000	2500	19	27
Microbiota deussata	2000	1000	22	32
Taxus × *media* 'Densiformis'	3000	1500	15	28
Thuja occidentalis 'Congabe', Fire Chief™ arborvitae	2000	1000	11	29
T. occidentalis 'Nigra Dark Green'	3000	1500	22	31
T. occidentalis 'SMTOYB', Polar Gold™ arborvitae	3000	1500	12	28

The foliar treatment applied once varied from 500-3750 ppm Hortus IBA Water Soluble Salts (20% indole-3-butyric acid) depending on taxon, and 700 ppm Kinetic (polyalkyleneoxide and modified polydimethylsiloxane) as a surfactant (Blythe et al., 2004). The foliar treatment concentration was 50% of the basal quick-dip treatment (Table 1) (Blythe et al., 2004). The cuttings were sprayed by hand, using a 750-mL spray bottle, immediately after being stuck in 72-cell trays and placed in the greenhouse. The media used was the same as the basal quick dip treatment. Each tray was sprayed with about 40 mL of solution in order to reach the point of dripping. This volume was based on the spray rate of 1 gal per 200 sq. ft (Drahn, 2007). The foliar treatment applied twice was the same treatment as described, applied to the same trays one week after sticking (Kroin, 2008).

The cuttings were rooted in a Westbrook greenhouse, with internal dimensions of 72 ft wide, 300 ft long and 14 ft tall. All growing conditions were maintained by Argus Titan version 8.2 systems control software. The air temperature was maintained between 4.4-10°C (40-50°F), while the floor heat was set at 21°C (70°F). Relative humidity levels were maintained between 60 and 100%, using an automated high-pressure fog system. Cuttings were misted periodically with automated travelling booms, set to run on vapor pressure deficit thresholds between 2.85 millibars and 9.5 millibars, depending on the rooting progress of the cuttings. Shade curtains were not used during the time of the study. Some taxa were rooted under supplemental lighting, including *C.* 'Duke Gardens' and 'Fritz Huber', *J. squamata* 'Blue Star', and *T. occidentalis* 'Nigra Dark Green' and 'SMTOYB', Polar Gold™ arborvitae. Supplemental lighting occurred for 12 h between 7:00 a.m. and 7:00 p.m. at 80 µmol m^{-2} s^{-1}. All environmental conditions were based on standard production protocol at Spring Meadow Nursery.

Rooting progress of the experimental treatments was evaluated two times: first, when the roots of the commercial production group half-filled the cell and second, when the

commercial production group was rooted well enough to be transplanted into its finished size. The first evaluation took place between 8-24 weeks after sticking (15 Dec. 2016, through 16 May 2017), while the second evaluation took place between 22-33 weeks after sticking (13 April 2017, through 22 June 2017), depending on taxon (Table 1). Rooting progress was evaluated twice, in order to record any differences within a given treatment over time. Cuttings were carefully removed from the cell using a plastic fork, in order to avoid breaking the roots. They were rinsed with water to remove the media, so the quality of the roots could be determined.

Rooting quality was graded on a scale from 0-5, with these descriptions: 0-necrotic stem, 1-live cutting with no response, 2-swelling, breaking or root initials, 3-few small visible roots, 4-developed roots at the base of the stem and 5-developed roots along the length of the stem (Figure 2). This scale was modified from a similar scale by McGuire and Sorensen (1966). Rooting percentage was determined by considering a rooting score of 0-3 as unrooted, while a score of 4-5 as rooted. This delineation represented the quality of rooted cuttings that were potted to the finished size.

Figure 2. Rooting evaluation guideline for all taxa. Each cutting was assigned a rooting score based on the quality of rooting: 0-necrotic stem, 1-live cutting with no response, 2-swelling, breaking or root initials, 3-few small visible roots, 4-developed roots at the base of the stem, 5-developed roots along the length of the stem (*I.* × *meserveae* 'Hachfee', Castle Spire® blue holly basal quick dip, 8 weeks after sticking).

Experiment 2: rooting response of deciduous cuttings to foliar or basal applications of IBA

Deciduous cuttings were taken from field-grown stock plants at Spring Meadow Nursery, in Grand Haven, Michigan, from June to August 2017. Four taxa were used in the study, including *Buddleia* 'Miss Molly', *Hydrangea paniculata* 'SMHPFL', Fire Light® panicle hydrangea, *Physocarpus opulifolius* 'SMPOTW', Tiny Wine® ninebark and *Weigela florida* 'Verweig 6', Sonic Bloom® Red weigela. The cuttings were either terminal or two-leaf, depending on taxon, condition of stock plants and standard production protocol. The storage environment was the same as for the evergreen cuttings described in the previous experiment.

This experiment included three treatment groups: a basal quick dip treatment, a foliar treatment applied once at 100% concentration of the standard treatment, and a control with no treatment. Each group had two 32-cell trays (64 cuttings) per treatment. Treatment groups were labeled and placed within the commercial production group.

The basal quick dip treatment hormone was 500 ppm Dip 'n Grow (indole-3-butyric acid plus 1-naphthaleneacetic acid). Bundles were treated using the basal quick dip method as described previously. The cuttings were stuck by hand into 32-cell trays containing

soilless media (30% decomposed pine bark by volume, 35% peat, 35% perlite, 3.5 pounds per cubic yard limestone and 6 pounds per cubic yard 15-9-12 slow release fertilizer).

The foliar treatment hormone was 500 ppm Hortus IBA Water Soluble Salts (20% indole-3-butyric acid) and 700 ppm kinetic (polyalkyleneoxide and modified polydimethylsiloxane) as a surfactant (Blythe et al., 2004). Since there was not a second foliar application in this experiment due to quick rooting times of softwood cuttings, the concentration for the foliar treatment was the same as the basal quick dip treatment (Kroin, 2011). This was applied to the commercial production group and the experimental group at the spray rate of 1 gal per 200 sq. ft (Drahn, 2007). It was applied using a 15 L (4 gal) back-pack sprayer, due to the increased volume needed to cover the large commercial production group. The cuttings were stuck using the ISO Cutting Planter 2500, in the same tray and media as described above. Timing of the application occurred in the morning following sticking, in order to avoid high misting rates from the automated booms in the afternoon (Kroin, 2011).

The control was directly stuck by hand into 32-cell trays and not treated with either a basal quick dip or a foliar application.

The cuttings were rooted in a Westbrook greenhouse as described in the previous experiment. The air temperature was maintained between 18.3-28.9°C (65-84°F), while the floor heat was set at 21°C (70°F). Relative humidity levels ranged between 30-100%, depending on the time of day. The cuttings were not grown in a high-pressure fog house as in the previous experiment, but were misted in the same manner.

Rooting scores were evaluated when the commercial production group was rooted well enough to move out to growing greenhouses. This took place between 3 and 5 weeks after sticking, depending on taxon. Rooting quality was graded in the same manner as described in the previous experiment.

Rooting scores for both experiments were evaluated using the statistical program RStudio, using one-way analysis of variance and Tukey's highly significant difference test, both at the 0.05 level. Variables compared included: taxon, weeks from sticking, treatment, hormone concentration, evaluation round, and leaf type.

RESULTS

Experiment 1: Rooting response of evergreen cuttings to foliar or basal applications of IBA

The rooting scores of each taxon were graphed as boxplots, using RStudio statistical software (Figure 3). Statistical differences were determined by using one-way analysis of variance and Tukey's highly significant difference test at the 0.05 level.

In order to simplify comparisons within each taxon, the mean rooting scores were found for each treatment and each evaluation round (basal quick dip Round 1, basal quick dip Round 2, foliar once Round 1, foliar once Round 2, foliar twice Round 1, and foliar twice Round 2). The foliar treatment with the highest mean was compared to the basal quick dip treatment with the highest mean. Based on these comparisons, the taxa were grouped into three categories:

1) The foliar treatment was significantly higher than the basal quick dip treatment.
2) The foliar treatment was not significantly different than the basal quick dip treatment.
3) The foliar treatment was significantly lower than the basal quick dip treatment.

The highest mean rooting scores of each treatment and evaluation round were compared in order to control for notable crop losses in the time between round 1 and round 2, including *J. horizontalis* 'Hegedus', Good Vibrations® Gold and *C. pisifera* 'Gold Mop'.

Three of the taxa, *B.* 'Green Velvet', *C. pisifera* 'Gold Mop' and *C. pisifera* 'Dow Whiting', Soft Serve® false cypress; and *I.* × *meserveae* 'Hachfee', Castle Spire® blue holly, showed that the foliar treatment with the highest mean was significantly lower than the basal quick dip treatment with the highest mean.

The majority of the taxa did not show a statistical difference between the basal quick

dip treatment and the foliar treatment with the highest means, including: *B. microphylla* var. *japonica* 'Winter Gem'; *C. harringtonia* 'Duke Gardens'; *C. pisifera* 'Gold Mop'; *I. crenata* 'FarrowSK6', Patti O® Japanese holly; *I. glabra* 'Compacta'; *M. decussate; T.* × *media* 'Densiformis'; *T. occidentalis* 'Congabe', Fire Chief™ arborvitae; *T. occidentalis* 'Nigra Dark Green'; and *T. occidentalis* 'SMTOYB', Polar Gold™ arborvitae.

Five of the taxa showed that the foliar treatment with the highest mean was significantly higher than basal quick dip treatment with the highest mean, including *C. harringtonia* 'Fritz Huber'; *I. crenata* 'ANNYS1', Brass Buckle® Japanese holly; *J. horizontalis* 'Hegedus', Good Vibrations® Gold; and *J.* 'Blue Star'.

When comparing rooting scores of evaluation round one and round two within treatments, all of the taxa showed either a significant increase in rooting scores or no significant difference. The only taxa that showed a significant decrease were taxa that had notable crop losses during the experiment as mentioned previously.

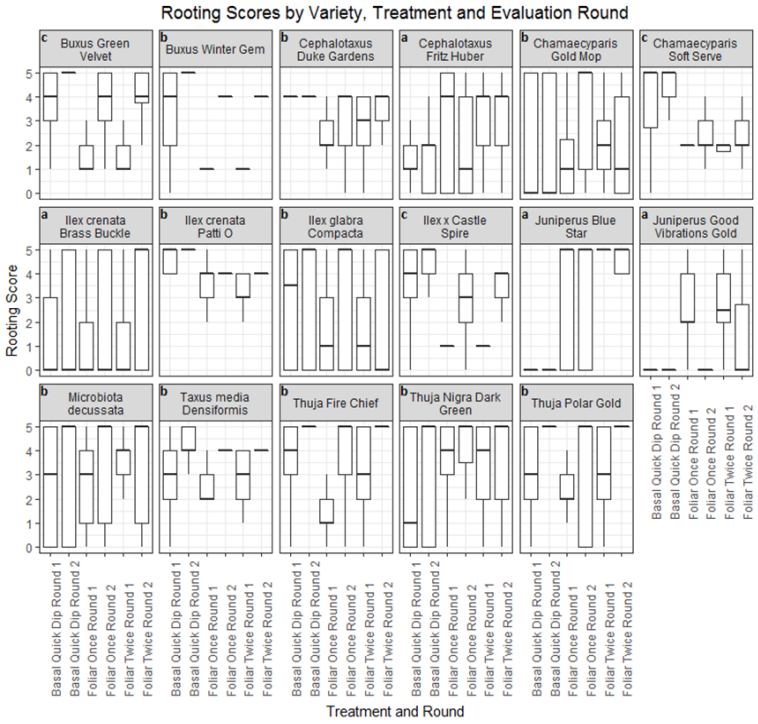

Figure 3. Comparison of rooting scores, treatments, evaluation rounds and hormone concentration for each taxon. Rooting quality was evaluated on a scale of 0-5: 0-necrotic stem, 1-live cutting with no response, 2-swelling, breaking or root initials, 3-few small visible roots, 4-developed roots at the base of the stem, 5-developed roots along the length of the stem. Rooting hormone treatments included: a basal quick dip (1000-7500 ppm IBA/NAA), a foliar application once at sticking, and a second foliar application one week after sticking (500-3750 ppm IBA). The first rooting evaluation took place when the roots of the commercial production cuttings half-filled the cell. The second evaluation took place when the commercial production cuttings were transplanted to their final size. All foliar treatments were half the concentration of the basal quick dip of the same taxon. Groups were evaluated using Tukey's HSD test at 0.05 significance level. Letters denote a significant difference: a- highest foliar treatment was significantly higher than the highest basal quick dip treatment, b- highest foliar treatment was not significantly different than the highest basal quick dip treatment, and c- highest foliar treatment was significantly lower than the highest basal quick dip treatment.

To simplify comparisons, taxa were grouped by leaf type and rooting scores were compared (Figure 4). Broad leaved taxa included *Buxus* and *Ilex*, needle leaved taxa included *Cephalotaxus* and *Taxus*, while scale leaved taxa included *Chamaecyparis, Juniperus, Microbiota*, and *Thuja.*

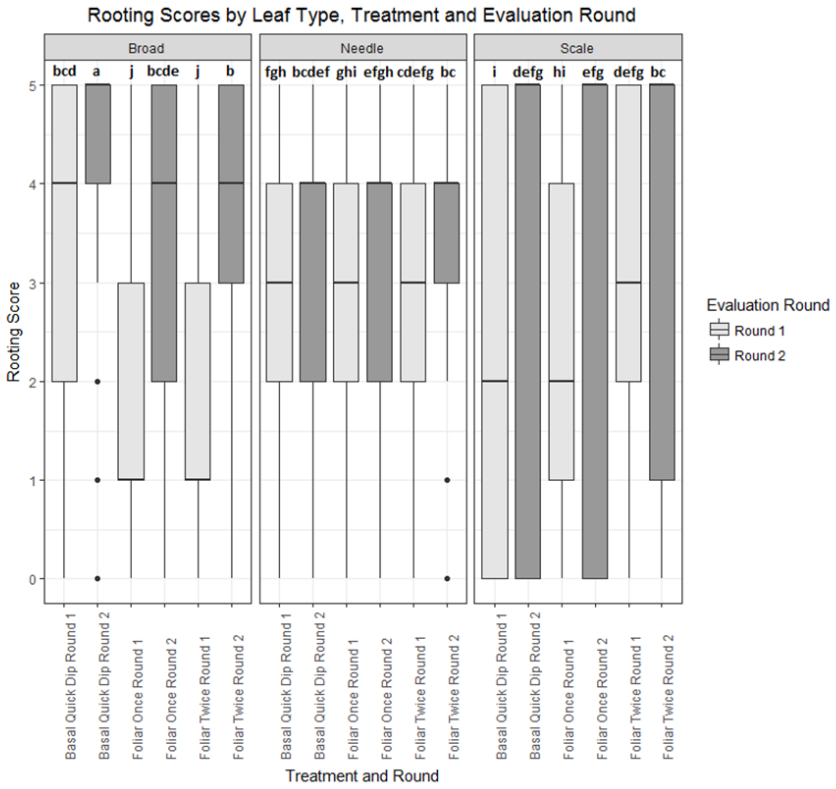

Figure 4. Comparison of rooting scores, treatments and evaluation rounds for each leaf type. Broad leaved taxa included Buxus and Ilex, needle leaved taxa included *Cephalotaxus* and *Taxus*, and scale leaved taxa included *Chamaecyparis, Juniperus, Microbiota* and *Thuja*. Rooting quality was evaluated on a scale of 0-5: 0-necrotic stem, 1-live cutting with no response, 2-swelling, breaking or root initials, 3-few small visible roots, 4-developed roots at the base of the stem, 5-developed roots along the length of the stem. Rooting hormone treatments included: a basal quick dip (1000-7500 ppm IBA/NAA), a foliar application once at sticking, and a second foliar application one week after sticking (500-3750 ppm IBA). The first rooting evaluation took place when the roots of the commercial production cuttings half-filled the cell. The second evaluation took place when the commercial production cuttings were transplanted to their final size. All foliar treatments were half the concentration of the basal quick dip of the same taxon. Groups were evaluated using Tukey's HSD test at 0.05 significance level. Letters of groups with significant differences are at the top of the boxplot. All median lines of round 2 for both needle and scale are at the top of the boxplot.

The mean rooting score for each treatment was compared within leaf types, and between evaluation rounds one and two. There was a significant decrease in the mean broad-leaved rooting score when the basal quick dip treatment was compared to either foliar treatment in round one and round two. There was no statistical difference in the mean needle-leaved rooting score when all treatments were compared in round one, but there was a significant increase when the foliar once treatment was compared to the foliar twice treatment in round two. There was a significant increase in the mean scale-leaved rooting

score when the basal quick dip treatment was compared to the foliar twice treatment in round one and round two.

Rooting scores by taxon were converted to rooting percentages by considering a rooting score of 0-3 as unrooted, while a score of 4-5 as rooted (Figure 2). This delineation represented the quality of rooted cuttings that were potted to the finished size. Rooting percentages of evaluation round 2 for both types of foliar treatments were compared to standard expected rooting percentages. These are based on historical rooting records while using the basal quick dip method at Spring Meadow Nursery.

Ten taxa had at least one foliar treatment that had a rooting percentage within 5% or higher of the expected rooting percentage, including: *B.* 'Winter Gem', *C. harringtonia* 'Duke Gardens', *I. crenata* 'ANNYS1', Brass Buckle® Japanese holly and *I. crenata* 'FarrowSK6', Patti O® Japanese holly, *J.* 'Blue Star', *M. deussata, T.* 'Densiformis' and *T. occidentalis* 'Congabe', Fire Chief™ arborvitae, 'Nigra Dark Green', and 'SMTOYB', Polar Gold™ arborvitae.

All remaining taxa had foliar rooting percentages that were lower than 5% of the expected rooting percentage, although *C. harringtonia* 'Fritz Huber'; *C. pisifera* 'Gold Mop'; and *J. horizontalis* Good Vibrations® Gold all had foliar treatment rooting percentages that were higher than the basal quick dip treatment. *Buxus* 'Green Velvet', *C. pisifera* 'Dow Whiting', Soft Serve® false cypress, *I. glabra* 'Compacta' and *I.* × *meserveae* 'Hachfee', Castle Spire® blue holly had foliar rooting percentages that were lower than both the expected rooting percentage and the rooting percentage of the basal quick dip treatment.

Experiment 2: rooting response of deciduous cuttings to foliar or basal applications of IBA

The rooting scores of each taxon were graphed as boxplots, using RStudio statistical software (Figure 5). Statistical differences were determined by using one-way analysis of variance and Tukey's highly significant difference test at the 0.05 level. All taxa were evaluated at 3 weeks after sticking, except *W. florida* 'Verweig 6', Sonic Bloom® Red weigela, which was evaluated at 5 weeks after sticking due to a longer rooting time.

There was no significant difference in rooting scores between all treatments of *B.* 'Miss Molly' and *H. paniculata* 'SMHPFL', Fire Light® panicle hydrangea, with means between 4.7 and 5. There was a significant decrease in rooting scores of *P. opulifolius* 'SMPOTW', Tiny Wine® ninebark, when comparing basal quick dip treatment to either the foliar treatment or the control group (which were not significantly different from each other). There was no significant difference in rooting scores between the basal quick dip treatment and the foliar treatment of *W. florida* 'Verweig 6', Sonic Bloom® Red, but the control group had significantly lower rooting scores.

DISCUSSION

Results from both the evergreen and the deciduous foliar treatments of IBA showed that there are certain taxa that respond as well as a basal quick dip, but the rooting response was highly variable. At this time, foliar treatments will not completely replace basal quick dip treatments as standard practice at Spring Meadow Nursery, but certain taxa will continue to be studied. Protocol for certain scale leaved evergreen cuttings is likely to change to a foliar treatment for the 2018 evergreen production season. Protocol for certain deciduous cuttings has already changed from a basal quick dip to a foliar treatment.

The evergreen study showed that foliar treatments of some broad leaved evergreens do not respond as well as a basal quick dip treatment. This outcome could be because the concentration for the foliar treatment was half that of the basal quick dip treatment, although there was no significant difference in rooting scores of broad and needle leaved evergreens when the foliar once and foliar twice treatments were compared. Another possibility for lower rooting scores is that the application temperature of 4.4-10°C (40-50°F) was not warm enough for the evergreen stomata to be open (Kroin, 2011). The majority of the rooting scores of broad leaved evergreens with a foliar treatment improved during the time between the first and second round of evaluation. For some broad leaved taxa, this improvement over time was enough to be comparable to the basal quick dip treatment.

Some rooting scores of needle and scale leaved evergreens were comparable to a basal quick dip treatment. In some cases, the foliar treatment had better rooting scores than the basal quick dip treatment. One possibility for this positive response is the larger total surface area of scale leaved cuttings, compared to the smaller surface area of broad leaved cuttings (White, 1983). Another possibility is that broad leaved evergreens have less stomata per surface area, whereas scale leaved evergreen cuttings have a higher concentration of stomata available to take up the rooting hormone (Woodward and Kelly, 1995), which is the entry point into the leaf tissue (Kroin, 2011). Future studies could include evergreen control groups with no hormone treatment and a foliar spray at the same concentration as the basal quick dip treatment. More evergreen taxa would also be studied. Because of the comparable results of the study, certain varieties within the genera *Buxus, Cephalotaxus, Ilex, Juniperus, Microbiota,* and *Thuja* could now be treated with a foliar spray as standard production protocol.

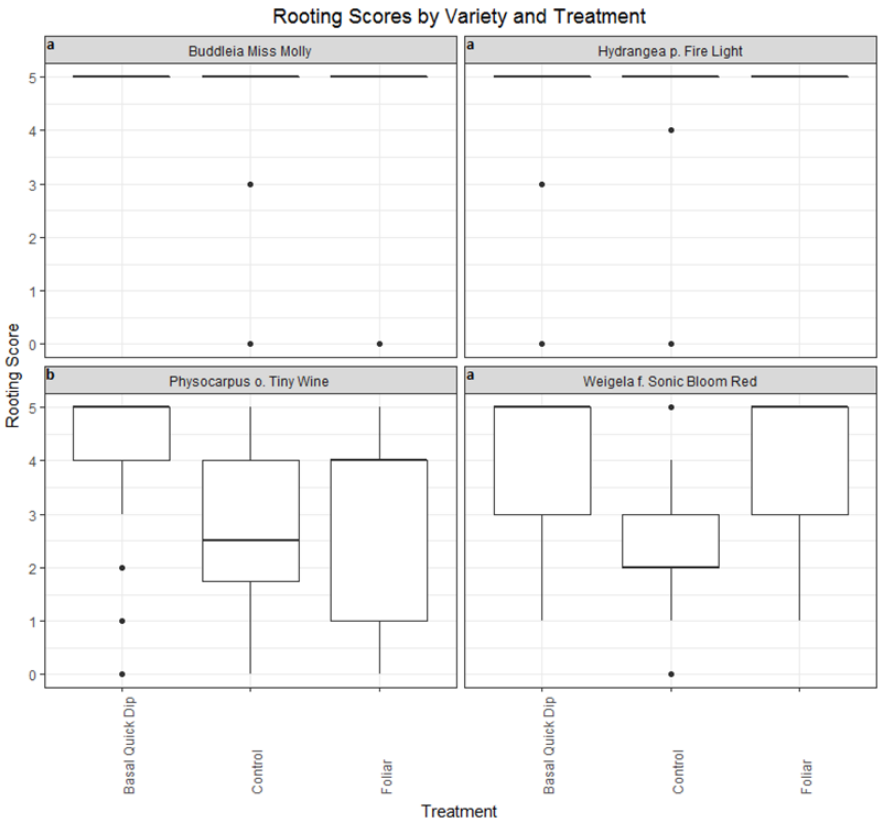

Figure 5. Rooting scores by taxon and treatment. Rooting quality was evaluated on a scale of 0-5: 0-necrotic stem, 1-live cutting with no response, 2-swelling, breaking or root initials, 3-few small visible roots, 4-developed roots at the base of the stem, 5-developed roots along the length of the stem. Rooting hormone treatments included: a basal quick dip treatment (500 ppm IBA/NAA), a foliar treatment (500 ppm IBA), and a control. Rooting was evaluated when the commercial production group was rooted enough to move out to growing greenhouses. Groups were evaluated using Tukey's HSD test at 0.05 significance level. Letters denote a significant difference: a- mean rooting score of the foliar treatment was not significantly different than the mean rooting score of the basal quick dip treatment, and b- mean rooting score of the foliar treatment was significantly lower than the mean rooting score of the basal quick dip treatment. There were no taxa that had a mean rooting score of the foliar treatment that was significantly higher than the mean rooting score of the basal quick dip treatment.

The deciduous study showed that for most taxa there was no significant difference when the basal quick dip and the foliar treatment were compared. This outcome has changed the standard production protocol from a basal quick dip treatment to a foliar treatment for the genera *Buddleia, H. paniculata*, and *Weigela*. In a large scale follow-up experiment, commercial production groups of *Buddleia* and *H. paniculata* taxa that were stuck using the ISO production line were treated with a foliar spray of 500 ppm IBA in the same manner as the experiment, but the application was done using a high pressure sprayer, due to the increased volume to cover the large production groups. Rooting percentages of these groups were compared to expected rooting percentages, and were all within an accepted 5% range. Long-term effects on growth and morphology could be monitored as foliar treated groups reach their ready date (Drahn, 2007). For two of the four taxa, *B.* 'Miss Molly' and *H. paniculata* 'SMHPFL', Fire Light® panicle hydrangea, there was no significant difference when all three treatments were compared, including the control group. The comparable response of the control group to the basal quick dip treatment could possibly lead to the discontinuation of hormone application, or a reduction in concentration for similar taxa. The same study could be repeated in the spring and in the fall to determine if there is a change in rooting response. Other cultivars within the genera that were included in the study (*Buddleia, H. paniculata* and *Weigela)* are currently being evaluated. Other genera that are stuck using the ISO production line that could be tested in the future are *Callicarpa, Cornus, Deutzia, Diervilla, Hibiscus, Loropetalum, Spiraea*, and *Syringa.*

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Restoration horticulture: propagation, production, and marketing of native plants©

B. Schneider[a]

Wildtype, Ltd., 900 N. Every Road, Mason, Michigan 48854, USA.

Wildtype, Ltd. was established in 1996 as both a native plant producer and environmental restoration contractor. The term wild type was borrowed for the name of the nursery to reflect the genetic status of the plants we grow. The nursery currently grows about 250 species of grasses, wildflowers, trees, shrubs and emergent wetland plants. We are primarily a wholesale/commercial producer. Our customer base is largely federal, state and local governments, landscape contractors, universities, conservancies and nature centers. We are open to the public only 12 days a season. While we have a very enthusiastic and knowledgeable retail customer base, the market does not appear to us to be large enough to support a stand-alone retail native plant nursery in our location.

The term restoration horticulture has only recently come into fashion. The need for such a moniker is obvious as native plant production slowly takes its rightful place within the broader field of horticulture. The cornerstone of crop improvement is the selection of desired genetic attributes. In traditional ornamental horticulture and agriculture this includes traits such as bloom time, flower color, drought and pest resistance and nutrient composition among many others. Once these traits are isolated, large numbers of genetically identical or highly inbred plants can be propagated. Uniformity is essential to the marketing of this type of plant culture. The selection process (or lack thereof) is what largely distinguishes restoration horticulture from other types of plant production where uniformity is the goal.

Restoration horticulture is distinguished from other types of plant production first and foremost by reliance on native plants and regional genotypes. In addition, the goal of restoration horticulture is to naturalize the plants that are produced with the objective of producing self-sustaining populations. The naturalization of plants is common in projects such as wetland mitigation, detention basins, bioswales, prairie re-creation, erosion control, and some re-forestation. These plants also find their way into an increasing number of high concept ornamental landscapes within urban and suburban areas.

In selecting plant material for restoration projects homozygous cultivars and varieties should be avoided in favor of straight species, which are generally more heterozygous. Establishing clones or inbred lines in these situations would diminish the genetic diversity a population needs to adapt to seasonal and long-term changes in the environment. For this reason, plants used in ecological restoration are typically grown from seed, from open pollinated plants (Figure 1).

Restoration projects often require large numbers of plants to be established in remote locations or areas that are difficult to access with larger equipment. For this reason direct seeding is commonly used. When plants are called for, they are commonly specified in small containers to reduce unit costs and increase efficiency of out-planting. Furthermore these plants are regionally marketed which creates a self-limiting market. For the most part, straight species are not patentable, providing few proprietary opportunities.

Restoration horticulture is generally synonymous with growing native plants. The term “native plant” is ambiguous at best and therefore defining what this means must be done contextually. For the purposes of this discussion a native plant is one that evolved naturally in a specific locality prior to European settlement. Clearly Native Americans did their share of moving plants around although this dissemination took place with far fewer species and over a much longer time period than the thousands of plant species introduced to North America since Europeans arrived. Through early surveys and botanical records an

[a]E-mail: wildtypeplants@gmail.com

accurate picture of what is native emerged. Political boundaries are sometimes referred to but are really no help when thinking about native ranges and environments these plants inhabit naturally. Range maps of native species are readily available through USDA Plant Database (USDA, NRCS. 2017. The PLANTS Database (http://plants.usda.gov, 29 October 2017). National Plant Data Team, Greensboro, NC 27401-4901, USA). Eco-region maps have been created for many parts of the country, which are largely based upon physiographic criteria. This still does not tell the whole story since plants are found within very specific habitats within their respective ranges and eco-region.

Figure 1. Germinating Prairie Dock, *Silphium terebinthinaceum*.

Since 1996 Wildtype has collected over 450 species from 54 Michigan counties. This represents approximate 10,000 collections primarily from existing remnant populations. The location and date of collections are noted and recorded in a database. We have established populations of some species at the nursery for seed collecting. We are careful not to collect from anything but F_1 populations to minimize the risk of selection. This means we do not use seed produced at the nursery to produce more plants with the intent of producing more seed for our nursery production. To further minimize the risk of narrowing the gene pool from populations established at the nursery, we start or augment these plantings with a mix of seed collected from multiple locations.

Although, we have collected over 450 species, we currently grow only about 250 species that leaves approximate 200 species we have collected but are not marketing. This group includes some recalcitrant species but more often engineers, landscape architects and consultants that write specifications are unfortunately relying on a surprisingly small number of species.

Not all projects require the same genotypic standard. When designing our own projects we try to place each new endeavor along a continuum ranging from residential and commercial landscapes at one end, to restoration of native landscape remnants at the other. The middle of this continuum includes projects such as rain gardens, detention basins, bioswales, wetland mitigations, park plantings, etc.

When natives are incorporated into traditional residential or commercial landscapes they are generally not intended to naturalize and therefore genotype may not be as important. The use of cultivars may be desired and acceptable. In almost all stormwater, erosion control, stream bank, wetland, lakeshore, prairie, and re-forestation applications mentioned above, the naturalization of the plants is the objective. It remains an open question whether using local genotypes improves colonization on an inextricably altered site like a detention basin where the soils, hydrology and microclimate have all been changed. When working on high quality landscape remnants we feel the most stringent genetic criteria should be followed. In these situations, we almost never add plants or seed to these projects but attempt to reestablish the ecological processes that created and sustained these landscapes historically. If plants or seeds are needed on these projects, seed is collected from

the site or adjacent sites, grown in the greenhouse and returned to the site (Figure 2).

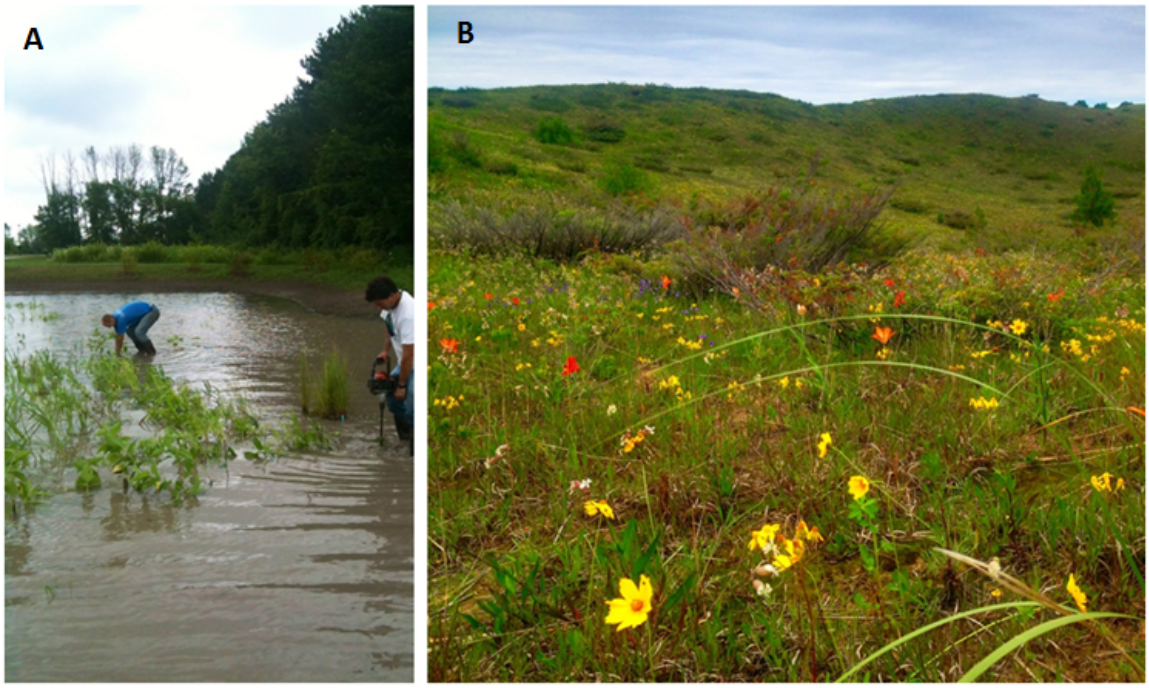

Figure 2. A: Detention basin—man-made landscape element with new hydrology, soils and microclimate. B: High quality site on Manitou Island Michigan. Photos by Matt Yageman with permission.

We make two broad genetic assumptions at the nursery. First, that regional genotypes are as good or better than non-regional genotypes and that heterogeneity is critically important for the perpetuation of most species. Although Wildtype specializes in growing plants from wild collected seed (genetic wild types) we have asked ourselves the question broached above – how much heterogeneity are we capturing and preserving in the seed we collect? Secondarily how much selection are we introducing in the way we collect and grow our plants?

Until relatively recently, we made seed collections and accessioned them by recording date and location of the collection (Figure 3). Each accession was grown separate from another accession of the same species. In doing so we were growing populations of plants collected from fragmented populations. We became increasingly concerned that this practice was contributing to the narrowing of the genetic diversity in our production. For this reason, when possible, we have begun to pool collections across eco-regions so that each crop of plants contains individuals from different sites, which we hope results in greater heterogeneity. We are growers, not populations geneticists and admittedly do not have a means to easily assess the genetic status of the plants we collect. For example, when seed collecting we having no idea of the ploidity or mixed polyploids we collect or the degree of introgression and hybridization in the samples we collect.

When collecting we make every attempt to take a represented sample of the plants we are collecting, meaning we try not to collect the tallest or shortest, those that bloom early or late. Furthermore in our production we try to unify and optimize germination and impose no selection on the plants we transplant, with just a few exceptions. In doing so we are confident that a representative sample of the population's genetics is collected and propagated. The exception is in the production of oaks and a few other trees where significant percentages of the germinated seed show obvious traits that render individuals unfit to produce marketable trees. In our oak production we are commonly culling 30 to

60% of the seedlings we produce.

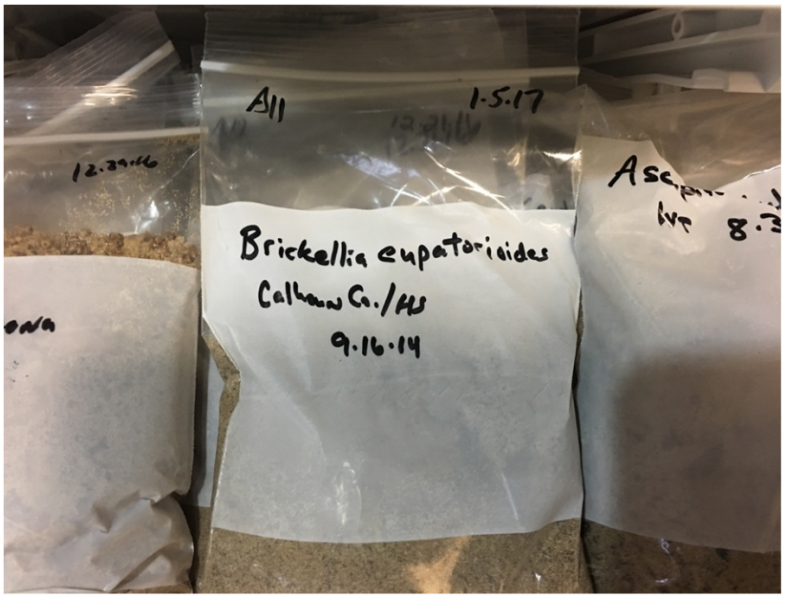

Figure 3. Each collection is accessioned with the date and location it was collected.

There is broad consensus the climate is changing and will inevitably rearrange the distribution of flora worldwide. There is increasingly more being written about assisted migration in order to mitigate these changes. Suggestions of latitudinal shift due north appear to be very simplistic and only account for changes in temperature and ignore all the other climatic changes including precipitation patterns. Furthermore, while the climate is changing, photoperiod and the physical properties of soils and topography are not. In time it may turn out that the heterogeneity of the seeds we collect is a more important determinate of successful colonization than genotype alone. This suggests that the preservation of germplasm of our local and regional flora will play a critical roll in the revegetation of our landscape in the future.

Plant breeding at North Dakota State University©

T.P. West[a]

North Dakota State University, Plant Sciences, Loftsgard Hall 266E, Fargo, North Dakota 58102, USA.

Woody plant evaluations at North Dakota State University began in 1954. In 1971, Dr. Dale E. Herman initiated the Woody Plant Improvement Program (WPIP). To date, this program has released 56 woody plant selections into the ornamental nursery trade. Historically this program utilized two methods for woody plant selections, landscape observations and mass selection (seed lot variation). Prior to 2012, there were no structured breeding efforts being conducted at NDSU for ornamental woody plant improvement.

The WPIP has three primary goals:

1) Evaluate unreleased or released cultivars from the nursery trade to determine usability in the United States Northern Great Plains.
2) Select and/or breed new cultivars suitable for the Northern Great Plains (fortunately, many of the selections are suitable for much wider use).
3) Increase plant diversity. Diversity is important and there is a great need for adapted, winter hardy, pest resistant woody plants suitable for use in the northern USA and prairie Canada. Many of the current commercially available nursery cultivars are not suitable for USDA cold climatic Zones 3 and 4, lower annual moisture availability, and higher soil pH levels. There is also a need to increase plant diversity in response to disease and insect pest issues and loss of adapted genera and species (*Fraxinus* spp., *Ulmus americana*, *Picea* spp., and *Pinus* spp.).

The WPIP has nine research evaluation sites in North Dakota (Figure 1) There are three primary research evaluation sites:

1) NDSU Horticulture Research Farm (HRF) and Dale E. Herman Research Arboretum (DEHRA) (Absaraka, North Dakota).
2) Research plots (Fargo, North Dakota).
3) NDSU Langdon Research Extension Center (Langdon, North Dakota).

The other secondary sites include Williston, Grand Forks, Dickinson, and Bismarck, North Dakota. The first two primary sites are located in a USDA plant hardiness Zone 4a while the NDSU Langdon REC is classified as a hardiness zone 3b. The NDSU WPIP has evaluated 200+ genera and 3,000+ species and cultivars of trees and shrubs. Over 9500+ accessions obtained, evaluated since planting began in 1974. The largest and most diverse woody ornamental plant collection in North Dakota and the Northern Great Plains is located at the NDSU HRF and DEHRA with a total of 80 acres (~32 ha).

The NDSU WPIP selections are ideally suited for urban planting conditions. Typically, urban soils are: compacted, dry and have a high pH (>8.0). North Dakota is one of the driest states in the United States and the soil pH is typically >8.0.

The NDSU WPIP is involved with several woody plant evaluations including cultivar comparison with industry cooperators, northern site for hybrid maple evaluations (*Acer palmatum* × *A. pseudosieboldianum*). Currently, we are involved in *Cornus mas* (Cornelian cherry) evaluations (Figure 2; Table 1). To date, the program has 47 grafted cultivars in the collection which may be the largest collection in the United States. Micropropagation studies of *C. mas* are still in progress.

[a]E-mail: Todd.P.West@ndsu.edu

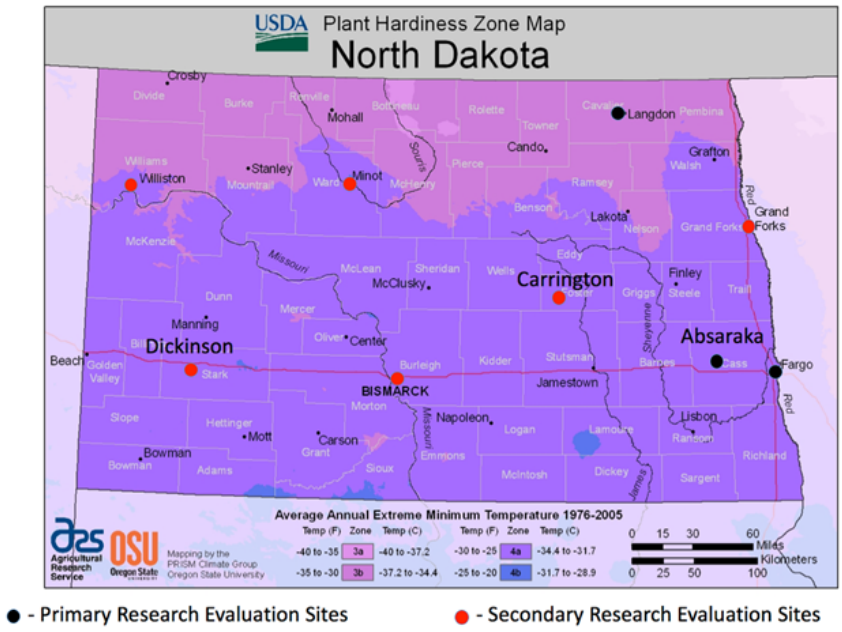

Figure 1. Evaluation site locations in North Dakota for the NDSU Woody Plant Improvement Program.

Table 1. Grafted cultivars of *Cornus mas*.

Albanos (Eppler's Black)	Juliusz	Schonbrunner Gourmet
Aurea	Kotula	Shan
Black Plum	Kuklen	Shumen
Bukouvinski	Lagodekhi #1	Slowianin
Butilochni	Lagodekhi #2	Spring Glow
Chicago	Lagodekhi Yellow	Surprise
Dripping Cherries	Lukanovski	Tcarigradski
Dublany	Lutea	TS804 (UW-Arboretum)
Early Bird	Macrocarpa	Typ 3
Early Purple	Neczhnyi	Vavilov
Elegant	Palzoski	Violacea
Flava	Priorski	Vladimirski
Florianka	Pyramidalis	Vrača
Gelbe Selection	Raciborski	Yantarny
Golden Glory	Red Dawn	Yellow September
Jolico	Red Star	

Figure 2. *Cornus mas* plant, flowers, and fruit.

For plant evaluation, selections and breeding, germplasm is collected from three different methods including:

1) Foreign and domestic seed sources (growing out seedling populations and selection individuals with superior attributes).
2) Plant breeding (tradition breeding including F_2 populations to observe segregation of traits including hybridizing with both intra and interspecific hybridization).
3) In vitro tissue culture utilizing somaclonal variations, embryo rescue and mutagenesis.

Three plant improvement methods utilized are: Selections by landscape observation, mass selection (seed source and seed lot variation), and breeding (both traditional and mutagenic).

The NDSU WPIP is focusing on breeding four primary genera: *Acer*, *Magnolia*, *Sambucus*, and *Ulmus*. The primary goal of all of the breeding work is on increased hardiness and secondarily on aesthetic improvements. With the large germplasm collection located at the NDSU HRF and DEHRA, there are many accessions that have shown outstanding hardiness and make excellent parents for improvement through breeding efforts. These include Spring Welcome® magnolia (*Magnolia* × *loebneri* 'Ruth'), Fall Grandeur™ red maple (*Acer rubrum* 'Minnkota'), *Sambucus nigra* 'TS14019' (prostrate form), and Northern Empress® Japanese elm (*Ulmus davidiana* var. *japonica* 'Burgundy Glow'). Magnolia breeding objectives focus on flower tepal color, introducing any color from *M. acuminata* hybrids coupled the hardy Spring Welcome® selection (white flower color) (Figure 3). Maple (*Acer* spp.) breeding objectives are utilizing known hardy and environmental tolerant selections to develop a better adapted Freeman maple (*A.* × *freemanii*). The current selections, such as Autumn Blaze, do not have consistent performance with respect to pH tolerance and hardiness. Utilizing a red maple selection that is known to be pH tolerant and have outstanding hardiness would be better suited for a Freeman maple hybrid selection. Elm breeding objectives focus on crossing Northern Empress® Japanese elm (outstanding burgundy fall color and other attributes) with Hallelujah lacebark elm (*Ulmus parvifolia* 'Hallelujah') which has outstanding ornamental bark.

Ornamental breeding research at NDSU includes developing freeze test procedures for earlier hardiness screening, traditional breeding efforts (making interspecific crosses with cold hardy species and hybrids) and developing molecular markers for breeding selection. Freeze tests and molecular markers will assist in reducing time, efforts and costs with selection of desirable progeny.

Figure 3. Spring Welcome® magnolia.

What's old and new about phase change and propagation©

R.L. Geneve[a]

University of Kentucky, Department of Horticulture, Lexington, Kentucky 40546, USA.

INTRODUCTION

Physiological aging (cyclophysis) is an important factor associated with propagation. It is important for determining the time to first flowering and therefore seed set. Equally important is the relationship between a plant's physiological age and the ability to regenerate adventitious organs (like rooting in some woody perennial cuttings). The relationship between plant age and the ability of cuttings to form adventitious roots has been known since the early 1900s and in a landmark study, Gardner (1929) established the role juvenility on rooting in cuttings from 21 tree species. Juvenility was also the subject of one of the first IPPS presentations made by F.L. O'Rourke in 1950 and published in Volume 1 of the proceedings (O'Rourke, 1950). Although there has been recent work on the mechanisms controlling phase change (especially the transition from the juvenile to reproductive maturity), many of the concepts related to the impact of juvenility on propagation have not changed in the past 70 years (Klaehn, 1962; Preece, 2003). The objective of this paper is to revisit physiological aging and discuss current methods of plant manipulation related to phase change and cutting propagation.

PLANT LIFE CYCLE

Plants transition from embryo to a reproductive mature plant through several qualitative phases (Figure 1). These have been designated as embryonic, juvenile, transition and mature (adult) phases (Davies et al., 2018; Hackett, 1985). The embryonic phase begins with sexual gamete fertilization leading to zygote formation and finally seed maturation. The juvenile phase begins with seed germination and seedling establishment. During the subsequent juvenile growth phase, the plant is not able to respond to environmental signals that would ordinarily induce flowering. This is also the phase where the plant has the highest growth rate and capacity for adventitious organ regeneration (i.e. de novo shoot or root initiation). This is followed by a transition phase that can be a few days in some herbaceous plants or decades for some woody perennials. The final phase of ontogenetic development is the mature or adult phase where the plant attains the ability to flower. However, not all plant characteristics of an adult habit appear simultaneously. The transition phase is characterized as a time where several morphological characteristics for development change asynchronously prior to the plant finally attaining a mature reproductive phase. This is most obvious in those plants with heteromorphic leaf development associated with phase transition (Figure 2). In these plants, juvenile phase leaves are distinctly different in size and shape compared to mature phase leaf morphology. However, this abrupt transition in leaf morphology usually occurs prior to attaining the ability to flower. Other important but less morphologically obvious features also change in the transition phase. Most notable is the loss or reduction in adventitious organ regeneration capacity that impacts the rooting ability in woody perennial cuttings.

[a]E-mail: rgeneve@uky.edu

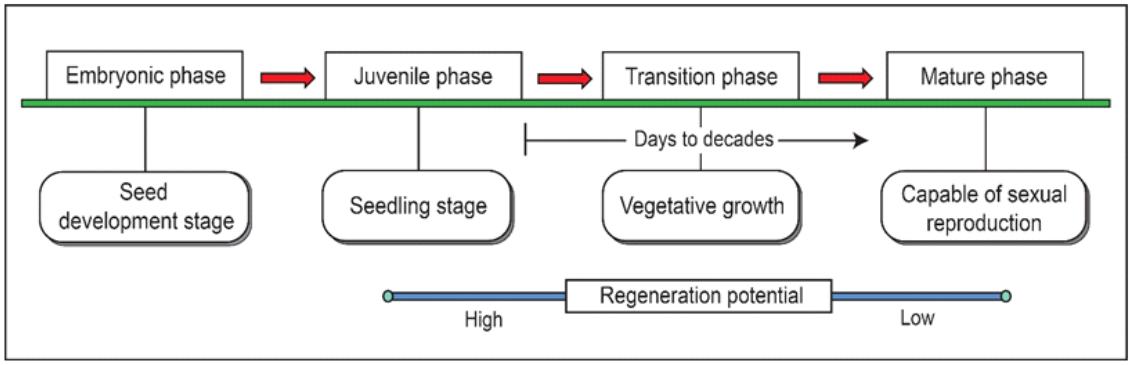

Figure 1. Schematic representation of the phase change during a plant's life cycle.

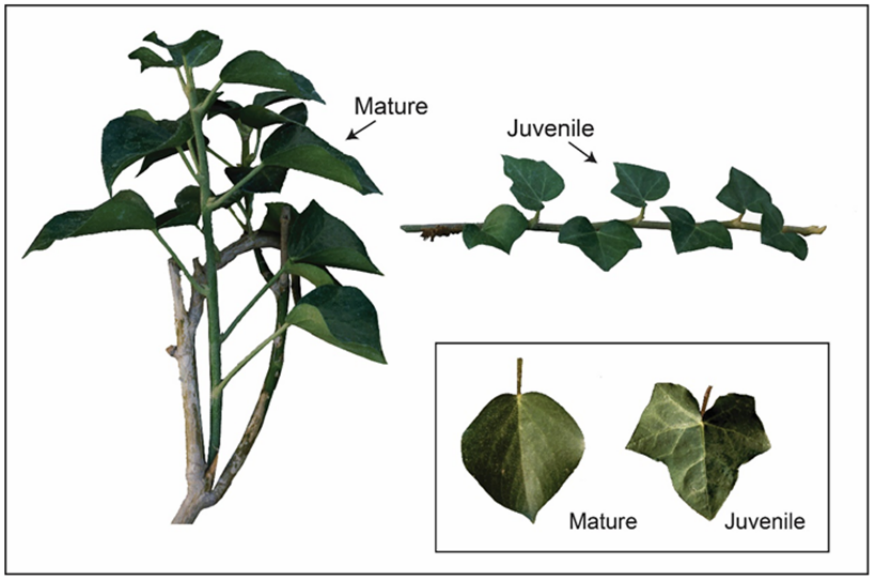

Figure 2. Leaf dimorphism related to phase change in English ivy (*Hedera helix*). English ivy has been used as a model system to study adventitious root formation because of the easily distinguished easy-to-root juvenile and difficult-to-root mature phases.

Paradox of aging in woody perennials

Although the life cycle phases of plant development appear to progress in a strict chronology related to the plant's age, chronological age does not completely describe the physiological age of all plant tissues in the plant at any given time. Therefore, in woody perennials, it is better to consider the physiological age of a specific plant tissue rather than its chronological age. In general, tissue closest to the root/shoot junction retains a more juvenile state than tissue near the distal growing shoots. This is the "cone-of-juvenility" (Figure 3). The paradox of plant age relative to position on the plant indicates that tissue that is chronologically oldest (tissue formed soon after seedling emergence) retains a physiologically juvenile state, while seasonal new growth at the top of a tree that has just recently formed would be physiologically "old" and behave as mature tissue (capacity to flower). Therefore, position on the plant is more important than strict chronological age when considering juvenility as it relates to organ regeneration potential.

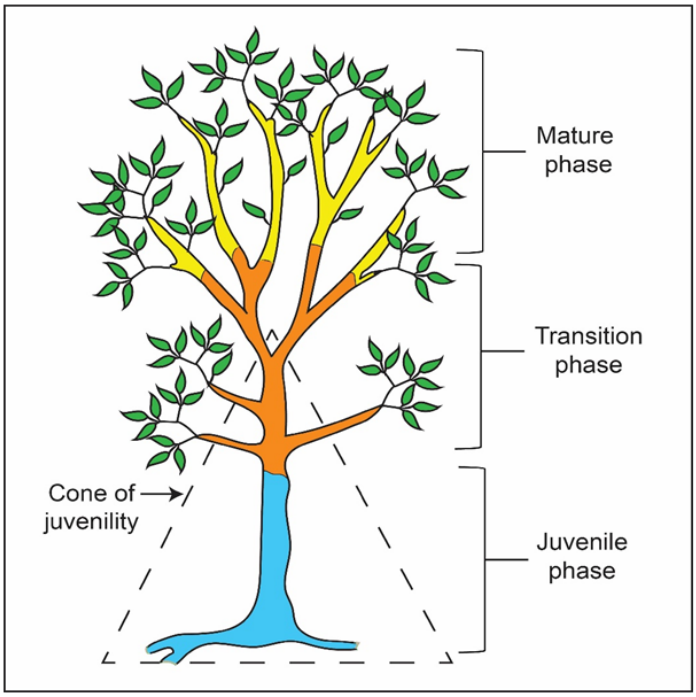

Figure 3. Representation of the cone-of-juvenility.

Juvenile phase retention

Tissue within the cone-of-juvenility naturally retain juvenile phase characteritics, but these usually remain undeveloped during the plant's growth cycle. However, some plants produce specialized structures within this juvenile zone that afford the plant certain ecological advantages usually associated with shoot regeneration. These naturally occurring juvenile tissues include epicormic shoots, sphaeroblasts, lignotubers and root suckers. Epicormic shoots develop or emerge from latent buds under the bark on the main trunk usually after biotic or abiotic stress. Sphaeroblasts are specialized tissues on the lower trunk of some tree species with a high capacity to form epicormic shoots. Lignotubers are similar to sphaeroblasts and occur at or below the soil surface at the root/shoot junction. Lignotubers are an ecological adaptation in fire prone species designed to have a high regeneration capacity and provide a cache of buds for quick reestablishment. Root suckers are adventitious shoots arising from roots. These naturally occur in plants that form clonal colonies. It is highly presumed that roots remain juvenile so shoots arising from roots retain a relatively juvenile phase character.

Systems for inducing and maintaining juvenility (rejuvenation)

One of the important aspects of phase change in propagation is loss of rooting capacity in cuttings as plants transition from juvenile to mature phases. Rooting recalcitrance in some woody plant species requires that they be propagated by seeds, grafting or micropropagation. However, it is possible to induce or reacquire juvenility in stock plants for cutting production that is more amenable to rooting. Most of these manipulations involve induction of adventitious shoots from tissue near the root/shoot junction.

Practices designed to rejuvenate stock plants that have commercial implications include (1) severe pruning or hedging; (2) induction of epicormic shoots; (3) shoots from lignotubers; (4) second generation cuttings from tissue culture; and (5) embryogenesis.

1. Severe pruning or hedging.

Severe pruning can have a dramatic rejuvenation effect on mature phase plants that are pruned near the root/shoot junction to induce stump sprouts. This is not a long-term

stock plant management strategy for cuttings, but has been used to recover rooting potential in individual plants (Schreiber and Kawase, 1975). However, severe cut-back pruning is the basis for mound layering systems where plants are cut to the root/shoot junction each year to induce new shoots that root under stool bed conditions (Davies et al., 2018).

Severe pruning to produce hedged stock blocks for cutting production is the more common stock plant management system used to maintain high rooting potential. It has been recognized since the 1950s that hedging reduces or retards the progression toward a mature phase state (Libby et al., 1972). Hedging has the additional advantages of producing more cuttings per stock plant, reducing or eliminating flowering stems, and producing upright stems that produce regenerated plants with less tendency for horizontal, plagiotropic growth (topophysis), especially in conifers. Hedging remains the most important stock plant management tool for sustained production of cuttings with high rooting potential.

2. Induction of epicormic shoots.

Large severed limbs from certain hardwood species have the ability produce epicormic shoots when placed under a proper environment. These shoots when used as cuttings have demonstrated high rooting success in certain recalcitrant species like oaks, white ash, maple, and honeylocust (Preece and Read, 2007). For example, 10-cm diameter branch segments from mature red maple trees produced 6.5 shoots per hardwood stem segment and softwood cuttings taken from those shoots showed 59% rooting when treated with auxin and placed under mist (Henry and Preece, 1997).

3. Lignotubers.

Although lignotubers naturally occur in only a few species, they have played an important part in establishing stock plants for clonal *Eucalyptus* production (Assis, 2011). *Eucalyptus* are clonally propagated from "mini-hedge" stock plants that are established initially from juvenile shoots growing from lignotubers. Mini-hedge stock plants are grown using a modified hydroponic system to optimize nutrition, and cuttings are consistently removed (hedged) to keep cutting wood from maturing. This procedure has been termed "minicuttings" and they result in vigorous rooted cuttings that have better root systems compared to traditional cuttings (Cliffe, 2010). *Eucalyptus* has served as a model to develop systems to root additional hardwood species that do not make lignotubers (Chinnaraj and Malimuthu, 2011). The key aspect to adapting a mini-hedge system to a new species is to initiate stock plants from a clonal, rejuvenated source such as stump sprouts, epicormic shoots, sphaeroblasts or root suckers.

4. Second generation cuttings.

It has been well established that woody species that are difficult-to-propagate from cuttings can often be successfully micropropagated. The ability of microcuttings to form adventitious roots has been attributed to a transient reversion to a more juvenile state or "invigoration". This rooting capacity can carryover in micropropagated plants as second-generation cuttings. Commercial propagation for second-generation cuttings has become a common way to cost effectively use plants from micropropagation, but rooting potential retention appears to be transient. Establishment of managed stock plants from second-generation cuttings would appear to be worth further investigation.

5. Zygotic and somatic embryogenesis.

As stated earlier, the natural reestablishment of the juvenile phase in a plant's life cycle occurs during seed formation. Therefore, seedling stock plants tend to produce cuttings with high rooting potential. However, the plant characters of most interest to forestry and nursery producers such as growth habit or flowering are not evident in seedling populations. One scenario to produce clonal material with superior characteristics would be to select seedling populations with high rooting potential that are maintained as hedged stock plants or maintained in cryopreserved storage. Clonal selection can then take place as the progeny

matures and superior plant characteristics become evident. This type of reverse selection has been successful for several oak species like *Quercus lyrata* and *Q. phellos* (Drew and Dirr, 1989).

Somatic embryogenesis mimic zygotic embryogenesis, but the originating tissue is vegetative rather than from reproductive gametes. Somatic embryogenesis would also reestablish the juvenile phase. Somatic embryo formation from mature plants offers the potential for clonal rejuvenation or multiplication of planned crosses from parents with elite genetics. Somatic embryo-derived seedlings can be used to establish hedged or mini-hedged stock blocks to produce clonal cuttings. This system has been developed for a few crops including conifers for clonal forestry systems (Bonga, 2014; Smith, 1999) and for mini-cuttings in coffee (Georget et al., 2017).

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Managing water and oxygen for optimum rooting©

E. Yafuso and P. Fisher[a]

Environmental Horticulture Dept., University of Florida, PO Box 110670 Gainesville, Florida 32611, USA.

INTRODUCTION

Propagation of unrooted cuttings requires high humidity and frequent irrigation events through mist emitters to hydrate cuttings. Container substrate is maintained at a high moisture level, which increases the risk of low oxygen availability and root pathogens such as *Pythium* (Chérif et al., 1997). Oxygen is essential to plants for healthy root growth and nutrient uptake. Oxygen can be supplied to roots through either air-filled pores in container substrate or through dissolved oxygen (DO) in irrigation water. The diffusion of oxygen gas is approximately 10,000 times greater in air compared to in water and oxygen solubility in water decreases as temperature increases. There are limited data on the use of oxygen injecting technology to increase the dissolved oxygen levels in irrigation water for use in greenhouse production. The objective was to measure the effect of ambient "tap" or oxygenated water on DO in irrigation water, root substrate, and on root growth during propagation and finished plant production.

METHODS

The experiments were carried out at the University of Florida Environmental Horticulture Research Greenhouse Complex in Gainesville, Florida. The water source in all experiments was greenhouse tap water. The main water types were ambient "tap" water which was either not oxygenated (6 to 7 mg L^{-1}) or oxygenated water (25 to 30 mg L^{-1}). Oxygenated water was injected (Mazzei) with pure oxygen as water flowed at 1.8 GPM or 7 LPM that increased DO three times above saturation. Dissolved oxygen was measured in water and substrate with an optical oxygen sensor (NeoFox, Ocean Optics). Data were analyzed in SAS (SAS Version 9.4; SAS Institute, Cary, North Carolina) using ANOVA with Tukey's Honestly Significant Difference (HSD) at p=0.05 for mean separation.

Propagation plant trial

The propagation plant trial ran for two weeks during late March to April 2016. There were two factors of water type (oxygenated or ambient water) and plant species (*Calibrachoa* × *hybrida* 'Aloha Kona Dark Red' and *Lobelia erinus* 'Bella Aqua') in a factorial design. The water types were pumped through propagation nozzles (Coolnet Pro Fogger, Netafim, droplet size of 69 microns) to separate sections on a bench. Calibrachoa and lobelia unrooted cuttings were transplanted in 102-count trays (20.3 mL $cell^{-1}$). Trays were filled with a 60:40 peat:perlite substrate. Irrigation frequency was high for the first three days and gradually decreased. The average day temperature was 22.5°C and average percent relative humidity was 72%. Root length, root and shoot dry mass were measured on day 7 and 14.

Persistence of supersaturated DO in water over time

Dissolved oxygen was measured over time to study the effect of water type (ambient tap or oxygenated water) and water movement (not stirred or stirred at 100 gal h^{-1} or 378.5 L h^{-1}) on DO persistence in water. The water type was held in an unpressurized 5-gal or 18.9-L container. There were three replicate containers for each combination of water type and water movement. Dissolved oxygen was measured in water at 4-cm depth from the surface over time (0, 30, 90, 150, 210, and 270 min.).

Dissolved oxygen measured for the irrigation system

Dissolved oxygen was measured in tap water or oxygenated water at three delivery points. The water delivery points consisted of (1) an initial "source tank", (2) "bench no

[a]E-mail: pfisher@ufl.edu

nozzle" where water was pumped from the source tank through an irrigation line to an open container, and (3) a "bench with nozzle" point where water was pumped from the source tank through an irrigation line and then a propagation nozzle.

Plant trial in pots

Calibrachoa, *Lobelia* and *Pelargonium* 'Patriot Red' (geranium) rooted cuttings were transplanted into pots (4-in diameter containers). Plants were irrigated when the average of 6 pots dried to 45% of container capacity allowing for wet-dry cycles. Tap water with soluble fertilizer (17-4-17 at 150 ppm) was supplied without oxygenation ("ambient") or was passed through the oxygen injector ("oxygenated"). Water was delivered through top watering or subirrigation (180 mL). The average day temperature was 25.3°C. A sub-group of geranium plants were grown to measure the effect of water type (oxygenated or ambient water) and substrate moisture level (medium of 45% or high at 80% of CC) on plant growth. Total root length, root, and shoot dry mass were measured after 4 weeks of growth.

Substrate-oxygen levels measured in pots

The objective was to measure the effect of water type (oxygenated or ambient water) and applied water volume at two depths (2 and 4 cm) on substrate-DO without plants. Substrate (60:40 by volume peat:perlite) was filled in pots. The pots were subirrigated overnight and drained to container capacity. The applied water volume to substrate was based on percent container volume from 0 (0 mL, 0% CC), 25 (106 mL, 44% CC), 50 (212 mL, 87% CC), 100 (425 mL, 175% CC), and 200% (850 mL, 350% CC) also shown was the actual water added and reference to percent container capacity. A toothpick was used to indent the substrate prior to inserting the oxygen sensor. Oxygen sensor and temperature probe was allowed to equilibrate for 40 to 120 s before recording a measurement.

RESULTS AND DISCUSSION

Propagation plant trial

Oxygenation of irrigation water did not increase or decrease root growth compared with ambient water. All plants were rooted by day 7. There were no differences observed in root or plant growth when compared by species for water type on day 7 or 14 (Table 1). Species difference showed that *Calibrachoa* had greater total dry mass at day 7 and grew faster than *Lobelia* by day 14. It is likely that there were no observed effects of water type on plant growth because water that passed through fine mist emitters equaled 100% DO saturation (Figure 1).

Table 1. The propagation trial showed no effect of water type on root or shoot growth of *Calibrachoa* or *Lobelia* cuttings.

Plant species	Water type	Day 7		Day 14			
		Root length (cm)	Total dry mass (g)	Root length (cm)	Shoot dry mass (g)	Root dry mass (g)	Total dry mass (g)
Calibrachoa	Ambient	8.7	0.053	128	0.071	0.017	0.088
Calibrachoa	Oxygenated	8.8	0.051	123	0.078	0.018	0.096
Lobelia	Ambient	7.3	0.020	81	0.026	0.011	0.037
Lobelia	Oxygenated	7.3	0.019	69	0.027	0.012	0.039
Summary of ANOVA analysis							
Water type		NS	NS	NS	NS	NS	NS
Species		NS	***	***	***	***	***
Water type*species		NS	NS	NS	NS	NS	NS

NS = not significant.

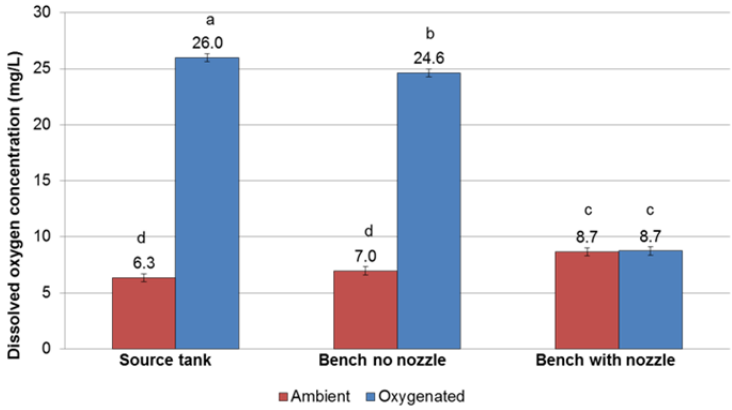

Figure 1. Water that passed through the bench with nozzle equaled 100% DO saturation regardless of water type.

Persistence of supersaturated DO in water over time

Dissolved oxygen in ambient tap water was not affected by the movement of water and the average DO was 7.1±0.05 mg L^{-1} (mean±standard error). Oxygenated water that was not stirred initial DO was 28.3 mg L^{-1} and after 4.5 h. DO was 26.5 mg L^{-1}. Dissolved oxygen in oxygenated water decreased from an initial measurement of 26.8 to 16.9 mg L^{-1} (a 37% decrease) after 4.5 h. Oxygenated water that was stirred decreased in DO because the movement of water increases the surface area of water exposed to air and supersaturated water holds more DO than water can hold at a given temperature. The DO in water held in unpressurized containers after 4.5 h. was 208 and 324% of saturation for oxygenated water that was stirred and non-stirred, respectively.

Dissolved oxygen measured for the irrigation system

At the source tank ambient tap water DO was measured at 6.3 and 26.0 mg L^{-1} for oxygenated (Figure 1). Water that was pumped from the source tank through irrigation lines and out of the bench no nozzle or hose end slightly decreased for oxygenated water compared to ambient water. Water that passed through the bench with nozzle, a fine mist emitter equaled 100% DO saturation at 8.7 mg L^{-1}, regardless of water type. Fine water droplets increases the surface area of water exposed to air (Vestergaard, 1984; Schröder, 1994; Schröder and Lieth, 2002) that resulted in an increase in DO for ambient tap water and like-wise off-gassed oxygen in supersaturated water.

Plant trial in pots

During the trial, irrigating plants with oxygenated water did not increase or decrease rooting or plant growth. All plants were healthy and grew vigorously. There was a slight but statistically significant increase in shoot and root dry mass for lobelia with ambient water (Table 2) compared to oxygenated water. Top watering increased root growth in *Calibrachoa* compared to subirrigation. There were no treatment effects on geranium growth (data not shown). In the geranium sub-group, there was greater root length and root dry mass for "high" moisture level compared to "medium" moisture level (Table 3). Although, water was delivered to pots without passing through a fine breaker and oxygenated water was shown to increase substrate-DO (Figure 2) there were no benefits of irrigating with oxygenated water. In container substrate oxygen can also be supplied to roots through air-filled pores. Peat substrate contains high air porosity even at container capacity (Argo et al., 1996; DeBoodt and Verdonck, 1971; Handreck and Black, 1994) and measured in 4-in diameter pots at 19%. In other studies, plants with adequate supply of oxygen at the root zone generally showed no growth benefits by irrigating with oxygenated water (Bonachela et al., 2005, 2010). However, corn grown under low oxygen and saturated root zone conditions observed an increase in plant growth by irrigating with oxygenated water (Lei et al., 2016).

Table 2. Effect of water type and delivery method on plant growth for *Calibrachoa* and *Lobelia* grown in pots and analyzed by species.

Plant species	Water type	Water delivery	Root length (cm)	Shoot dry mass (g)	Root dry mass (g)
Calibrachoa	Ambient	Top watered	2277	2.98	0.22
Calibrachoa	Oxygenated	Top watered	2320	3.08	0.21
Calibrachoa	Ambient	Subirrigated	1896	2.47	0.16
Calibrachoa	Oxygenated	Subirrigated	1923	2.84	0.19
Summary of ANOVA analysis for *Calibrachoa*					
Water type			NS	NS	NS
Water delivery			*	NS	*
Water type*water delivery			NS	NS	NS
Lobelia	Ambient	Top watered	2917	2.14	0.30
Lobelia	Oxygenated	Top watered	2685	1.90	0.26
Lobelia	Ambient	Subirrigated	2748	1.99	0.28
Lobelia	Oxygenated	Subirrigated	2361	1.91	0.23
Summary of ANOVA analysis for *Lobelia*					
Water type			NS	*	*
Water delivery			NS	NS	NS
Water type*water delivery			NS	NS	NS

NS = no significance, * = significant at p=0.05 level.

Table 3. Effect of water type and substrate moisture level on plant growth of *Pelargonium* 'Patriot Red' (geranium).

Plant species	Water type	Moisture level	Root length (cm)	Shoot dry mass (g)	Root dry mass (g)
Geranium	Ambient	Medium	1273	4.97	0.41
Geranium	Oxygenated	Medium	1236	4.91	0.42
Geranium	Ambient	High	1608	6.03	0.50
Geranium	Oxygenated	High	1566	5.12	0.45
Summary of ANOVA analysis					
Water type			NS	NS	NS
Moisture level			**	NS	*
Water type*moisture level			NS	NS	NS

NS = no significance, * = significant at p=0.05 level.

Substrate-oxygen levels measured in pots

When a large volume of oxygenated water was applied an increase in substrate-DO was observed. The application of ambient water did not change the substrate-DO and the average DO was 8.5 mg L^{-1} at 2-cm depth (Figure 2). The substrate-DO was generally lower at the deeper depth by 1.8 mg L^{-1} measured from 2 cm compared to 4 cm (data not shown). The addition of oxygenated water resulted in an increase in substrate-oxygen from 8.6 to 14.5 mg L^{-1} (a 68% increase) with increasing water applied (from 0 to 200% container volume) at 2-cm depth. To provide a practical point of reference, 100% of container volume represented 14 oz (425 mL) of water for a 4-in diameter pot which is more water than normally applied in a typical irrigation.

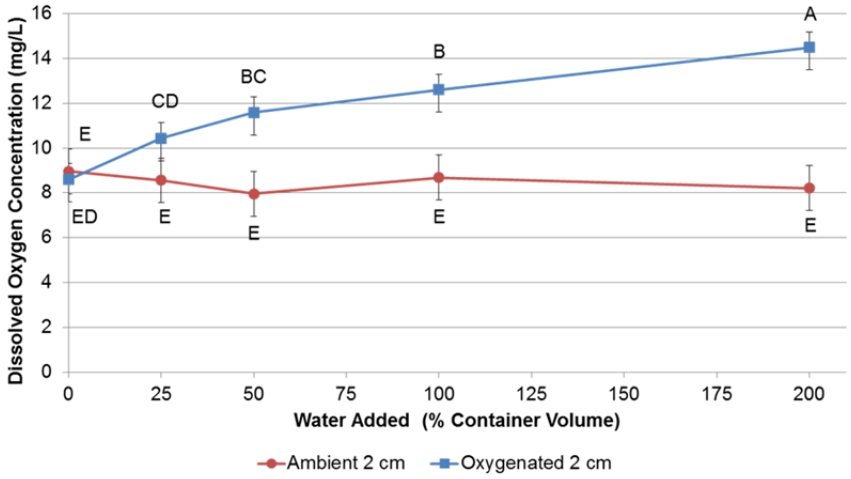

Figure 2. There was a positive increase in substrate-DO as the applied volume for oxygenated water increased compared to ambient water.

CONCLUSIONS

In the propagation trial, there were no differences in root or plant growth with mist propagation of oxygenated or ambient tap water. Oxygenated water held in unpressurized containers remained supersaturated after 4.5 h. Water that passed through fine mist emitters equaled 100% DO saturation regardless of water type by increasing the droplet surface area.

Continued growth of transplants in 4-in pots showed that irrigating with oxygenated nutrient supplemented water did not enhance root or plant growth of three bedding plants. Slight differences were measured with *Calibrachoa, Lobelia* and geranium, however those differences were not of practical significance for plant growth. Oxygenated water increased the substrate-DO by 68% when water was applied from 0 to 200% of container volume. Adding oxygenated water to an already saturated container substrate is not a recommended approach to irrigation management. Drying down the substrate is more likely to be effective by allowing pores to fill with air (oxygen). Container substrate with high porosity and irrigation management are essential to roots and healthy plant growth.

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New Plant Forum©

Compiled and Moderated by C. Tubesing
Presenters:

J.R. Ault[a]

Director of Ornamental Plant Research, Chicago Botanic Garden, Glencoe, Illinois 60022, USA.

Phlox 'Pink Parasol' PPAF
Phlox 'Running With Scissors' PPAF
Veronica 'Blue Sprite' PPAF

B. Horvath[b]

Intrinsic Perennial Gardens, Inc., 10702 Seaman Rd, Hebron, Illinois, 60034, USA.

Delosperma 'Orange Crush' PPAF
Geum 'Cherry Bomb' PPAF
Geum 'Top Shelf Margarita' PPAF
Rudbeckia 'Glitters like Gold' PPAF
Sedum rupestre 'Making Progress' PPAF

T. Ranney[c]

Department of Horticultural Science, College of Agriculture and Life Science (CALS), North Carolina State University Mountain Horticultural Crops Research & Extension Center, 455 Research Drive, Mills River, North Carolina 28759, USA.

Spiraea 'NCSX1', Double Play® Candy Corn® spirea pp #28313
Spiraea 'NCSX2', Double Play® Doozie® spirea ppaf

T.P. West[d]

Woody Plant Improvement Program, North Dakota State University, Fargo, North Dakota 58108, USA.

Acer saccharum 'SeptDak', September Flare® sugar maple
Aesculus glabra 'LavaDak', Lavaburst® Ohio buckeye
Betula tianschanica 'EmerDak', Emerald Flare™ birch
Ulmus davidiana var. *japonica* 'Burgundy Glow', Northern Empress® Japanese elm

T. Wood[e]

Product Development Manager, Spring Meadow Nursery, Inc., 12601 120th Ave, Grand Haven, Michigan, 49417, USA.

Hydrangea arborescens 'NCHA8', Invincibelle Limetta™ smooth hydrangea
Hydrangea serrata 'SMNHSDD', Tuff Stuff Ah-Ha™ mountain hydrangea
Rosa 'HORCOGJIL', At Last® rose

***Acer saccharum* 'SeptDak', September Flare® sugar maple**

Single plant selection originated from a northwest Minnesota native population seed

[a]E-mail: jault@chicagobotanic.org
[b]E-mail: BrentH@intrinsicperennialgardens.com
[c]E-mail: tom_ranney@ncsu.edu
[d]E-mail: todd.p.west@ndsu.edu
[e]E-mail: Tim@SpringMeadowNursery.com

lot and was noted for its early intense fall coloration as a 2-year-old seedling. This selection has been fully hardy in USDA hardiness Zone 3b. September Flare® sugar maple is a very hardy sugar maple seedling selection exhibiting heavy-textured tatter-resistant foliage, consistent mid-September into early October showy red-orange fall coloration (Figure 1), and excellent winter hardiness in the Northern Plains to -40°F. This selection is notable for its early annual display of excellent reliable fall color, which is photoperiod initiated and not frost dependent in this northern climate setting. September Flare® sugar maple begins fall coloring before other trees in the landscape which extends the fall color season significantly. Early fall coloring is also indicative of increased winter hardiness because of earlier winter acclimation. Growing in a full sod boulevard condition for it length of evaluation, September Flare® sugar maple will reach a height of 40 ft with a 30-ft canopy spread. Recommended for use as a landscape, public grounds, boulevard (larger), parks, schools, and golf course tree, wherever tree diversity and adaptability to northern conditions are important. September Flare® sugar maple prefers a deep, well-drained, non-droughty soil and will tolerate higher pH levels than the species. Foliage exhibits heavy-textured tatter-resistant foliage with excellent medium green color throughout the summer showing no signs of chlorosis on a soil pH exceeding 8. Grafting studies have shown that early fall coloring is a consistent trait and grafted plants reliably color at the same time each ear, mid-September, independently from seasonal temperatures and fall frost events like other fall coloring trees. Availability: pending.

Figure 1. *Acer saccharum* 'SeptDak', September Flare® sugar maple.

***Aesculus glabra* 'LavaDak', Lavaburst® Ohio buckeye**

Single plant selection originating from an unknown seed source. This selection has been fully hardy in USDA hardiness Zone 3b. Growing in full sod condition for its length of evaluation, Lavaburst® Ohio buckeye has reached a height of approximately 25 ft with a 14-ft canopy spread making it ideal for limited space landscape including street boulevards and possibly for use under power lines and near other overhead structures. Mature height may exceed this in other areas of the country but overall it is a smaller, more compact upright Ohio buckeye selection. Lavaburst® Ohio buckeye is a narrow upright northern hardy Ohio buckeye selection with shorter internode stem growth than typical for the species and other *Aesculus* cultivars. This shorter internode stem growth gives Lavaburst® Ohio buckeye the superior compact foliage. Based on grafting trials, Lavaburst® Ohio buckeye has reproduced the atypical shorter stem nodal lengths setting it apart from other cultivar selections. Foliage shows greater resistance to leaf scorch than non-selected buckeyes and maintains a bright green summer color changing to lava orange-red in autumn (Figure 2). Compact growth habit makes this selection ideal for limited space planting sites where a full-sized buckeye is not suitable. Seed production is light as compared to the species and other selected cultivars which is highly desirable as buckeye fruit (seed) are considered to be poisonous and can be messy in a formal landscape. Lavaburst® Ohio buckeye is soil adaptable but prefers a well-

drained, non-droughty soil and tolerates higher pH levels. Propagation is by side or cleft graft onto seedling *Aesculus* rootstocks and will perform best on *A. glabra* in northern climates to insure root hardiness. Availability: pending.

Figure 2. *Aesculus glabra* 'LavaDak', Lavaburst® Ohio buckeye.

***Betula tianschanica* 'EmerDak', Emerald Flare™ birch**

Single plant selection originating from *B. tianshanica*, Tianshan birch, from an unknown seed source and designated as TS95115-2 with the NDSU Woody Plant Improvement Program. The selection TS95115-2 has darker green foliage during the summer months than the other sibling trees from original seed source. This selection has been fully hardy in USDA hardiness Zone 3b. Growing in full sod condition for 17 years and 4 years mulched for its length of evaluation. Emerald Flare™ birch has reached a height of approximately 23 ft with a 12 ft canopy spread growing as a double leader. If trained in the nursery as a single leader, size would be approximately 23 ft tall with an 8 ft canopy spread, making it ideal for limited space or group planting within the landscape. Mature height may exceed this in other areas of the country but overall it is a more narrowly pyramidal (Figure 3), formal birch selection. Emerald Flare™ birch had exhibited outstanding drought tolerance with higher than average resistance to bronze birch borer which is essential for birch species. Foliage is an excellent medium emerald-green color throughout the summer showing no signs of chlorosis on a soil pH exceeding 8. Summer foliage is of high quality without blemishes resulting from birch leafminer or leaf spot. During summer drought conditions, Emerald Flare™ birch exhibits no foliar stress symptoms such as leaf scorch or early leaf drop which is seen on many other birch species. Autumn coloration is an outstanding golden-yellow. Flowers consist of male catkins and female strobiles which do not have significant ornamental value and are not considered messy within the landscape. The bark is slightly exfoliating with darker grey peeling to white with faint orange undertones. Young branches are a reddish brown prior to exfoliating to the white bark and have an ornamental contrast with the exfoliating white bark of the main supporting trunk. Propagation is by side grafting or chip budding onto *B. tianshanica* seedlings or by softwood or semi-hardwood cuttings. Availability: pending.

Figure 3. *Betula tianschanica* 'EmerDak', Emerald Flare™ birch.

***Delosperma* 'Orange Crush' PPAF**

Great orange blooms (Figure 4) on this hardy ice plant with a spreading mound—12 in. wide and only a few inches tall. Foliage is a yellow-edged, green succulent-type.

Figure 4. *Delosperma* 'Orange Crush' PPAF.

***Geum* 'Cherry Bomb' PPAF**

A *Geum* with ruffled, semi-double to single, pink flowers (Figure 5), on dark stems coming out of a basal green mounds; a heavy flowering selection.

Figure 5. *Geum* 'Cherry Bomb' PPAF.

***Geum* 'Top Shelf Margarita' PPAF**

A *Geum* with an abundance of clear yellow flowers (Figure 6) on purple stems. This *Geum* is an early bloomer with some rebloom in July. Foliage is clean and green.

Figure 6. *Geum* 'Top Shelf Margarita' PPAF.

***Hydrangea arborescens* 'NCHA8', Invincibelle Limetta™ smooth hydrangea**

A beautiful rounded dwarf selection with dark green leaves and showy round flower heads that emerge a lush lime green, lighten to soft greenish-white (Figure 7), and then age to green again. The stiff stems and dwarf habit make it an excellent container as well as garden plant. It is very hardy and blooms on new wood so it is a very reliable bloomer.

Figure 7. *Hydrangea arborescens* 'NCHA8', Invincibelle Limetta™ smooth hydrangea.

Developed by Tom Ranney at North Carolina State University. Native. USDA 3, AHS 9, 2.5-3 ft, summer rebloomer.

***Hydrangea serrata* 'SMNHSDD', Tuff Stuff Ah-Ha™ mountain hydrangea**

Dinner plate-sized blooms encircled with large, pastel, very large waterlily-like double flowers of blue or pink (depending upon pH and aluminum availability) (Figure 8) that age to green. It one of the strongest rebloomers we have trialed and it is nearly always in flower during the season. Developed by Megan Mathey of Spring Meadow Nursery by crossing the hardy, reblooming Tuff Stuff™ *H. serrata* 'MAK20' and the dwarf reblooming Let's Dance® Blue Jangles™ *H. macrophylla* 'SMHMTAU' and trialed in Michigan where it has consistently flowered and rebloomed every year. USDA 5, AHS 9, 2-3, summer rebloom.

Figure 8. *Hydrangea serrata* 'SMNHSDD', Tuff Stuff Ah-Ha™ mountain hydrangea.

***Phlox* 'Pink Parasol' PPAF**

Selected for its display of vibrant violet-pink flowers, vigor, hardiness and uniformity. The ¾ in. wide flowers are produced for 3 to 4 weeks, commencing in late April in northern Illinois (USDA Zone 5). At peak bloom, the plants are covered 90 to 100% with flowers (Figure 9). Two-year-old plants measured 12 in. wide and 5 in. tall at peak bloom, and 5-year-old plants were 21 in. wide and 7 in. tall at peak bloom. more mounded growers than the similar but more spreading and layering moss phlox, *P. subulata*. Best cultivated in full sun and on a well-drained soil.

Easy to propagate from cuttings taken after the plant finishes flowering. Likely hardy to USDA Zones 4-8. Developed at Chicago Botanic Garden from a cross made in 2006 between a putative *P. borealis* (we suspect this to be *P. subulata*) and *P. bifida*.

Figure 9. *Phlox* 'Pink Parasol' PPAF.

***Phlox* 'Running With Scissors' PPAF**

The 1 in. wide, light to medium violet flowers are produced for 4 to 6 weeks in spring starting in mid to late April in northern Illinois (USDA Zone 5). Close up, you can appreciate the flowers' cleft petals and conspicuous purple striae adjacent to the floral tube. A bonus is the faint but pleasant sweet hay fragrance. At peak bloom, the plants are covered 90% to 100% with flowers (Figure 10).

Figure 10. *Phlox* 'Running With Scissors' PPAF.

Two-year-old plants were 20 in. wide and 7 in. tall at peak bloom, and 4-year-old plants were 38 in. wide and 7 in tall at peak bloom. A mounded grower that continues to spread over time. Best cultivated in full sun and on a well-drained soil.

Easy to propagate from cuttings taken after the plant finishes flowering. Likely hardy to USDA Zones 5-8. From a cross made in 2008 between *P.* 'McDaniel's Cushion' and *P. bifida*.

***Rosa* 'HORCOGJIL', At Last® rose**

Finally, a fragrant, modern rose! At Last® rose combines all the romance of a fragrant, fully-petalled English rose with the no-nonsense practicality of a healthy landscape rose (Figure 11). It provides a non-stop display of large, sweetly perfumed sunset-orange blossoms from late spring through frost. Handsome, glossy foliage and a vigorous, rounded habit make it ideal for use in the landscape or the flower garden. Hybridized by the late Colin Horner of Stansted Mountfitchet, Essex, UK. It originated from a cross-pollination of a proprietary selection of (*R.* × *hybrida* 'Laura Ford' times 'Goldbusch'), as the female with *R.* × *hybrida* 'Horjilly', a non-patented selections as the male parent. This consumer favorite won the 2016 Shrub Madness Championship. USDA 5, AHS 9, 2-3 ft, summer rebloomer.

Figure 11. *Rosa* 'HORCOGJIL', At Last® rose.

***Rudbeckia* 'Glitters like Gold' PPAF**

A *Rudbeckia* with round hairy foliage and resistant to disease. Plants are 3 ft. plus and begin to flowering in mid-July with rich golden 3½ in. blooms (Figure 12).

Figure 12. *Rudbeckia* 'Glitters like Gold' PPAF.

***Sedum rupestre* 'Making Progress' PPAF**

A unique sedum with red foliage, fall to spring (Figure 13).

Figure 13. *Sedum rupestre* 'Making Progress' PPAF.

***Spiraea* 'NCSX1', Double Play® Candy Corn® spirea pp #28313**

You have to see it to believe it—candy-apple-red foliage starts the show in spring. As the season progresses, the foliage transforms to pineapple yellow (Figure 14A). Dark purple blooms appear in late spring (Figure 14B), making this the most eye-popping colorful Double Play® spirea yet. A deciduous shrub with a height of 18-24 in. and a spread of 18-30 in.

Figure 14. A: candy-apple-red foliage; B: dark purple blooms.

***Spiraea* 'NCSX2', Double Play® Doozie® spirea ppaf**

Double Play® Doozie® spirea is a ground-breaking non-invasive spirea. Its lack of seed also means it is a perpetual bloomer, putting all of its energy into creating wave after wave of red-pink flowers from early summer through frost (Figure 15). No deadheading required. Naturally grows as a neat mound.

Figure 15. *Spiraea* 'NCSX2', Double Play® Doozie® spirea ppaf.

***Ulmus davidiana* var. *japonica* 'Burgundy Glow', Northern Empress® Japanese elm**

Single plant selection originating from within a Harbin, China seed source grown for over 30 years at the NDSU Dale E. Herman Research Arboretum. This selection has been fully hardy in USDA hardiness Zone 4. Based on regional experience with the species and seed origin should be fully hardy throughout Zone 3 and possibly into Zone 2b of the Agriculture Canada hardiness zone map. Growing in a full sod condition for its length of evaluation, Northern Empress® Japanese elm has reached a height of approximately 26 ft with a 20-ft canopy spread making it ideal for limited space landscapes and possibly for use under power lines and near other overhead structures. Mature height may exceed this in other areas of the country but overall it is a smaller, more compact elm selection. Based on grafting trials, Northern Empress® Japanese elm has reproduced reduced growth with shorter internodes than the species. Structural branching is open and widely spaced which eliminates the narrow branch angle problems associated with several of the recently selected and available hybrid elm cultivars. Branch terminals are not excessively twiggy and are not prone to twig drop. Mature plant form is a rounded crown. Foliage is an excellent medium green color throughout the summer showing no signs of chlorosis on a soil pH exceeding 8. Black leaf spot of elm is present in the NDSU elm collection and only minimally affects Northern Empress® Japanese elm if at all while other cultivars may be severely affected. Japanese elm has an inherent resistance to elm leaf beetles and Dutch elm disease (DED). Seed production has been very light and is not considered to be a negative maintenance issue. Autumn coloration on Northern Empress® Japanese elm occurs later than other Japanese elms in the collection by 1 to 2 weeks and highlights one of its standout attributes. Rather than the standard yellow fall coloration of most elm species including Japanese elm, Northern Empress® Japanese elm gradually progresses from an apricot-orange color to an attractive burgundy-red, which is quite striking at its peak (Figure 16). This is only the second elm cultivar that has fall coloration other than yellow. Frontier Elm [*U. carpinifolia* × *U. parvifolia*) 'Frontier'] has similar fall color to Northern Empress® Japanese elm but is not reliably hardy in Zone 4 and has more of an upright-pyramidal form. Propagation is by tissue culture, side grafting or chip budding onto *Ulmus pumila* rootstocks, and possibly by semi-hardwood cuttings. Availability: Carlton Plants LLC, AgriForest Bio-Technologies Ltd.

Figure 16. *Ulmus davidiana* var. *japonica* 'Burgundy Glow', Northern Empress® Japanese elm.

***Veronica* 'Blue Sprite' PPAF**

This compact, durable and showy selection made from a relatively unknown *Veronica* species has proven itself over 7 years of trials. The brilliant violet flowers are densely born on compact spikes only 4-5 in. tall. Blooming commences in late May to early June, and continues for upwards of 6 weeks, which is long for such a veronica. The plants form low, uniform dense clumps that slowly spread over time (Figure 17). Three-year-old plants measured 17 in. wide and less than 2 in. tall out of bloom. The foliage has been clean and disease-free through both wet and dry summers. Best cultivated in full sun and on a well-drained soil.

Easy to propagate from cuttings taken after the plant finishes flowering or by division in spring or fall. Likely hardy to USDA Zones 4–8. Selected in 2009 from open-pollinated seed collected from *V. allionii* in 2007.

Figure 17. *Veronica* 'Blue Sprite' PPAF.

Seed dormancy in seven-son flower (*Heptacodium miconiodes*)©

R.L. Geneve[a] and S.T. Kester

University of Kentucky, Department of Horticulture, Lexington, Kentucky 40546, USA.

INTRODUCTION

Seven-son flower (*Heptacodium miconiodes*) has recently become an established nursery crop in North America. It is the only member in the genus and is considered an endangered species endemic to China (Jin and Li, 2007). Seven-son flower is routinely propagated by softwood cuttings (Lee and Bilderback, 1990). However, there is little information on seed propagation.

Seven-son flower is in the *Caprifoliaceae* and seeds (achenes) have a small underdeveloped embryo. Most members in the *Caprifoliaceae* produce seeds with morphophysiological dormancy. Once seeds with morphophysiological dormancy have been dispersed, they must experience embryo growth within the seed prior to germination. There are at least eight different types of morphophysiological dormancy described based on the single or multiple cycles of warm or cold stratification required to satisfy dormancy (Baskin and Baskin, 2004). The specific type of morphophysiological dormancy in seven-son flower has recently been shown to be nondeep simple morphophysiological dormancy (Geneve and Kester, 2018).

RESULTS AND DISCUSSION

Seven-son flower has seeds with an underdeveloped embryo at the time of fruit dispersal with an embryo that occupies approximately 12% of the seed length. The fastest germination was observed following 8-weeks of cold stratification (5°C) followed by 8-weeks warm germination conditions (20°C). The embryo only enlarged during the warm period. Final germination percentage was approximately 85% (Table 1). Previous recommendations for seed pretreatments to relieve seed dormancy in seven-son flower included 5-months warm stratification followed by 3-months cold stratification (Dirr and Heuser, 2006). It appears that the initial warm stratification period is not required as seeds germinated well after a cold followed by warm dormancy release strategy. It is recommended that seven-son flower seeds be cold stratified for 2 to 3 months followed by germination under warm conditions (at least 20°C). Germination in these seeds was complete approximately 16 weeks after moving seeds to warm conditions (Table 1).

Table 1. Germination in seven-son (*Heptacodium miconiodes*) flower seeds exposed to warm (20°C) and cold (5°C) stratification prior to germination at 20°C.

Dormancy release treatment	Germination (%)	Days to complete germination after sowing
8-weeks warm	87.5	34 weeks
8-weeks cold	84.6	24 weeks
8-weeks warm followed by 8-weeks cold	75.0	36 weeks

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[a]E-mail: rgeneve@uky.edu

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Use of K-IBA as a foliar spray for softwood cutting propagation©

T. Gregory and R.L. Geneve[a]

Department of Horticulture, University of Kentucky, Lexington, Kentucky, 40546, USA.

INTRODUCTION

Common softwood cutting propagation involves the application of auxin as indole-3-butyric acid (IBA) in talc as a quick dip to the basal end of the cutting. Alternatively, auxin can be applied as a foliar spray over the top of cuttings after they are stuck (McGuire and Sorenson, 1966). This method has become a viable alternative for commercial cutting propagation because it offers several advantages over traditional application methods. The major benefits of foliar IBA sprays are reduced labor costs and increased worker safety. Additionally, the auxin spray could be administered at potentially any time after sticking giving the producer increased flexibility in the production process. An auxin spray also avoids potential alcohol damage to the basal portion of cutting that traditional applications might exhibit.

This study utilized two species (*Hydrangea paniculata* 'Limelight' and *Rhus aromatica* 'Gro-Low') that were chosen based on their sensitivity to a foliar auxin treatment. The objective of this study was to determine the effects of auxin concentration and timing of application on the rooting of the two species.

METHODS AND MATERIAL

Cuttings of both species (*H. paniculata* 'Limelight' and *R. aromatica* 'Gro-Low') were sourced from Decker's Nursery, located in Groveport, Ohio. The cuttings were then transported to the University of Kentucky Horticulture Greenhouse where they were prepared and stuck. Both species were prepared for treatment identically to the production in Decker's Nursery. *Hydrangea* cuttings were cut to an average length of four inches and the upper two sets of leaves were left intact. *Rhus* cuttings were processed to leave five nodes per cutting. Over seven-hundred cuttings were prepared for each species and stuck into deep celled, nursery production 6-packs. The cuttings were divided into 11 treatment groups after preparation: IBA quick dip (5,000 ppm), single spray treatment the day after sticking (Day 2), on Day 4, and Day 6. Multiple spray applications were on Day 2 plus Day 4 and Day 2 plus Day 6. K-IBA concentration for *Hydrangea* was 1,000 ppm and *Rhus* at 2,000 ppm. Following sticking, the cuttings were placed in a mist bed with bottom heat and a misting interval of 10 seconds every 10 minutes. The entire mist bed was covered in a single layer of shade cloth to reduce heat load throughout the day.

The flats were treated by spraying the cuttings in the morning with a hand sprayer until the leaves were saturated and slightly dripping. The K-IBA solution was allowed to completely dry on the leaves before misting was resumed. *Hydrangea* cuttings were evaluated 17 days after sticking, while *Rhus* cuttings were evaluated after 30 days. Cuttings were evaluated for roots per cutting and cutting quality was estimated on a scale of 0 to 5 where 0 was unrooted and 5 had numerous elongating roots. A subsample of rooted cuttings was transplanted to the greenhouse and evaluated after 2-months for branching and shoot length.

RESULTS AND DISCUSSION

In *Hydrangea,* the foliar K-IBA application was more effective for rooting than a quick dip, except when treated with 1,000 ppm the day after sticking (Figure 1). The best rooting occurred with a treatment of 2,000 ppm the day after sticking with 94% rooting and an average of 40 roots per cutting. The remaining applications exhibited good rooting as well,

[a]E-mail: rgeneve@uky.edu

but the applications of 1,000 ppm K-IBA performed better than applications of 2,000 ppm. Hydrangea responds well to foliar applications (Blythe et al., 2003) and the suggested concentration is between 500-750 ppm (Kroin, 2009). The efficacy of the auxin spray compared to a quick dip at similar concentrations is supported by Drahn (2007), working with several different cutting types. However, *Hydrangea* cuttings did not root well at the lower auxin concentration the day after sticking (18% rooting and 2.3 roots per cutting at 1,000 ppm). This indicates that while a lower concentration may be sufficient, the cuttings needed to fully acclimate to the misting environment to root without a higher auxin concentration. This may be partly explained by the delay in sticking following transport of the cuttings that could have led to lower foliar auxin absorption.

There were no significant differences in *Hydrangea* rooting when auxin application was delayed for up to 6 days after sticking (Figure 1). There was also no obvious additive or synergistic effect observed in rooting with multiple auxin sprays. From a practical standpoint, these data provide a window for initial auxin sprays where auxin remains effective for rooting and also indicates that there is no incentive for multiple foliar treatments in *Hydrangea* cuttings.

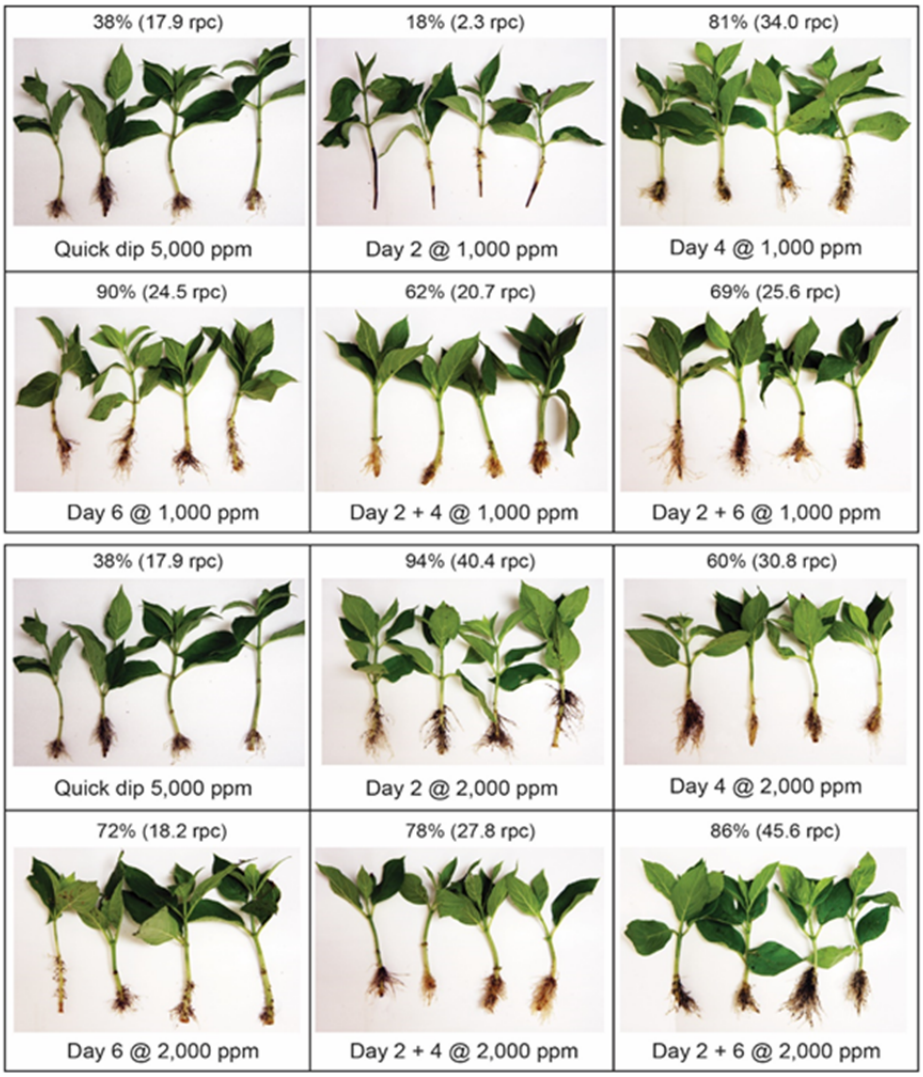

Figure 1. Rooting percentage and roots per cutting (rpc) in *Hydrangea paniculata* 'Limelight' cuttings treated with 1,000 or 2,000 ppm IBA foliar sprays at different times after sticking.

Rhus cuttings are difficult-to-root and often not responsive to auxin (Tipton, 1990). It was not unexpected to observe that *Rhus* cuttings experienced poor rooting success across all treatments (<10% rooting—data not shown). The treatments with 2,000 ppm K-IBA had marginally higher rooting success than the 1,000 ppm treatments. The quick dip treatment also had unsatisfactory rooting, even with a concentration of 5,000 ppm. However, there was no observable difference between the quick dip and spray suggesting that a foliar application could be successful with a higher auxin concentration. Additionally, cuttings with a higher leaf area may exhibit a higher response to the auxin spray (McGuire, 1967). Further trials would need to be conducted to assess this.

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Developing a modified hydroponic stock plant system for redbud©

V. Lewis, S.T. Kester and R.L. Geneve[a]

Department of Horticulture, University of Kentucky, Lexington, Kentucky 40546, USA.

INTRODUCTION

Cutting propagation is a major propagation method for the nursery industry, but there is very little stock plant management compared with the floriculture and forestry industries. Stock management of tropical annuals for cutting production has become a very specialized practice with most production occurring outside the U.S. Its stock plant management is characterized by starting with initially clean disease-free clonal material that is produced in containers under strict nutritional management. For woody plants, a selected number of deciduous forestry trees have been clonally propagated by selecting juvenile starting material for stock plants and then managing stock plants using a modified hydroponic system to optimize stock plant nutrition. The forestry industry has moved into commercial clonal production for a number of difficult-to-root crop species including *Eucalyptus* and some conifers (Assis, 2011; Chinnaraj and Malimuthu, 2011). The industry has been very successful with this approach, propagating large quantities of rooted cuttings for planting-out each year. There are three basic stock plant management principles that have allowed for consistent (>90%) cutting success. These include initial selection of juvenile material (stump sprouts, lignotubers or tissue culture), managed stock plant nutrition using a modified hydroponic system, and consistent, timely removal of cuttings to keep cutting wood from maturing. This procedure has been termed "minicuttings" and they result in vigorous rooted cuttings that have better root systems compared to traditional cuttings (Cliffe, 2010). These stock plants produce vigorous managed shoot growth that yields cuttings that consistently root when taken as minicuttings.

The objective of this research was to develop a modified hydroponic system for minicutting production using eastern redbud as a model system. Eastern redbud makes a good model system because in addition to juvenile seedlings, eastern redbud cultivars available from tissue culture present a good juvenile stage starting material for a minicutting stock plant program. In addition, although eastern redbud is difficult-to-root from cuttings, it does show rooting potential during a brief window of time during the growing season.

METHODS AND MATERIALS

Plant material

Juvenile eastern redbud (*Cercis canadensis*) plants were raised as seedlings. Mature clones were established as hedged stock blocks at the University of Kentucky research station.

Stock plant production system

Stock plant production systems were established for minicutting production in sand beds and coir bags. Each was irrigated with a modified hydroponic nutrient solution using an automated timing system. Initial experiments compared full-strength with half-strength nutrient solution for stock plant growth. In addition, clonal plants purchased as grafted material were established in hedged stock blocks in field beds. Stock plants were pruned every 3 weeks to three nodes.

Cutting propagation

Terminal cuttings were rooted under mist. Cuttings were treated with IBA concentrations ranging from 0 to 15,000 ppm as a quick dip. Cuttings were evaluated for

[a]E-mail: rgeneve@uky.edu

time to first root emergence, rooting percentage, number of roots per cutting.

RESULTS AND DISCUSSION

Stock plants grow vigorously in the modified hydroponic sand beds (Figure 1). It was determined that plants responded equally well when irrigated at full or half-strength nutrient solutions (Figure 2). Subsequently, all sand beds were moved to half-strength fertilizer solutions. Stock plants in sand beds have gone through four rounds of pruning and it appears that cuttings will be available every 2 to 3 weeks.

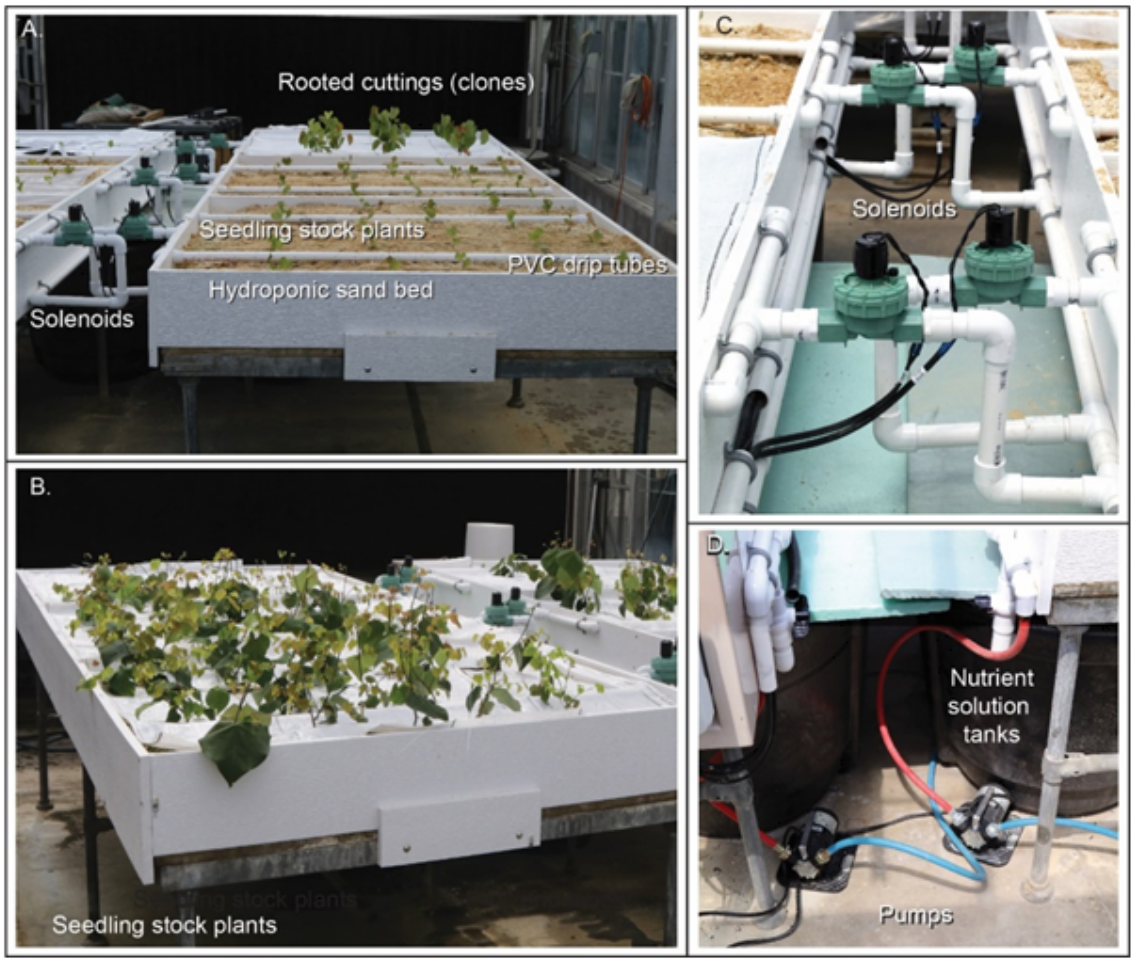

Figure 1. Sand bed production of stock plants. A. Sand bed. B. Stock plants after several rounds of hedging. C and D. System for pumping nutrient solution to sand beds.

A preliminary dose response to auxin using seedlings or clonal cuttings from hedged stock plants indicated that cuttings responded to 10,000 and 15,000 ppm auxin as a quick dip. Rooting was very similar for cuttings taken from greenhouse and field-grown stock plants (Figure 3). Seedling and rootstock cuttings were easier to root compared to cuttings from clonal plants. The highest rooting for clones was below 30%. Also, 'Oklahoma' cuttings consistently rooted at lower percentages than 'Appalachian Red'.

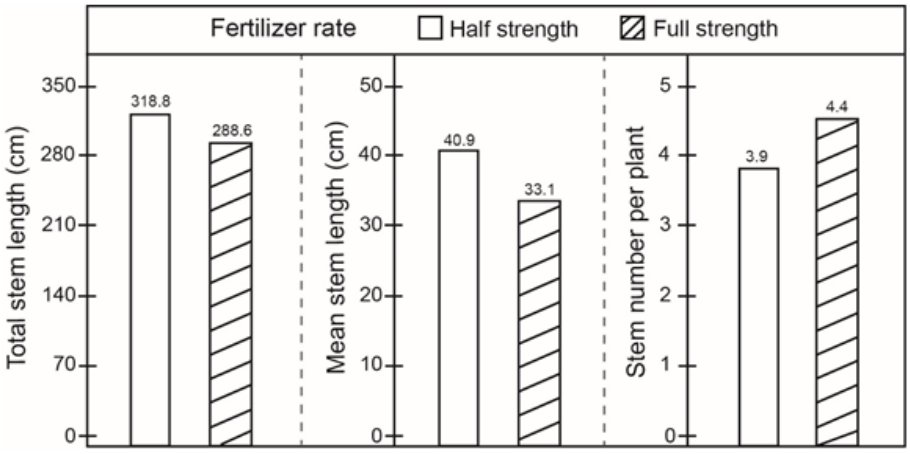

Figure 2. Impact on nutrient solution rate on greenhouse-grown stock plant development.

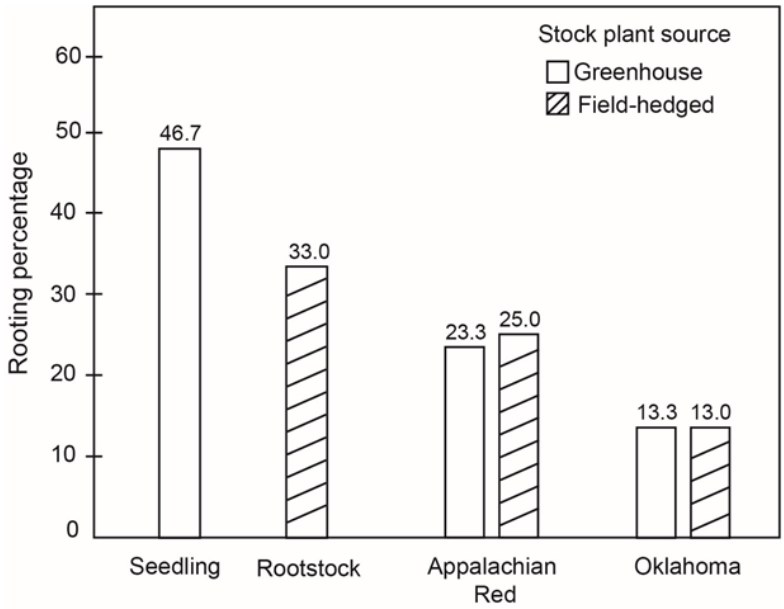

Figure 3. Rooting percentages for seedling and clonal redbud cuttings taken greenhouse or field-managed stock plant plants.

ACKNOWLEGEMENTS

This research is supported by a grant from the Horticultural Research Institute and the IPPS-ER.

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Using Osmocote® Bloom in propagation and production©

T. Bosma[a]

ICL Specialty Fertilizer, 1045 Woodspointe SW, Byron, Michigan 49315 USA.

SUMMARY

A series of trials were conducted at commercial growers to show the feasibility and benefits of using Osmocote® Bloom mini-prill in commercial production. Osmocote® Bloom encouraged faster, stronger root development, resulting in more compact, consistently sized plants. Additionally Osmocote® Bloom proved to be cost efficient, reduced nutrient run-of and provided constant steady feeding even after product cycle.

PLANT GROWTH TRIALS

Research and trial results demonstrate Osmocote® Bloom produces a plant response equal to or better than water soluble fertilizer (WSF) in a wide variety of plant types including geranium, petunia, verbena, and cyclamen (Figure 1). With liners Osmocote® Bloom compared favorably to WSF treatment during production and after liners rooted Osmocote® Bloom continued to feed the liner when WSF was cut off (Figure 2).

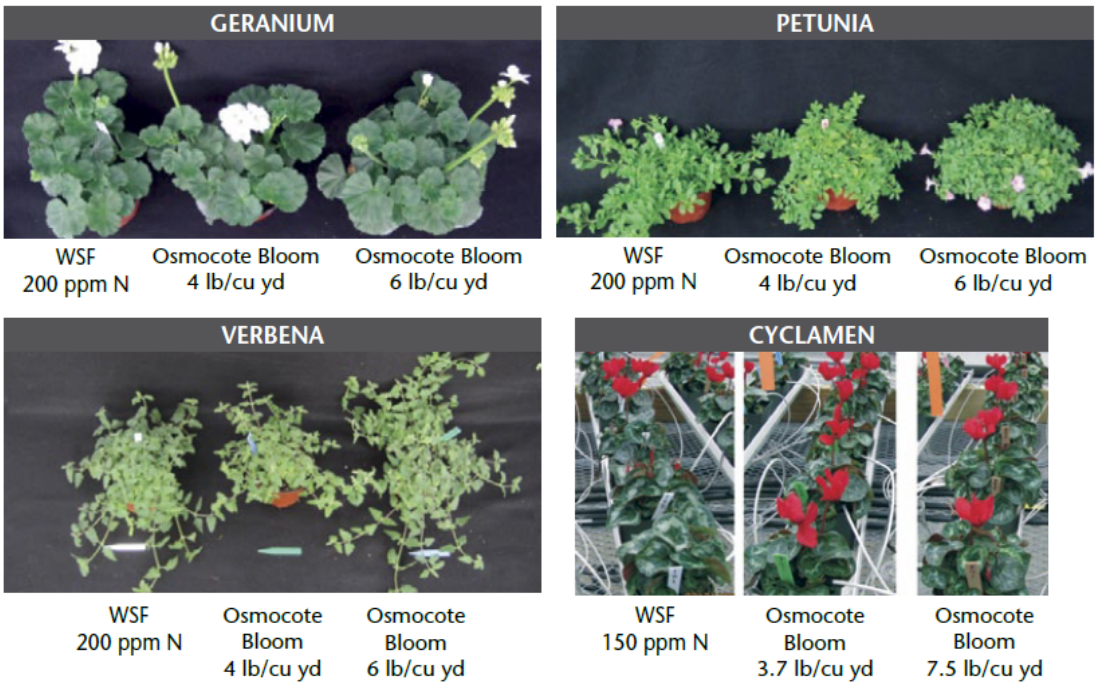

Figure 1. Comparison of Osmocote® Bloom and water soluble fertilizer on the growth of four different plants (*Geranium*, *Petunia*, *Verbena,* and *Cyclamen*).

[a]E-mail: tom.bosma@icl-group.com

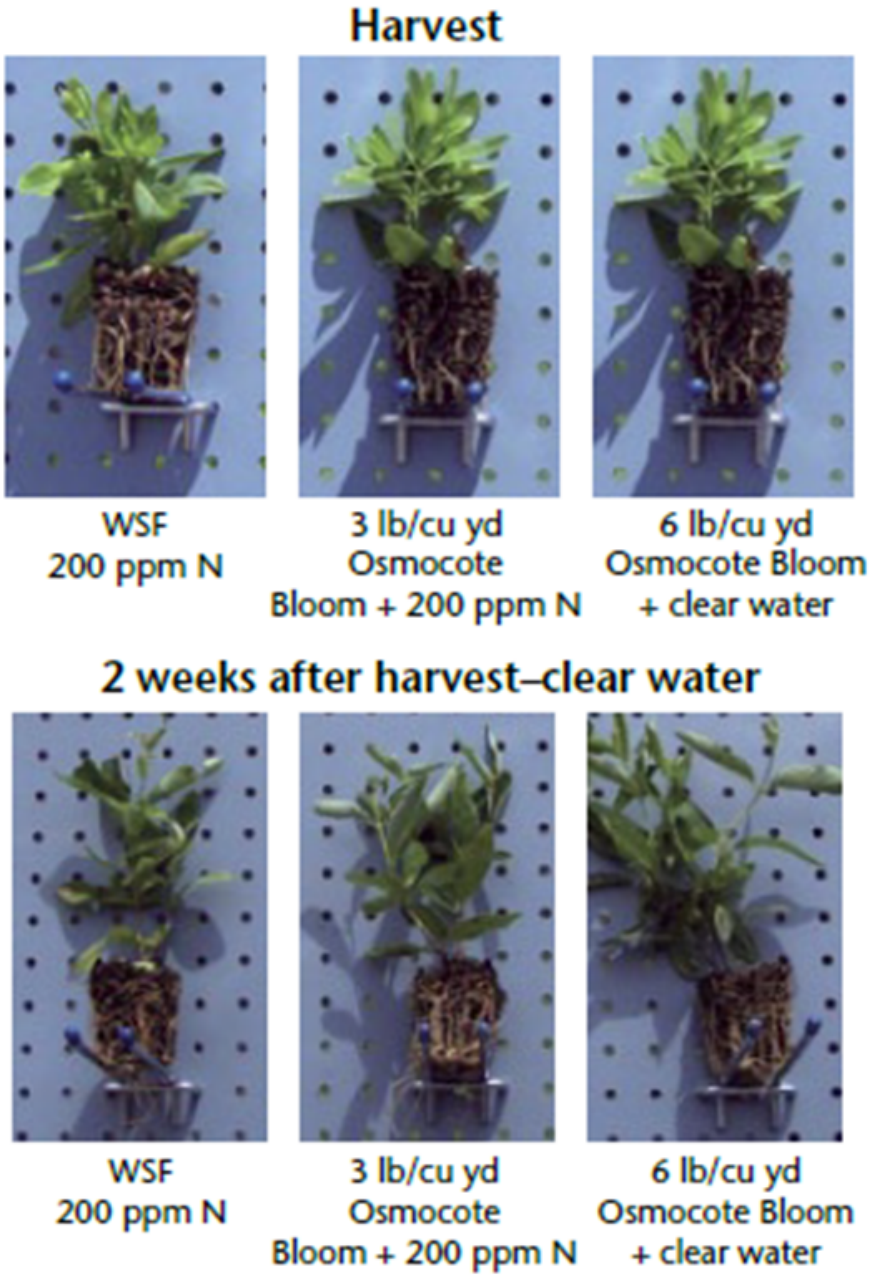

Figure 2. Growth of rooted liners (top: at harvest; bottom 2 weeks after harvest).

A commercial pansy trial compared Osmocote® Bloom at 3 lbs. per cu yard vs. WSF. The grower reported back some very positive results: bigger pansy (*Viola*) plants, 15-20% more blooms, at least a 25% reduction in production time, and a significant savings in the total fertilizer cost.

REDUCED NUTRIENT RUN-OFF

Osmocote® Bloom showed a 64% lower N and 84% lower P leaching than with WSF and a 59% lower P leaching than with standard organic fertilizer (Figure 3).

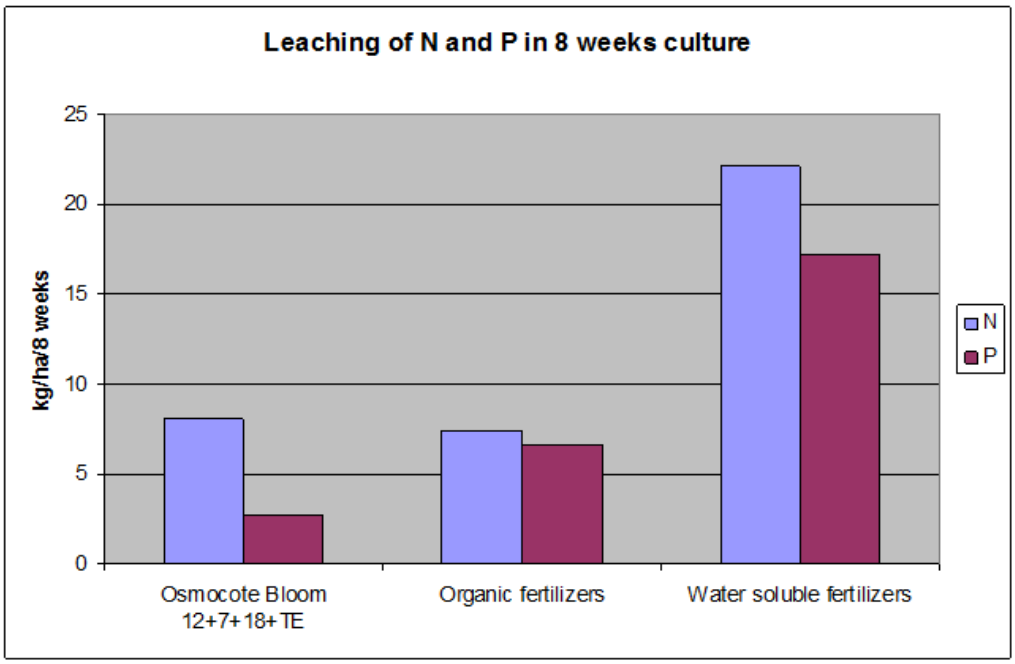

Figure 3. Leaching of nitrogen (N) and phosphorus (P) during and 8 week trial.

OSMOCOTE® BLOOM: WHAT IS IT

Osmocote® Bloom is 100% coated and contains a complete package of N-P-K, blended with magnesium and essential micronutrients. It is available in 2-3 month and 5-6 month longevities. A key feature is smaller prills or particles. The prill is about 1/5 the size of a standard Osmocote® prill. This smaller size provides better uniformity and even distribution of nutrition in smaller containers, optimizing plant utilization.

A screening to study the effect of smoke solutions, gibberellic acid, and cold-moist stratification on various grass species©

D. Schoemaker, S. Ebelhar and D.L. Sanford[a]

Department of Plant Science, The Pennsylvania State University, Berks Campus, Reading Pennsylvania 19610, USA.

INTRODUCTION

The research was conducted to serve as screening of several grass species to determine the effect smoke, gibberellic acid, and cold-moist stratification had on germination.

Researchers have discovered that there are two important compounds inside smoke: karrikins and cyanohydrins. Scientists have isolated four different karrikins compounds ranging from Kar_1 to Kar_4. When karrikins are released from smoke, the compound rests in the soil. Once precipitation occurs, the compound mixes with the soil and germination occurs. Plants that are known to positively correlate with smoke are called "fire-followers." These types of plants typically have an evolutionary history of living in environments where fires are present.

MATERIALS AND METHODS

The experimental groups were a 0.5, 1.0, and 2.0% gibberellic acid solutions and the same solutions mixed with "Cape Seed Primer" smoke paper [one disk per 50 mL deionized water (DI)]. There was also one experimental group consisting of just smoke paper and a DI water solution as the control.

Utilize a 10.0, 5.0, and 1.0% bleach solution for sterilization of each species. Place seeds in each solution for 1 min. Between each sterilization, rinse the seeds in DI water for 1 min. Change out the water between each rinse. Seeds were soaked in each experimental solution or control for 24 h. Once the 24 h was complete, seeds were removed from the solutions and placed into Petri plates with filter paper and 2.5 mL DI water. Forty seeds per plate were transferred for a total of 8 Petri plates per experimental group. Seeds were stored in a 1.6-4.4°C cold room for 30 or 60 days depending on the experimental trial. Once cold-moist stratification was complete, all seeds were transferred to new Petri plates with a filter paper and 2.5 mL of DI water.

There were a total of 16 Petri plates, each containing 20 seeds transferred to the growth chamber. The growth chamber was set to 23°C for 12-h light period and 15°C for a 12-h dark period each 24 h.

RESULTS

The percent germination was collected once a week for a total of 3 weeks. Results are presented in Table 1.

[a]E-mail: dls30@psu.edu

Table 1. Germination rate (%) for selected grass species with a 30 and 60 day cold-moist stratification period, a cold-moist stratification with gibberellic acid, and cold-moist stratification with gibberellic acid plus smoke. The table above displays the percent germination for each grass species 30- and 60-day cold-moist stratification. The values of 30 and 60 after each species represents the number of cold-moist stratification days for the individual trial.

Species	Control	0.5% GA	1% GA	2% GA	Smoke paper	.5% GA and smoke paper	1% GA and smoke paper	2% GA and smoke paper
Sporobolus compositus (syn. *S. asper*) (30)	8.15	13.13	6.25	14.38	18.75	10.63	12.50	9.38
Sporobolus. compositus (60)	0.00	5	11.25	18.75	22.50	35.00	34.38	35.00
Sporobolus cryptandrus (30)	0.63	7.50	10.63	15.63	2.50	8.13	20.00	14.38
Sporobolus cryptandrus (60)	6.25	15.63	15	22.50	5.63	16.88	27.50	26.25
Sporobolus heterolepis (30)	63.75	68.75	58.13	65.63	68.13	69.38	68.13	64.38
Sporobolus heterolepis (60)	73.75	72.50	73.13	70.63	69.38	70.00	76.25	73.75
Agrostis hyemalis (30)	NA	6.25	25.63	26.88	30.63	26.25	14.38	25
Agrostis hyemalis (60)	36.00	36.88	38.75	36.88	28.13	41.25	28.75	25.00
Chasmanthium latifolium (30)	20.63	23.13	26.25	19.38	16.88	27.50	25.63	20.00
Chasmanthium latifolium (60)	39.38	56.25	50.63	43.75	40.00	31.25	33.75	48.75
Scirpus atrovirens (30)	15.00	9.38	8.13	4.38	14.38	7.50	11.25	11.25
Scirpus atrovirens (60)	12.50	6.25	8.13	4.38	13.25	7.50	8.13	10.63

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Krock, S., Smith, S., Elliott, C., Kennedy, A., and Hamman, S.T. (2016). Using smoke-water and cold-moist stratification to improve germination of native prairie species. Native Plants J. *17* (*1*), 19–27 https://doi.org/10.3368/npj.17.1.19.

Characterization of microbial community structure in pine bark substrates©

J. Altland[a], F.C. Michel, Jr. and S. Valles

USDA Agriculture Research Service, Wooster, Ohio 44691, USA.

A large body of research has addressed the biological community in soilless substrates. Most of this research pertains to specific sets of pathogens or plant growth promoting microbes. Very little is known about the overall microbial community in terms of species range, diversity and relative population density. The objectives of this research were to analyze microbial community structure in a typical pine bark substrate used for nursery crop production and determine the impacts of compost amendment and plant growth on these communities. Three substrates (v/v); 80:20:0, 80:10:10, and 80:0:20, pine bark:sphagnum peat:leaf compost were prepared. The substrates were filled into 20 L nursery containers and half were planted with a single birch liner (*Betula nigra* 'Cully', Heritage® river birch) from a 50-cell flat while the other half remained fallow. Containers were fertilized with 73 g controlled release fertilizer. There were six single-pot replications per treatment. The microbial consortia in the potting media were characterized using high-throughput ribosomal RNA gene and intergenic spacer region sequencing. Representative samples (500 g) were taken from each container starting on April 12 and monthly thereafter throughout the growing season (4 months) and stored at -22°C until analyzed. DNA was extracted and purified using DNeasy PowerSoil Kit components. The product size was verified by gel eletrophoresis. A 25 µL aliquot at a 5 mg mL^{-1} concentration was used for PCR amplification. Universal as well as population-specific bacterial and fungal primers were used to identify and quantify tens of thousands of individual ribotypes within each sample by comparison of the amplified sequences to 16S gene and ITS databases. The data was processed using an open-source bioinformatics pipeline (QIIME). Bacterial communities of the substrates immediately after potting differed in composition. The compost amended substrate (80:0:20) was dominated by proteobacteria (37.4%), actinobacteria (35.6%) and acidobacteria (23.0%). The peat amended substrate was initially dominated by proteobacteria but also had relatively large percentages of chloroflexi and bacteroidetes. Over time, bacteroidetes increased while actinomycetes and acidobacteria decreased in all of the mixes. While there were initially differences in microbial communities between the substrate types, after 2 months the communities in all substrates were similar. Planting trees or adding compost to the media did not have a strong impact on bacterial community composition after 2 months.

[a]E-mail: James.altland@ars.usda.gov

Irrigation water alkalinity, not pH, affects substrate pH©

J. Altland[a]

USDA Agriculture Research Service, Wooster, Ohio 44691, USA.

Substrate pH of container-grown crops is predominantly affected by irrigation water alkalinity and much less so (if at all) by irrigation water pH. Despite this issue having been discussed in numerous extension and trade publications, there still seems to be widespread confusion as to how irrigation water should be managed to maintain optimum substrate pH. While irrigation water pH and alkalinity can be related, a survey of 192 Ohio groundwater samples showed no correlation between the two variables (R = -0.1077, *P* = 0.1369). High irrigation water pH does not necessarily result in high alkalinity, and vice versa. The objective of this study was to provide nursery growers and extension educators with a simple demonstration of how irrigation water pH and alkalinity affect substrate pH. There were three substrate treatments. One treatment included 15-cm diameter pots filled with a substrate composed of 80 pine bark: 20 peatmoss (fallow). The second treatment included the same substrate amended with a controlled release fertilizer (Osmocote 15-9-12) incorporated at 7.7 kg m^{-3}. The third treatment included the same substrate and fertilizer potted with a single liner of rose (*Rosa* 'Radrazz', Knock Out® rose). Containers were irrigated with either reverse osmosis (RO) water, a 0.0001 mM KOH solution in RO water, or a 0.005 M $KHCO_3$ solution in RO water. The RO water had pH of 6.26 and alkalinity of 3.4 mg L^{-1} $CaCO_3$. The KOH solution had pH of 8.23 and alkalinity of 10.0 mg L^{-1} $CaCO_3$. The $KHCO_3$ solution had pH 8.28 and alkalinity of 275 mg L^{-1} $CaCO_3$. There were six replications per treatment combination. Substrate pH was recorded over 3 months using the pour-through procedure. Substrates irrigated with the $KHCO_3$ solution had higher pH throughout the study. Substrates irrigated with RO or KOH solution had similar, but lower, pH values throughout the study. Substrates containing roses and fertilizer had slightly lower pH compared to fallow substrates, but both substrates responded similarly with respect to the irrigation treatment received. These data demonstrate with a simple case study how irrigation alkalinity, and not irrigation pH, increases substrate pH in fertilized or non-fertilized container substrates over time.

[a]E-mail: James.altland@ars.usda.gov

Water temperature and exposure time for killing weed seed on recycled plastic containers©

J. Altland[a]

USDA Agriculture Research Service, Wooster, Ohio 44691, USA.

Seeds of many weeds, most notably creeping woodsorrel (*Oxalis corniculata*) and bittercress (*Cardamine flexuosa*), adhere to plastic containers and trays and are reintroduced into the production system when the containers and trays are reused. Some nurseries use hot water or steam for sterilizing reused containers and propagation trays. Initially, this technology was adopted as a means for eliminating pathogens. But these nurseries soon noted vast improvements in weed control. Nursery operations are using hot water or steam at temperatures ranging from 60 to 90°C, with exposure times from 15 minutes to 4 h. While they have reported increased levels of weed control using this form of sterilization, the temperature and exposure times selected were based on best guesses or to satisfy some certification processes for disease control. Therefore, the objective of this research was to determine the specific temperatures and exposure times necessary to kill creeping woodsorrel and bittercress seeds using hot water.

Initial experiments with creeping woodsorrel and bittercress were conducted separately. Glass test tubes were filled with ten seeds each, then placed into a digitally programmable hot water bath. The hot water bath was set at 60, 75, or 90°C for 1, 5, 10, 30, or 60 minutes to determine creeping woodsorrel and bittercress tolerance. There were five replicate test tubes per treatment, including a group of five control test tubes that remained at room temperature. After heat treatment, the seeds from each test tube were transferred to a Petri dish containing an agar base made using 15 g L^{-1} granulated agar in a modified Hoagland solution (in mM: 7.5 N, 0.5 P, 3 K, 2.5 Ca, 1 Mg, 1 S, 0.071 Fe, 0.009 Mn, 0.0015 Cu, 0.0015 Zn, 0.045 B, 0.0001 Mo, 0.024 Cl, and 0.0002 Na). Petri dishes were placed in a growth chamber providing a 12-hour photoperiod and 18°C night/22°C day air temperature. After 2 weeks, weed germination in each Petri dish was tabulated.

Creeping woodsorrel treated with 60°C water had a similar germination percentage as non-heated controls. Those heated at 75°C still germinated, but at a lower percentage than the non-heated controls. None germinated when exposed at 90°C for 5 minutes or longer. Within each temperature, exposure time did not affect creeping woodsorrel germination. Similarly, bittercress were not controlled with 60°C water. Bittercress germination was reduced when treated with 75°C water, and germination decreased with increasing exposure time. Like creeping woodsorrel, none of the bittercress germinated when treated with 90°C water. For rapid exposure times of 5 minutes or less, high temperatures of at least 90°C will be needed for effective control of creeping woodsorrel and bittercress. Lower temperatures of 75 to 85°C might be effective with sufficiently long exposure time.

[a]Email: James.altland@ars.usda.gov

A screening to study the effect of various smoke solutions and cold-moist stratification on *Carex*©

D. Schoemaker, S. Ebelhar and D.L. Sanford[a]

Department of Plant Science, The Pennsylvania State University, Berks Campus, Reading Pennsylvania 19610, USA.

INTRODUCTION

The research was conducted to serve as screening of several *Carex* species to determine the effect smoke and cold-moist stratification had on germination.

Since early hunter-gather society, humans have observed that after a forest fire, small, prairie plants, are one of the first species to germinate. The rejuvenation in growth is known as secondary succession. For centuries, this process has been suggested as a natural occurrence, however, current research shows that species react to fire due to internal genetic signaling through the protein MAX2 and smoke isolate compound karrikin.

MATERIALS AND METHODS

The current research looked to screen for the effect that liquid smoke and cold-moist stratification has on nine different *Carex* species. Each *Carex* species was tested with a 30, 60, and 90 day cold-moist stratification periods and four different smoke groups, plus a control of deionized water. The species *C. vulpiniodea* and *C. bicknelli* had germination percentages greater than 50%. All other species percent germination was less than 50%. Within *C. vulpiniodea* and *C. bicknelli*, cold-moist stratification assisted in increasing the percent of germination better than any of the smoke solutions.

Each *Carex* species was rinsed in 10, 5, 1% bleach, and deionized water before being transferred to cold-moist stratification. Using HEPA filter environment, each *Carex* species was transferred into Petri dishes containing a filter paper and three milliliters of deionized water. The seeds were then placed into a cold room at and removed after 30, 60, or 90 days. The cold room temperature ranged between 1.6 and 4.4°C, and contained no light. A total of 800 seeds per cold treatment were transferred for each species.

A 2, 5, and 10% Haddon House Hickory Smoke liquid smoke solutions were made. Also, a solution of Super Smoke Plus from Cape Seed Primer was made from smoke infused filter paper. Finally, a control of deionized water was tested. After seeds were removed from the cold stratification, 160 seeds were transferred to each smoke solution for a 24-h soak at 21°C.

After soaking the seeds were transferred to Petri dishes containing filter paper and 3 mL DI water. There were eight trials per experimental group. Each Petri dish contained a total of 20 seeds. Petri plates were placed in a growth chamber set at 23°C during a 12-h light photoperiod and 15°C dark period during each 24-h cycle.

RESULTS

The number of seeds germinated per group per Petri dish was counted on a weekly basis for a total of 3 weeks. The seedling was considered “germinated” at the first sight of a root radicle. The percent germination was collected once a week for a total of 3 weeks. Results are presented in Table 1.

[a]E-mail: dls30@psu.edu

Table 1. Percent germination for selected *Carex* species with 0, 30, 60, 90-day cold-stratification followed by a 24-h soak in a smoke solution. The table shows the percent germination, smoke group, and cold-stratification period for each of the *Carex* species studied during the screening process. All numbers in parentheses after the species name represents the cold-stratification in number of days for the individual species.

Species-cold period (days)	Control (%)	2% Smoke (%)	5% Smoke (%)	10% Smoke (%)	Smoke paper (%)
C. bicknellii (0)	1.25	2.50	1.88	1.88	1.25
C. bicknellii (30)	18.13	14.38	8.75	3.13	27.50
C. bicknellii (60)	48.75	45.63	34.38	18.75	50.00
C. bicknellii (90)	40.00	51.88	45.00	10.00	58.75
C. blanda (0)	0.00	0.00	0.00	0.00	0.00
C. blanda (30)	6.25	11.25	4.38	4.38	8.13
C. blanda (60)	3.75	1.25	1.88	3.13	2.50
C. blanda (90)	11.25	7.50	1.88	1.88	8.75
C. cryptolepis (0)	0.00	0.00	0.00	0.00	0.00
C. cryptolepis (30)	0.00	0.00	0.00	0.00	0.00
C. cryptolepis (60)	0.00	0.00	0.00	0.00	0.00
C. cryptolepis (90)	0.00	0.00	0.00	0.00	0.00
C. comosa (0)	0.00	0.00	0.00	0.00	0.00
C. comosa (30)	0.00	0.00	0.00	0.00	0.00
C. comosa (60)	0.00	0.00	0.00	0.00	0.00
C. comosa (90)	0.00	0.63	1.25	0.63	0.00
C. crinite (0)	0.00	0.00	0.00	0.00	0.00
C. crinita (30)	0.00	0.00	0.00	0.00	0.00
C. crinita (60)	0.00	0.00	0.00	0.00	0.00
C. crinita (90)	0.00	0.00	0.00	0.00	0.00
C. frankii (0)	0.00	0.00	0.00	0.00	0.00
C. frankii (30)	1.25	1.88	0.00	1.25	4.38
C. frankii (60)	3.13	3.75	5.63	1.88	5.63
C. frankii (90)	1.25	3.75	4.38	1.88	8.13
C. *haydenii* (0)	0.00	0.00	0.00	0.00	0.00
C. *haydenii* (30)	1.25	0.63	0.00	1.25	1.25
C. *haydenii* (60)	5.00	2.50	1.88	0.00	4.38
C. *haydenii* (90)	1.25	1.25	1.88	1.88	1.88
C. pensylvanica (30)	12.50	6.25	2.50	0.00	12.50
C. pensylvanica (60)	15.00	6.25	4.38	1.25	15.63
C. pensylvanica (90)	5.63	5.63	3.13	1.25	15.00
C. vulpinoidea (0)	5.00	0.63	0.63	1.25	6.88
C. vulpinoidea (30)	93.75	95.00	86.25	53.13	95.00
C. vulpinoidea (60)	91.88	97.50	88.75	76.25	95.63
C. vulpinoidea (90)	93.13	97.50	93.75	86.25	96.25

Additional reading

Guo, Y., Zheng, Z., La Clair, J.J., Chory, J., and Noel, J.P. (2013). Smoke-derived karrikin perception by the α/β-hydrolase KAI2 from *Arabidopsis.* Proc. Natl. Acad. Sci. U.S.A. *110* (*20*), 8284–8289 https://doi.org/10.1073/pnas.1306265110. PubMed

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Seasonal emergence of invasive ambrosia beetles in Western Kentucky in 2017©

Z. Viloria[1], G. Travis[1], W. Dunwell[1,a] and R. Villanueva[2]

[1]University of Kentucky, Department of Horticulture, 1205 Hopkinsville Street, Princeton, Kentucky 42445, USA; [2]University of Kentucky, Department of Entomology, 1205 Hopkinsville St., U.K. Research & Education Center, Princeton, Kentucky 42445, USA.

NATURE OF WORK

Xylosandrus crassiusculus (granulate ambrosia beetle, GAB) and *X. germanus* (black stem borer, BSB) are considered the most destructive insect pests to the nursery crop industry. These beetles usually mass attack nursery crops in spring, causing important loss due to the negative effect on the plant growth, aesthetic, economic value and unmarketable tree quality (Ranger et al., 2016). Ambrosia beetles bore sapwood and inoculate the galleries with fungi, which are collectively named as ambrosia fungi. These fungi are derived from plant pathogens in the ascomycete group identified as ophiostomatoid fungi (Farrell et al., 2001). Ambrosial fungus garden is the food source for ambrosia beetles and larvae. According to the field and container nursery growers of southeastern USA, GAB was ranked third as a key pest, 18% nursery growers identified it as prevalent and difficult to control. In Tennessee, *Cnestus mutilatus* (camphor shot borer, CSB) was found widely distributed and considered a new pest for nursery crops with unknown magnitude of damage (Oliver et al., 2012). Camphor shot borer was first reported from Kentucky in 2013, although a single specimen was found in Whitley Co., it was believed it would be everywhere in the state due to its wide spread in the neighboring states (Leavengood, 2013). The main objective of this study was to determine the phenology of the most abundant invasive ambrosia beetles in western Kentucky.

MATERIALS AND METHODS

Double bottle Baker traps were baited with ultra-high release ethanol (Contech Enterprises Inc., Canada). The ethanol pouch was attached to the upper bottle and set over 1 m above the ground. The catching bottle contained approximately 150 mL commercial antifreeze to collect and kill insects. Four traps per location were set at the edge of the woods surrounding nursery stocks and orchards, and inside the orchards and nursery stocks. Traps were deployed in Calloway, Caldwell, Graves, and Todd Counties, in western Kentucky in March 2017. Catching bottles were replaced weekly during March and April, and biweekly thereafter until early August, 2017. In the laboratory, after filtering and rinsing each bottle's content, ambrosia beetles were grouped and tallied under a dissecting stereoscope. Total number of beetles per trap per week was recorded.

RESULTS AND DISCUSSION

The most common and numerous ambrosia species identified were GAB, BSB, CSB and *Xyleborinus saxesenii* (Fruit-tree pinhole borer, PHFB), which are identified as invasive species. Invasive ambrosia beetles once established in new habitats surpass the populations of native species (Miller and Rabaglia, 2009; Helm and Molano-Flores, 2015; Werle et al., 2015; Gandhi et al., 2010).

Granulate ambrosia beetle populations started to rise the last week of March to reach the highest populations in April in the four counties (Figure 1A). In Todd Co., the highest GAB population (768 beetles/week) was captured the 3rd week of April, thereafter the number decreased abruptly. The second largest population was recorded in Graves Co. the 2nd week of April. In Caldwell and Calloway Counties the maximum populations (141 and 182, respectively) occurred the 1st week of April. The GAB populations were still high in May and June, with very low captures in Caldwell Co. Apple and peach orchards have a pesticide

[a]E-mail: winston.dunwell@uky.edu

program that includes frequent insecticide sprays, thus it could deter ambrosia beetles. In chestnut nurseries, ambrosia beetle population peaks in spring and fall coincided with the time of attacks and tree damage (Oliver and Mannion, 2001).

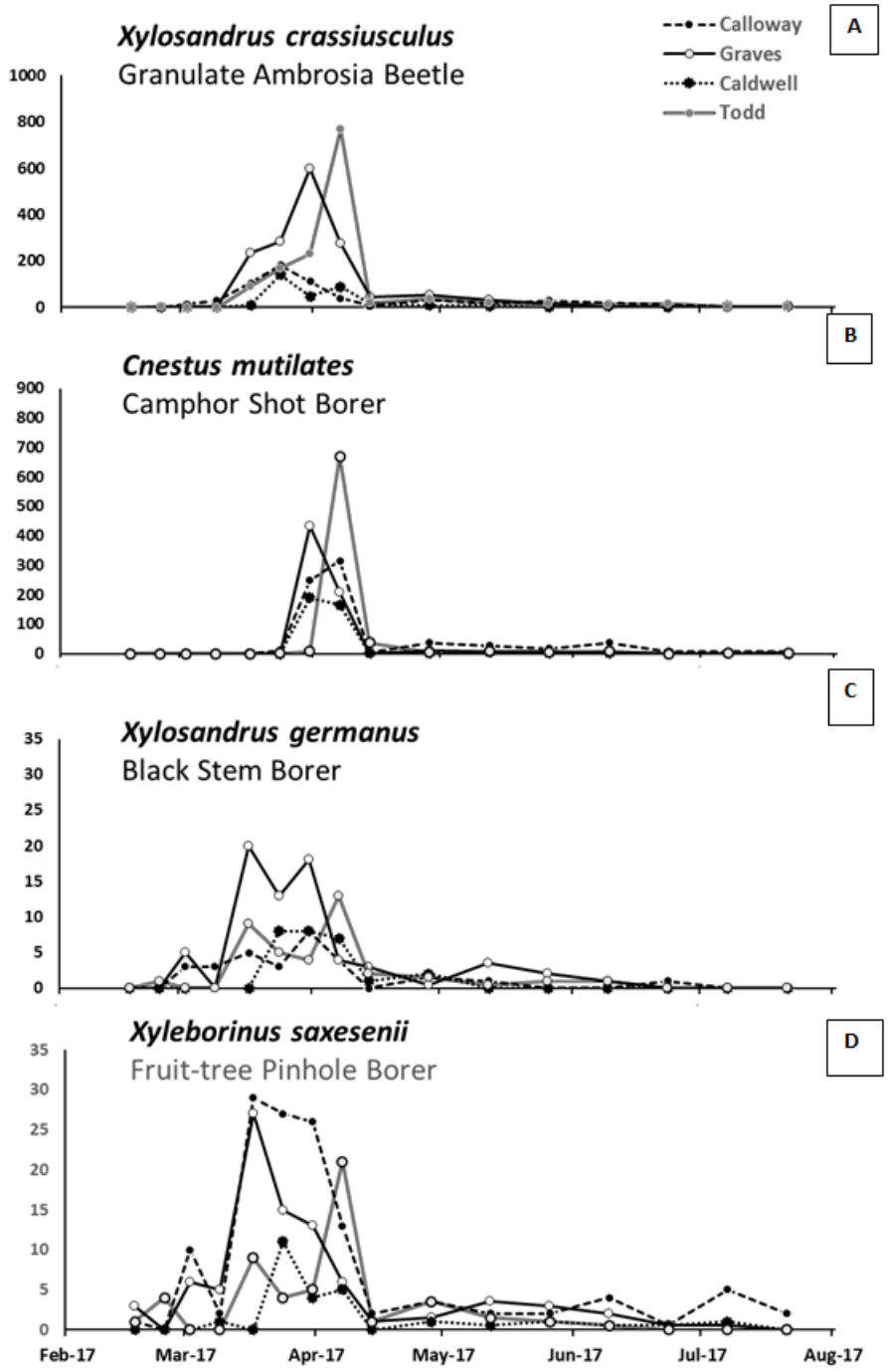

Figure 1. Seasonal captures of *Xylosandrus crassiusculus* (A), *Cnestus mutilates* (B), *Xylosandrus germanus* (C), and *Xyleborinus saxesenii* (D) in western Kentucky.

Camphor shot borer was the second most abundant invasive ambrosia beetle. The largest captures of CSB were recorded the second and third weeks of April, with the highest counts in Graves and Todd Co. (Figure 1B). Populations decreased considerably the last week

of April in all counties. More CSB were captured in Calloway Co. in May and June. Spring Ambrosia beetle attacks to nursery, landscape and fruit trees have been reported in western Kentucky year after year. In 2017, we identified GAB as responsible of a mass attack to 'October Glory' maple in a nursery. Few CSB were also found in the galleries of infested trees. These two species were also identified attacking nursery apple trees in Jackson Co., and 5-7mm diameter red bud branches from a home garden.

Regarding BSB, low populations were recorded from the four counties for short time in the growing season (Figure 1C). Black stem borer started to emerge in March in Graves and Todd Counties, and disappeared in late June. In Caldwell, it was found from early April to mid-May, whereas in Calloway, the BSB was captured until early July. Low counts of BSB have recorded previously in the southeastern USA (Miller and Rabaglia, 2009; Oliver and Mannion, 2001, Werle et al., 2015), but larger populations have been reported from northern states such as Ohio (Reding et al., 2011, 2015) and New York (Agnello et al., 2017), which might be related with its adaptability to high altitudes and cool climates (Reding et al., 2011).

Fruit-tree pinhole borer reach the highest population in April, but its presence was detected during the growing season. Highest populations of FTPB were recorded in Calloway and Graves counties from late March to the third week of April, with a maximum of 29 beetles/trap/week (Figure 1D). In Todd and Caldwell Co., the FTPB population showed a single peak, with 21 and 11 beetles/trap/week, respectively. From late April on, the populations were low in all four counties. High PHFB populations have been reported in avocado (Carrillo et al., 2012) and stressed black walnut (Reed et al., 2015). Despite the high population of PHFB in nursery crops, the attack number is low and non-significant (Oliver and Mannion, 2001; Reding et al., 2011).

SIGNIFICANCE TO THE INDUSTRY

Granulate ambrosia beetle and camphor shot borer were found in large numbers in western Kentucky in early spring. Ambrosia beetle attacks were identified in nursery and land scape plants. Regrettably, nothing can be done to recover infested plant, especially those that belong to a nursery. Knowing Ambrosia beetle seasonal flight timing will provide valuable information to opportunely schedule preventive application of pyrethroids and thus increase the insecticide spray efficiency. Other more effective management strategies need to be evaluated.

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Use rooting hormones or not—multiple applications may be best©

J. Kroin[a]

Hortus USA Corp., PO Box 1956, New York, New York 10113, USA.

INTRODUCTION

Plant growers know when propagating plants from cuttings rooting hormones are essential to produce quality roots. The question may come up, if one rooting hormone application is good, are two or more applications better?

Rooting hormones can be applied by either basal or foliar methods. Basal methods use either dry power rooting hormones or rooting solutions. Foliar methods use aqueous K-IBA rooting solutions on leafy cuttings in the growing state. Traditionally these methods have been used by one application. However a secondary K-IBA rooting solution foliar applications may enhance the rooting of slow-to-root cuttings and may make crops that have differences in growth more uniform. The first rooting hormone application, at time of sticking, may be performed by any foliar or basal method. Secondary applications are performed by spraying on leaves by the Spray Drip Down Method®. Secondary applications are used on cuttings already in media; subsequent sprays do not disturb the cuttings. Secondary applications have been successful at 10 days to 2 weeks after the first application. Also successful are 3 day applications in sequence directly after sticking.

Many factors must be considered to develop single or multiple rooting hormone applications. For plants propagated from cuttings, the cuttings must be taken from carefully maintained stock plants. Rooting hormone applications improve root formation on unrooted (see the Ball FloraPlant™ study below) and rooted cuttings. Juvenile cuttings root at lower rooting hormone rates as compared with mature cuttings (see the *Ficus* study). To select the optimal rooting hormone rates trials must be made at low to high rates (see the *Ficus* and *Osteospermum* studies).

The first rooting hormone application may be performed by any basal or foliar method. Secondary K-IBA Rooting Solution applications must be foliar by the Spray Drip Down Method® using an aqueous solution such as Hortus IBA Water Soluble Salts®. First and secondary foliar spray applications may be at the same rate (see rates, methods and products below). There are positives to using secondary applications with no apparent negatives. When using secondary applications, herbaceous plant cuttings may perform better and plants may benefit from foliar spray where root generation is stimulated.

FOUR STUDIES CITED

- "Use rooting hormone or eat ice cream?" by K., Carlsson and L. Munoz, Ball FloraPlant™ (Carlsson and Munoz, 2016).
- *Osteospermum* study by A. Hammer (Hammer, 2017).
- Growth regulator effects on adventitious root formation in leaf bud cuttings of juvenile and mature *Ficus pumila* (Davies and Joiner, 1980).
- Decker Nursery study (Decker, 2016).

Ball FloraPlant™ study

"Use Rooting Hormone or Eat Ice Cream?" (*Grower Talks*) by Ball FloraPlant™ technical advisors, gave reasons for using rooting hormones. They note that some growers feel no need to use rooting hormones when propagating plants despite obtaining poor roots; they feel any roots are enough. However, poor cutting rooting results in poor plants and the application of rooting hormones to the cuttings result in high quality uniform roots. Ball FloraPlant™ scientists used K-IBA rooting solutions made with Hortus IBA Water Soluble

[a]E-mail: j.kroin@hortus.com

Salts®.

The Ball FloraPlant™ article states: “Is it worth it? Please trial under your propagation conditions to check.” “So, in conclusion, if you want to root cuttings as fast as Rickey Henderson steals bases, you should use rooting hormone. I think that you should start a trial today—even on crops that don’t require rooting hormone to see if you can root faster, high-quality liners. Our conclusion was that K-IBA spray at 100 ppm [for the crops studied] gave the best rooting results while providing the lowest input cost during sticking.”

***Osteospermum* study**

An *Osteospermum* study, by Dr. P. Allen Hammer, shows how optimum K-IBA rooting solution rates are selected and the effect of two solution applications. His *Osteospermum* herbaceous plant study was to find the optimum K-IBA rooting hormone rate and secondary spray timing. Trial K-IBA rooting solution rates were from low to very high. The study outline and results are shown below courtesy of Dr. Hammer.

Plant propagation from cuttings with single and multiple foliar K-IBA rooting solutions using *Osteospermum* cuttings.

1. Procedure.

- Cuttings were taken from *Osteospermum* “sweet yellow”.
- Cuttings were stuck.
- K-IBA rooting solutions were made with Hortus IBA Water Soluble Salts®.
- Cuttings were sprayed using the Spray Drip Down Method®.
- The K-IBA rooting solution was sprayed on leaves until drip down.
- The first and supplementary applications were at the same rate.

2. Treatment comparisons.

- Control cuttings had no treatment.
- One time treated cuttings had foliar solution application on day of sticking.
- Two times treated cuttings had foliar solution applications on day of sticking and the 10th day after sticking.

3. Results.

- The photos (Figures 1-3) taken on the 21st day after sticking
- Treated cuttings showed variable roots related to the K-IBA rooting solution rates. An optimum rate was established. Cuttings treated at rates lower and higher than that rate had reduced roots and root mass.
- Control: small roots and root mass.
- One time treated: variable roots and root mass at tested K-IBA rates.
- Two time treated: the best roots and root mass when treated two times at an optimum rate of 600 ppm K-IBA.

Control

Figure 1. Control (no treatment) rooting results with *Osteospermum* "sweet yellow".

200 ppm IBA One Treatment

400 ppm IBA One Treatment

600 ppm IBA One Treatment

1200 ppm IBA One Treatment

▲

Comparison Cutting

Figure 2. Rooting results (treat on the day of sticking) made with K-IBA rooting solutions made from Hortus IBA Water Soluble Salts®.

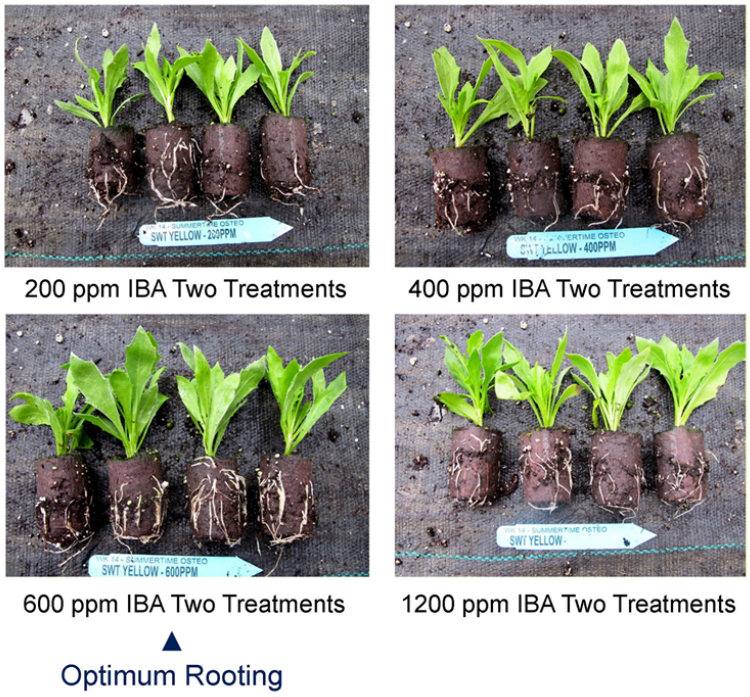

Figure 3. Rooting results (treat on the day of sticking) made with K-IBA rooting solutions made from Hortus IBA Water Soluble Salts®. Two times treated: first treat on the day of sticking and second treatment on the 10th day after sticking.

***Ficus pumila* study**

This study describes the efficacy of foliar applied aqueous K-IBA rooting solutions on root formation on juvenile and mature cuttings. It also discusses differences in root formation related to time-based applications. Dr. Davies' *F. pumila* study used either one foliar aqueous K-IBA rooting solution application at time of sticking and one application several days after sticking.

The study states: "Adventitious root formation was stimulated with foliar application of indolebutyric acid (IBA)." Dr. Davies' first step was to do "an experiment to establish optimum IBA concentration required for rooting." "All growth regulators were applied as aqueous sprays."

Juvenile vs. mature cuttings, "Lower IBA levels were required for optimal rooting in juvenile compared with mature LBC [leaf bud cuttings]." For the crop studied, they noticed rooting differences based upon type of cutting, "Hormonal effects during rooting stages: Percentage rooting in IBA pretreated cuttings was unaffected by additional IBA at any of the three time intervals after insertion, however, root length was reduced in all treatments. In juvenile LBC receiving no treatment, later IBA applications increased rooting in all dates, but in mature cuttings only the first or second application period was stimulatory."

Decker nursery study

"Foliar Applied Rooting Hormones" (International Plant Propagators' Society presentation), presented by Brian Decker. His study involved the propagation of woody cuttings and discusses the multiple foliar applications of rooting hormones. He used K-IBA rooting solutions made with Hortus IBA Water Soluble Salts®.

The study states: "Spray protocol for K-IBA spray application: Use a Hortus IBA water soluble salts solution." "Use a flag marker to mark each days sticking progress to track the 3-day spray rotation. All Hormone applications occur in early morning. Stomata are open and cuttings are generally not in moisture stress." "Improve root formation during positive trials

at either when spraying 3 days in a row after sticking, or spraying at three times weekly after sticking."

The first and secondary applications were at the same rate. Decker also used an alternate method, applying soon after sticking with a secondary application after about 2 weeks. These techniques gave cuttings a tronger root mass compared with single treated cuttings. Extending Decker's results, later weekly applications may improve the roots of slow-to-root cuttings.

DISCUSSION COMMENTS ON STUDIES

Rates, methods and products used in multiple rooting hormone applications

Two families of rooting products are used for plant propagation from cuttings.

1) For dry dip applications, dry dip rooting hormones consist of IBA in an insoluble talc base.
2) For foliar rooting solution applications, solutions are made using K-IBA dissolved in water. K-IBA is the water soluble form of IBA. If specified, K-IBA or IBA rates are the same.

1. Dry dip products, methods, and trial rates.

Products.

For the first rooting hormone application, one option is to treat by the dry dip method using an IBA rooting hormone powder. Some cuttings root best using dry dip powders. Typical rooting hormone powder products familiar to USA and European growers are: Rhizopon® AA #1 (0.1% IBA) which is used to root easy-to-root cuttings; Rhizopon® AA #2 (0.3% IBA), which is used to root easy to more difficult-to-root cuttings; and Rhizopon® AA #3 (0.8% IBA) which is used to root more difficult-to-root cuttings.

Method.

Dry dip method is only used for a first rooting hormone application: the basal ends of the cuttings are dipped about ¾ in. into the powder, then stuck in the medium.

Rates.

Trial rates using typical rooting hormone powders:

- Annual plant cuttings use dry dip powder Rhizopon AA #1, or Rhizopon AA #2.
- For perennial plant cuttings use Rhizopon AA #1, Rhizopon AA #2 or Rhizopon AA #3.
- For woody plant cuttings use Rhizopon AA #2, or Rhizopon AA #3.

2. Rooting solution products, methods, trial rates, and procedures.

When used for multiple applications, the first rooting solution application can be done by either the total immerse method or basal quick dip method. For the first and secondary K-IBA rooting solution applications the foliar Spray Drip Down Method® can be used. For secondary applications it is necessary to use the foliar Spray Drip Down Method®.

Products.

Rooting solution products: K-IBA is the water soluble form of IBA and the only labeled K-IBA rooting solutions for foliar methods are made with Hortus IBA Water Soluble Salts® and Rhizopon® AA Water Soluble Tablets.

Methods.

Rooting solution methods:

- Basal method:
  - Basal quick dip method is only used for a first rooting solution application: the basal ends of the cuttings are dipped about ¾ in. into the rooting solution then

stuck in the medium. Rates are established per plant type.

- Foliar methods:
  - Spray Drip Down Method® is used for first or secondary rooting solution applications. The cuttings are stuck in medium. The rooting solution is sprayed onto the leaves until the solution drips down. Spraying is done soon after sticking or when not under heat stress, such as early morning. An excess of solution is best rather than a starved liquid volume. Facility appropriate spray equipment is used such as backpack, hydraulic, booms, or robots.
  - Total immerse method is only used for a first rooting solution application: The cuttings are totally immersed a few seconds in the rooting solution then stuck in media.

Rates for foliar K-IBA rooting solution trials.

Rates for the Spray Drip Down Method® and Total Immerse Method® (for first time application) trialled IBA and rooting solution rates using Hortus IBA Water Soluble Salts®. The first foliar and supplementary applications are at the same rate. Where K-IBA or IBA rates are specified they should be considered the same.

- For annuals, perennials, chrysanthemums: 80-250 ppm IBA (typical 150-200 ppm).
- For herbaceous and hard-to-root perennial cuttings: 250-1500 ppm IBA (typical 750-1000 ppm).
- For woody ornamental cuttings: 300–1500 ppm IBA (typical 750-1000 ppm).

Procedures.

When starting cuttings trial, secondary applications for herbaceous and woody plant cuttings should be by first treating by any method, near or at the time of sticking. For secondary applications select either of these ways:

- First treat then should repeat with sprays at about 10 day to 2 week intervals.
- First treat then should spray the cuttings two additional days in a row.

When transplanting young rooted plantlets the objective should be to improve root generation and root mass

Rooted transplants, including grass divisions, may be treated both first and secondary by the foliar Spray Drip Down Method®. Repeat spray at about 2 week intervals. Foliar rooting solution rates are similar to those used for initial rooting.

Optimum cuttings and rooting hormones by single or multiple applications

The need for single or multiple rooting hormone applications is related to cutting quality. The best quality cuttings must be selected when propagating using rooting hormones.

Juvenile cuttings are preferred. It is first necessary to determine the optimal rate by performing a block of trials on un-rooted cuttings using low to high rates as seen in the *Osteospermum* study. When performing rate trials on herbaceous cuttings from off-shore plantations, it may be possible to determine standard optimal rates. Plantations maintain juvenile stock, discarding old plants. Rates may be specific to taxon but not necessarily suitable for the entire species. Cultivars not “needing” multiple sprays or higher dose of K-IBA Hortus IBA Water Soluble Salts® rooting solutions may not show problems, yet have positive results. Woody cuttings have an additional variable as seen in the *Ficus* study. Juvenile cuttings taken early in the season require lower rates than mature cuttings taken later in the season. Mature cuttings may not have as much reaction to application when applied later in the rooting cycle.

The strategy to perform multiple solution applications has merit. It needs to be tested on various plant taxa. If a specific species or cultivar has low rooting ability then multiple applications may be less likely to be effective, or may be timing dependent. The results might not be the same within a cultivar.

Secondary rooting hormone application may be beneficial if after one application is it

found cuttings are slow-to-root or have a low rooting percentage.

Trials must be made to compare a single application method with secondary applications. For secondary applications always use the foliar Spray Drip Down Method® using Hortus IBA Water Soluble Salts® rooting solutions. For all applications the Spray Drip Down Method® may be most effective and convenient. Growers who root many crops and cultivars at one time may find it is harder to spray different cultivars with a specific rooting solution rate that may be optimal for each cultivar. Spraying all cultivars with the rate that works for the most difficult cultivar is not detrimental for the better rooting cultivars, and easier for the grower.

To answer the question, if one rooting hormone application is good, are two or more applications better? It is worth trying!

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Automating a propagation nursery©

J. Cooley[a]

Proptek, 412 Westridge Drive, Watsonville, California 95076, USA.

In previous IPPS presentations, I have focused on roots in containers and how plants are not designed to grow good roots in containers. At the time, there was a lot of misinformation about containers and the containers that were available varied wildly in their quality. Fortunately, there are now good containers available that can produce a more natural root structure.

Containers that can produce a more natural root structure use a variety of different methods to manipulate roots, but I favor "air pruning" techniques. With air pruning, roots are forced to grow out of apertures in the wall of the container, where the relatively dry air kills the root tip and allows for secondary roots to develop. This has been done at the base of the propagation cell by many containers for years; however, if this can also happen along the sides of the container, then you can develop a large quantity of young, vigorous roots along the interior walls of the container. A "normal" container with no apertures creates a small number of roots that typically circle around the base of the container. Air pruning containers have now been available for some 20 years, with a bigger variety available every year. They have had good adoption in propagation sectors such as forestry, fruit trees, and even vegetables.

The woody ornamental sector stands out as not having adopted these air pruning containers. Why is this? I would think that having great roots that produce plants quicker would be of interest to the woody ornamental sector and trays are now practical, so they fit into current set-ups. There is, however, a third factor that is required to create good uptake is the economic incentive. It is clear there is not enough economic incentive currently.

Anything that saves labor would be a major help in bringing about these economic incentives. Another speaker stated he believes as much as 50% of gross sales income is spent on labor; this is a staggering proportion. Labor savings are available for our industry in the form of making people more efficient centrally or using machines to automate tasks. This requires a "headhouse" to which plants are brought and where most of the staff and machines are based. This requires an efficient, internal transport system which is currently only possible on new, purpose-built nurseries.

These purpose-built, automated nurseries are now even located in many places where labor cost is still relatively low and availability is high. For example, in Uruguay there have been two big automated eucalyptus nurseries built recently. We would normally expect such nurseries to be somewhere like The Netherlands, but clearly other people believe investing in the future to save in areas such as labor costs is correct.

I believe that having a headhouse with automation is possible at most current nurseries. However, the limiting factor is the cost of moving plants to the headhouse on what may be a regular basis. I believe there is a way to do this efficiently, which requires the combination of a fork system and a tray with legs. Figure 1 shows a typical fork system. Figure 2 shows a homemade fork system that has been used for this purpose for about 20 years in California. Figure 3 shows a schematic for the trays that will work with these forks and Figure 4 shows a typical nursery layout as currently adopted, i.e., one where labor moves to the jobs. Figure 5 shows a typical nursery workstation that is uncomfortable, inefficient, difficult to manage, and can lead to injury, especially due to all the bending down required. Beyond the costs involved, it is of concern that people still want to do jobs in this manner. Figure 6 shows my suggested system in which staff are based in the headhouse, which is comfortable, efficient, safe, easy to manage, and a better working environment. Plants are brought to the headhouse by forks. If work is done manually in the headhouse, then big savings can be attained. In addition, machines can be introduced here, reducing

[a]E-mail: john@proptek.com

labor costs even more.

Figure 1. A typical fork system being used to move plants in a nursery.

Figure 2. A homemade fork system that has been used to move plants at a nursery in California for about 20 years.

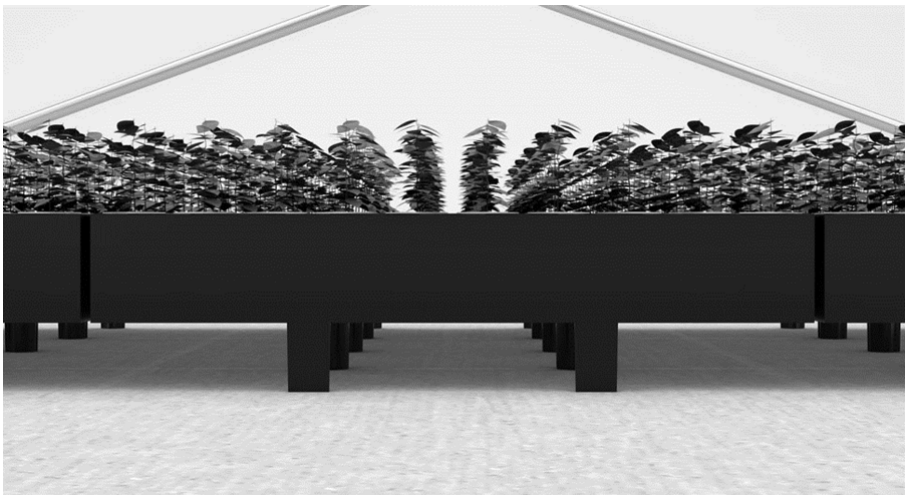

Figure 3. Schematic of trays with legs that will work with a fork system.

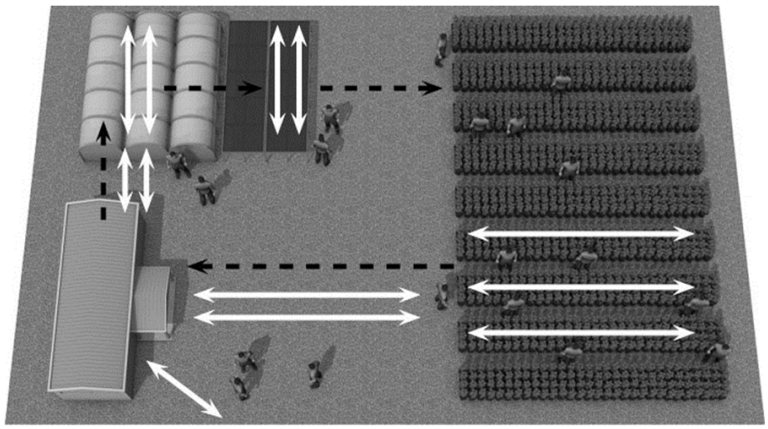

Figure 4. A typical nursery layout, i.e., a nursery in which labor moves to the jobs that need to be performed.

Figure 5. A typical workstation that is uncomfortable, inefficient, difficult to manage, and can lead to injury (due to the repeated bending required).

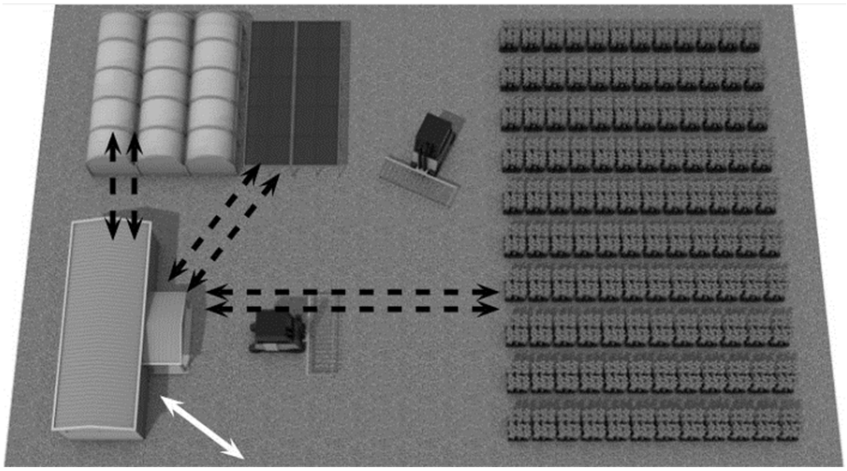

Figure 6. A suggested system in which nursery production staff are based in a headhouse, which is comfortable, efficient, safe, easy to manage, and a better working environment.

I estimate 50% of labor costs could be saved. So, if labor is 50% of gross sales and your nursery turnover is, for example, $4 million, then you could save $1 million per year by using a headhouse and automation. These are ballpark estimates, but the potential is huge. Even with investment in trays with legs, forklifts, and mechanization for the headhouse, the return on investment should be very quick. This would result in not only better profits, but better cash flow and happier staff doing more enjoyable jobs, and thus a better long-term future for the business in all respects.

My interest here is a great root system, and trays with legs can also be great air pruning trays. When the cells are elevated to allow for fork access, this also allows air to flow around the cells for air pruning. The only downside here is that, if you use under-floor heating, the heating system will be less efficient with this type of tray, but this is a small disadvantage in the big picture.

One other factor that needs consideration is the type of media to use for both mechanization and air pruning. The first choice to be made is use of loose fill or stabilized medium. The latter was developed mainly to create better roots or to work better with mechanization as you can lift plants while they are very young, lift cells with no plant in them at all, and handle trays with big and small plants in them. Also, since the whole plug is bound (including the top half), a stabilized plug maintains its integrity and shape. Figure 7 shows a stabilized plug that remains intact; a similar plug containing loose fill medium could collapse upon extraction, with dire effects on the potting machine's performance. Machines like uniformity. Figure 7 also shows that you can still get bad roots in a stabilized medium, so you do need to also use the right "air pruning" tray.

Figure 7. Plugs containing stabilized medium easily remain intact upon extraction.

I feel that stabilized media is the right way to go, although there is a massive assortment available, each with their niche market. My first distinction is whether the stabilized media can be made on site or must be bought in. Buying in means you cannot use your own soil as easily, and there is lead time, freight cost, inventory factor, and so on. Making stabilized media on-site means the units are fresh and you know what's in them. Table 1 shows some brands which are available, split into these two categories, plus a third category for media that can be bought in or made on-site. As far as I know, Ellepots are the only option here which make them very flexible.

Table 1. Some brands of stabilized media plugs made on-site and/or off-site (purchased).

Made on-site	Made off-site	Made on-site and off-site
Ellepot	Ellepot	Ellepot
Jiffy	Preforma	
Some glue plugs	Q Plug	
	Fertiss	
	FlexiPlugs	
	Grodan	
	Oasis	
	Horticubes	

One final point on stabilized media to consider is the amount of air flow around the plug. Some plugs are made in the tray and touch the walls, whereas others are placed into the tray after manufacture. With the latter, there is a gap between plug and cell walls that is great for air flow. Good air flow means air pruning of roots plus great aeration and drainage—a big advantage. Again, a good example here is the Ellepot, which is my choice in stabilized media.

To conclude, I believe that a tray with legs containing stabilized media plugs and moved around the nursery by forks to allow for mechanization in a headhouse, where the majority of staff and machinery are based, is a great way to significantly reduce labor costs on current nurseries, plus create jobs that people like.

Information on mechanization from multiple sources is listed by category on our website (www.proptek.com), along with suppliers of forks. We have also created several videos of machines we think will work well in a headhouse, plus more details on the concepts discussed above. We very much welcome feedback on this idea in order to help make this a reality for our industry and try to help with the labor challenges we all face.

QUESTIONS

Douglas Justice: Have you seen air pruning used in pot-in-pot systems?

John Cooley: I have not, but air pruning, by definition, requires movement of air around the pot, which you do not tend to have with a pot-in-pot system.

Chris Murphey: Have you had success with large nurseries considering the system and putting together some numbers?

John Cooley: My position has been that air pruning is needed to produce a good quality root system. We have been doing trials with nurseries for the past 20 years. It seems that woody plant nurseries are not as receptive to the air-pruning containers. This is the first time that I have put my thoughts together on adding other ideas to the mix, and labor savings is clearly the best economic incentive for making changes to production systems.

Adrian Reimer: Is anyone using the trays with legs with a forklift now?

John Cooley: Quite a few nurseries in Europe are using forklifts, but I have not seen forklifts used to move trays in North America, probably because most trays here do not have legs. So, it is a question of asking the suppliers to carry such products. I see no reason it should not work and could be a good idea for the future.

The development of fertilizer from the early years to today©

N. Lafaille[a]

Harrell's, Sturbridge, Massachusetts 01566, USA.

A BRIEF HISTORY OF FERTILIZER

Scottish physician, chemist, and botanist Daniel Rutherford is credited for the discovery of nitrogen through a series of experiments handed to him by his mentor and teacher, Joseph Black, working with what they called "noxious air, fire air, and foul air." Once isolated, nitrogen was determined to be one of the most abundant elements in the atmosphere. Nitrogen is an inert gas and forms many inorganic compounds used as fertilizers and gases. Nitrogen is a precursor for ammonia, which is a commercially used compound.

Nicolas-Theodore de Saussure, a Swiss chemist and plant physiologist, was a major pioneer in the study of photosynthesis. He discovered in 1804 that nitrogen was an essential nutrient for plant growth. He discovered that nitrogen is vital because it is a major component in chlorophyll. Chlorophyll is the compound by which plants use sunlight energy to produce sugars from water and carbon dioxide.

Urea was first found in human urine in 1773 by H.M. Roelle, and Freidrich Wohler first synthesized urea in 1828, with urea being the first organic compound to be synthesized from inorganic starting materials. This discovery was an accident, as Wohler was attempting to synthesize ammonium cyanate by treating silver cyanate with ammonium chloride. The result was a white crystalline material which proved to be identical to urea found in urine. Urea is produced commercially by reacting carbon dioxide with anhydrous ammonia under high pressure and high temperature. 140 million tons of urea are currently produced annually throughout the world.

Urea was found to have many uses. Adolf Bayer discovered in 1864 that urea and malonic acid form barbiturates. Also, the resin material melamine is formed by dehydration of urea, and is still used in adhesives, laminates, and various coatings. In agriculture, urea is used as a nitrogen fertilizer.

In 1842, Sir John Bennet Lawes created the first commercial fertilizer by treating phosphates with sulfuric acid, creating single super phosphate, the first patented fertilizer. This English entrepreneur experimented with manure and its effects on plant growth of potted and field crops, as well as the relationship between plant nutrition and animal feed quality. He also founded the Rothamsted Experiment Station, the oldest agricultural research station in the world.

Urea formaldehyde was first synthesized by Dr. Holzer in 1884. Then, in 1919, Hanns John of Prague, Czechoslovakia, patented the first urea formaldehyde resin. In addition to its use as fertilizer, urea formaldehyde is used in laminates, textiles, wrinkle-resistant fabrics, cotton blends, rayon, and as a bonding agent for particleboard, fiberboard, and plywood.

In the early 1900s, there were two major advances. In 1910, the Haber production process was invented. This process, which produces ammonia, was found by German chemists Fritz Haber and Carl Bosch. The process was later purchased by German company BASF. Ammonia was mainly used as a fertilizer but, during World War I, it was used to manufacture German explosives. The Haber process is an artificial nitrogen fixation process and is the main industrial process for the production of ammonia. The process converts atmospheric nitrogen (N_2) to ammonia (NH_3) by a reaction with hydrogen (H_2) using a metal catalyst under high temperature and pressure. Wilhelm Ostwald invented a process which converts ammonia into nitric acid (HNO_3). Without the Haber process, we would not have commercially available ammonium nitrate or urea.

[a]E-mail: nlafaille@harrells.com

In 1955, Nitroform slow-release urea formaldehyde was first offered for sale, with many additional short chain of methylene urea products following. In 1956, a research study was conducted on loblolly pine seedlings at Auburn University. The study concluded that one application of UF 38-0-0 (632 lbs. per acre, 240 lb. of N) resulted in seedling heights equivalent to those of seedlings receiving 8 separate applications of straight ammonium nitrate 34-0-0 (1,141 lb. per acre, 388 lb. of N). Nitroform was thus the first true slow-release fertilizer.

A BRIEF HISTORY OF CONTROLLED-RELEASE FERTILIZER (CRF)

The first CRF, Osmocote, was created in 1960 by the Archer Daniels Midland Company. Thirty-one years later, Pursell Technologies perfected and commercialized Polyon in 1991. The company also included the green color of the product in the product's patent. In-the-mid-1990s, Haifa began selling Multicote in the USA. Today multiple technologies are available from multiple companies in such products as Polyon, Osmocote, Nutricote, Multicote, Florikote, and Gal-Xe One.

When Osmocote was first introduced in the mid-1960s, it was intended to be used on cereal crops, but proved to be too expensive for those crops. Shortly after, the Osmocote know-how was sold to Sutter Hill, who formed Sierra Chemical. In the early 1970s, Sierra Chemical was sold off to private investors. New processes and procedures were created to make a better, more consistent product. Marketing began to focus on higher value crops. In the late 1980s, Sierra Chemical was sold to W.R. Grace and became Grace-Sierra. In 1994, Grace-Sierra was sold to the Scotts Miracle-Gro Company. In 2011, Israel Chemicals Ltd. purchased the Global Professional business of the Scotts Miracle Gro Company.

In the 1970s, sulfur-coated urea was created for the first time. The Tennessee Valley Authority created the technology which involves spraying sulfur and a layer sealant onto urea. Several companies built plants to manufacture sulfur-coated urea: CIL (now Agrium) in 1975, Lesco (now Turf Care Supply) in 1980, Scotts Company in 1982, and Pursell Technologies in 1985.

In the early 1990s, Pursell Technologies came out with Polyon CRF. In 2007, the Pursell family sold the Polyon technology to Agrium Advanced Technologies. Since 2014, Koch Agronomics has owned Polyon. Harrell's was the exclusive formulator and sales and marketing arm for Polyon east of the Rocky Mountains, whereas Simplot held the exclusivity west of the Rocky Mountains (and marketed the product under the Apex brand). Since 2014, Polyon has been formulated and marketed exclusively by Harrell's across the U.S. All Polyon green products are now formulated, manufactured, and marketed under the Harrell's brand. Poly is currently distributed in the Pacific Northwest under an agreement with Marion Ag Services. In 2014, Simplot parted ways with Polyon and began making Apex brand fertilizer with Gal-Xe.

No matter which brand we are talking about, there are multiple reasons to use CRFs. Nursery best management practices manuals (such as the BMP manual from the Southern Nursery Association) state that CRFs should be used and applied at the manufacturer's recommended rates. Reapplication should occur only when substrate solution nutrient status is below the desired level for the specific crop. The nutrients are released over a specific time frame, often matching the nutrient demand of the crop. Also, there is reduced nutrient leaching and run-off due to gradual release of nutrients into the growing substrate. In addition, they offer reduced volatilization of ammonia, with only small amounts being released. CRFs also reduce soluble salt injury, reduce potential contamination of surface water in nearby waterways, and increase irrigation efficiency (no "feeding when raining").

CRFs simply work! Multiple studies show that plants grown with CRFs produce plans of equal size to those grown with soluble fertilizers. Labor and energy use is also reduced; in certain operations, the time it takes to continually mix soluble fertilizer can be considerable. CRFs also have extended shelf life for the retailer.

WHAT ARE CONTROLLED-RELEASE FERTILIZERS?

Slow-release fertilizers and controlled-release fertilizers are not the same thing! Slow-

release fertilizers are defined by AAPFCO as fertilizers containing a plant nutrient in a form which either (a) delays its availability for plant uptake and use after application, or (b) is available to the plant significantly longer than a reference "rapidly available nutrient fertilizer," such as ammonium nitrate or urea, ammonium phosphate, or potassium chloride. Slow-release fertilizers have release mechanisms that are not controlled, contain unavailable nutrients, and are less efficient than CRFs. Their release mechanisms are hydrolysis (involving water and particle size), mineralization (involving microbial activity, soil temperature, moisture level, and oxygen), and catastrophic release (e.g., coating breakdown). Slow-release fertilizers include natural organics (e.g., Milorganite), synthetic organics (e.g., IBDU and Nitroform), and sulfur-coated products (e.g., Poly S and Trikote).

Conventional water-soluble fertilizer materials (substrates) are given a protective coating or encapsulation (water insoluble, semipermeable, or impermeable with pores) that controls water penetration and the rate of nutrient dissolution and nutrient release. Factors that play a role in CRF performance are coating, moisture, temperature, substrate (that is being coated), and the nursery manager.

The coating is the "control" in controlled-release fertilizers. The coating must have integrity to have longevity. Coating porosity must also be correct so that water can pass through the coating membrane and allow solutes and nutrients to pass back through the coating.

Moisture activates the CRF release mechanisms at a level below the wilting point. It thus becomes important to irrigate soon after potting into a CRF-containing substrate or after topdressing.

Temperature and nutrient release are directly correlated. All CRFs release nutrients faster with increasing temperature. In the plant, increasing temperature causes an increase in metabolic processes and demand for nutrients, and CRFs are able to match the demand. Coating integrity becomes especially important as temperature increases so that the product is not over-releasing ("dumping") nutrients. Duration of nutrient release listed on product bags are based on testing at a certain temperature. Unfortunately, there is no industry standard temperature for this testing; each company makes its own decision (70°F for Osmocote, Multicote, Florikote, and Gal-Xe; 77°F for Nutricote; and 86°F for Polyon).

The fertilizer substrate characteristics that are of importance are prill vs. granule, shape (angular or round), surface smoothness, particle size, and water solubility (N, P, and K). At this time, all CRF manufacturers are all obtaining their substrate from the same source (Yara).

The nursery manager needs to give attention to the choice of appropriate product, use the product at the proper rate, use the proper method of application, and use proper placement. The growing medium components also affect what happens with the CRFs: bark (aged vs. fresh), peat (providing more cation exchange), or other amendments. Before our company makes product recommendations, we always take a sample of the medium. Irrigation concerns are type, water source, water quality, frequency, and salts monitoring. Regular use of an EC meter is critical for quality control.

QUESTIONS

Martin Stockton: With different companies using different reference temperatures to measure release, how do you correlate one to another?

Norman Lafaille: We do wish there was an industry standard, but unfortunately there is not. The 86°F temperature used to measure release of Polyon has served us well as, over time, we have worked to convert growers from Osmocote to Polyon, especially in the warmer growing climates.

Voice: Is there any research being conducted with CRFs on field stock?

Norman Lafaille: Yes, we work quite a bit with field growers. We take field samples over a large area. Often phosphorus is not needed; adequate amounts are already present in the soil. The "sticker shock" is often tough on the field growers who are accustomed to using agricultural grade fertilizers. We often recommend supplying about 30% of the nitrogen rate with controlled-release fertilizer (400 to 600 pounds per acre with one application)

can allow trees to caliber-up just as well as they would with multiple applications. Plus, there are also labor savings.

Voice: Does the matrix of the coating remain stable or does it degrade over time?

Norman Lafaille: Coating integrity is important to permit controlled release over the specified period of time for the product. With time, microbial activity will take over and the coating will eventually be broken down.

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Biological control in propagation©

M. LaChapell Schalock[a]

Wilbur-Ellis, 640 NE 10th S., McMinnville, Oregon 97128, USA.

Biological control involves the release or application of natural enemies, including parasitoids (parasitic wasps), predators, and pathogens (entomopathogenic fungi and nematodes) to regulate an existing pest population. There are many benefits to releasing beneficial insects in any growing environment. For propagators, the benefit is an increase in plant health and a reduction in pest pressure that has the potential to remain until the plants are sold.

BENEFITS OF BIOLOGICAL CONTROLS

Combat difficult-to-control pests

Beneficial insects can help reduce difficult-to-control pests, such as fungus gnats, aphids, and thrips. A well-timed application when cuttings are placed in media will prevent heavy infestations of insects. Plants are especially prone to pests in the moist environment required for rooting.

Resistance management tool

There are cases where a previously effective insecticide loses potency over time. Beneficial insects can be an additional tool that allows for an increase in efficacy of other products as a rotational tool.

Reduce labor

Effective scouting and releasing beneficial insects ahead of heavy infestations will reduce the number of pesticide applications required. Reducing application frequency will reduce labor and pesticide cost.

Produce sellable crops

Ultimately, the goal for any propagator is to produce sellable crops. Biological control is another tool to accomplish the task of producing quality plants.

Marketing “bee friendly” plants

Implementing biological control can reduce the need for neonicotinoids and other systemic insecticides. There is a direct benefit to the consumer when marketing biological control at the retail garden center.

HOW TO APPROACH BIOLOGICAL CONTROL

There is no cookie-cutter approach to successfully implementing biological control. Every growing location comes with a different set of challenges. Three factors that need to be considered are:

1) Type of pest(s)
2) Pest pressure
3) Tolerance level for plant damage

Beneficial insect performance factors

It is critical to communicate pest type and production specifications to the supplier of beneficial insects. Another step is to check the vitality of the beneficial insect and contact the supplier right away if there is low survivorship or poor searching behavior. The safest approach is to release beneficial insects preventatively, ahead of infestations. It is also

[a]E-mail: mlachapellschalock@wilburellis.com

important to discuss insecticide history and spray programs with your supplier. These steps will increase the likelihood of success.

Limit exposure to noncompatible pesticides

Direct exposure of an insecticide to a beneficial insect is a lethal dose that results in immediate death. Indirect exposure of an insecticide to a beneficial insect is a sublethal dose which can reduce fecundity, foraging behavior, or progeny survival. For example, an organophosphate is more likely to immediately kill a beneficial insect, whereas imidacloprid has a longer-term residual effect that will lead to death over time.

Selecting compatible products

Beneficial insects are more likely to thrive on the plants if the pesticides applied have a shorter persistence or residue. A good example of a compatible product is BotaniGard for thrips control. It will not kill predatory mites and has a short residual period. Spot treatments based on scouting data can also help maintain existing beneficial insect populations. Another consideration is working with propagators to secure liners that are produced with biological control or compatible pesticides.

The benefit of working with a supplier who uses biological control

Iwasaki Nursery is a large commercial nursery that maintains an extensive biological control program. A melon aphid infestation was controlled by the predatory wasp *Aphelinus abdominalis*. The predator had not been released at the nursery and most likely came in on purchased plants.

Evaluating beneficial insect suppliers

There are ongoing trials with biological control at Iwasaki Nursery to evaluate supplier beneficial insects and the control of *Bemisia tabaci*. The ongoing trial is being conducted in six different ranges with three suppliers. BioBest's *Eretmocerus* mix appears to be most effective, but Bioline's *Eretmocerus* mix is more affordable. The pest pressure has been low so far in 2017. The iris whitefly and the banded whitefly are occurring, which might not be controlled by *Eretmocerus*. Applied Bionomic's *Encarsia* are an important addition.

NOTES ON SEVERAL BIOLOGICAL CONTROLS

Q-type *Bemisia tabaci* control

Eretmocerus eremicus is a tiny parasitic wasp (about 1 mm in length) that is indigenous to the southern desert areas of California and Arizona and is an important parasitoid of whiteflies. *Delphastus catalinae* is a small ladybird beetle which preys on all species and stages of whitefly.

Thrips management

Additional tools to combat thrips include introducing the predatory mite *Stratiolaelaps* to the soil. This is a beneficial predatory mite that will feed on fungus gnat larva and the soil stage of thrips. You can also drench the soil with the beneficial nematode Nemasys® (*Steinernema feltiae*). Releasing the predatory mite *Amblyseius* (*Neoseiulus*) *cucumeris* and *Amblyseius swirskii* can help manage the leaf-damaging stage of thrips.

Foxglove aphid management

Aphidius ervi is originally a European wasp species, but it has been widely introduced into North America, South America, and other regions in recent years as part of biological control programs for aphids on a variety of crops. Once a female finds an individual aphid or aphid colony, she will palpate the aphids with her antennae. If the aphid she is examining is of the correct size and has not already been parasitized, she rapidly curls her abdomen under her body and stabs the aphid with her ovipositor.

Two-spotted spider mite management

Predatory mites will eat pest mite eggs and adults. They kill by inserting their mouth parts in eggs or adults and sucking out the contents. *Phytoseiulus persimilis* is blind and relies on odor to locate prey. Predatory mite species thrive in different temperatures and relative humidity. It is important to select biocontrol that is suitable for the environment.

All predatory mites are not created equal

Type I predatory mites are specialist (specialized) predatory mites because they feed and survive only on spider mites in the family Tetranychidae (also referred to as Tetranychid), which includes the two-spotted spider mite, *Tetranychus urticae*. An example is *Phytoseiulus persimilis*.

Type II predatory mites are selective predatory mites with a broad host range. These predators will eat various prey and pollen. They are less likely to cannibalize in adverse conditions. Examples are *Neoseiulus californicus*, *N. fallacis*, and *N.* (*Amblyseius*) *cucumeris*.

Type III predatory mites are generalist predators that feed on eriophyid and broad mites. They will also feed on pollen, honeydew, and plant exudates. They are more likely to cannibalize in adverse conditions. An example is *Amblyseius swirskii*.

Adapting automation to your operation©

J. Kupillas[a]

Allied Solutions by Kupillas LLC, 31375 SW Kensington Dr., Wilsonville, Oregon 97070, USA.

Our industry is composed of a diverse membership that has in common the purpose to cultivate ornamental plant products for use as landscape plants. Due to this diversity, the challenge of integrating automation can be problematic. In my role, I interact with a wide community of representatives of nurseries in an effort to improve the sustainability of each nursery operation. In order to succeed, we need to overcome barriers that may be related to financial constraints, limitations related to existing practices, and challenges associated with existing facilities. I view this opportunity to address this topic as an open door to share key aspects to address in relieving barriers to improve the efficiency of production systems.

KEY MESSAGES

1. Realize a need to automate. If the need is sufficient, there will likely be enough resources applied to the effort to result in a favorable outcome.
   a. Labor can be a trigger to automate. Availability, cost, and ultimately the "quality" of labor is changing.
   b. Creating a more comfortable work environment can be a driver in this process.
   c. Product quality and uniformity expectations apply pressure on growers to automate.
   d. Pressure to increase revenue with a limited production area may require process adjustments.
   e. Customer demands for product packaging, labeling, or unique product structure may encourage automation.
2. Be systematic about how you apply the automation resources. Go through a process to identify the areas of the annual growing operation that are likely to present the best rewards.
3. Consider buy-in for different members of the organization and seek support and commitment to succeed with this process in advance.
4. Consider the value proposition of automating. How will a prospective process impact the organization both positively and negatively.
5. Have the right perspective in mind when placing emphasis on the prospective purchase aspects of automation. For example, apply much more emphasis on the benefit side of the equation as compared to the cost side of the equation.
6. Part of the process is to anticipate prospective return on investment. I caution people not to get overly complicated with this step because there will always be variables, the key is to be realistic and apply reason and logic to the process.
7. Place emphasis on the pre-planning. Be considerate of traffic lanes, creating process buffers and reasonable work flow expectations.
8. Once committed, don't look back. Apply resources necessary to make process adjustments to optimize the performance of the new system.

[a]E-mail: joek@asbyk.com

The struggle is real (but fun!): long-term breeding at a public university©

R. Contreras[a]

Department of Horticulture, Oregon State University, 4017 Agricultural & Life Sciences Bldg., Corvallis, Oregon 97331, USA.

The nursery industry releases a lot of new plants every year, with an abundance of branding programs. There are hundreds of new annuals, perennials, and woody shrubs there are released annually, but relatively few new trees in comparison due to the longer time required for evaluation and greater land requirements.

Oregon State University has a breeding program that tries to address long-term goals, which in turn requires evaluation of traits for many years to ensure stability. Often, we have a six- to ten-year generation period, so our program is a long-term proposition.

Plant breeding, at its core, is a numbers game—if you grow 1 million seedlings, the crop is likely to contain some real winners. Unfortunately, I cannot grow the numbers that the large nurseries can grow and select from. So why did the industry push to have a plant breeder at Oregon State University?

My goal is to support the industry by three main mechanisms. First, when the breeding effort would be too costly or too long-term for a nursery, or there is some technology or technique that I can apply in a laboratory situation or greenhouse-growing situation, that is where I come in. Below, I will discuss some of our work on maples and this is a great example of a project that may have significant impact on the nursery industry but, in the meantime, is costly to run and requires expensive equipment and careful attention to the scientific process. Second, I am here to train students who will become the next generation of horticulturists and plant breeders. Third, I am also here to contribute to the scientific knowledge base, for example, to assess the genome size of the entire genus *Acer*. This activity often does not result in a direct transfer of information or deliverable to the nursery industry, but it provides a foundation for me and other University breeders on which to build. Of course, I also have fun by doing things that I am passionate about!

Maples make up a major part of almost any urban canopy in the temperate USA. Maples currently constitute 31% of the U.S. shade tree market. Oregon is the number one shade tree-producing state in the U.S., producing 36% (worth more than $63 million) of the maples sold in the nation. Due to their importance in Oregon, regionally, and nationally, maples are a priority in my program. We have been looking at Norway maples (*Acer platanoides*) because they can escape cultivation. Weediness of Norway maples has led to a decline in sales. Some growers have reported more than a 90% decline in sales of Norway maples during the last decade. Some of this decline may also be attributed to urban managers diversifying the species planted in the urban canopy, but at least some of the reduced sales can be attributed to regulation of Norway maple as a weedy/invasive species in New England states, which historically have been a solid region for distribution.

My goal is to reduce or eliminate the weediness of Norway maple, while maintaining the species as a crop our growers can grow and our urban managers can plant. Therefore, our objective is to develop triploid Norway maples that will be sterile by crossing diploids with tetraploids. We create tetraploids by treating seedlings at the first true leaf stage with a 150 µM solution of oryzalin with 0.55% agar for five days. Of course, the process is not perfect, and triploids of some plant species (such as pear, *Pyrus*) can produce viable seed. Therefore, we must extensively test the triploid seedlings for many years. In the field, we interplanted tetraploids with diploids and collected the seed from the tetraploid plants. We have observed low germination percentages from tetraploid seed with 14% germination in 2017. In our first year (2017), 89% of our Norway maple seedlings were triploid and 84% of

[a]E-mail: ryan.contreras@oregonstate.edu

Amur maples (*Acer tataricum* subsp. *ginnala*) (another species with issues of weediness/invasiveness) were triploid. Of course, any new selections must also be production-worthy trees, so we are continuing to increase the population sizes of these and other triploids. We expect these populations to start flowering in 2019, after which time we will make critical observations on fertility with replication over years and locations. Further replications of trials with nurseries may begin as early as 2022, and we hope to have one or two good selections for full release by 2025, but it is hard to predict.

We are also working to varying extents on several other woody genera:
Berberis (looking to develop sterile triploids)
Celtis
Cercidiphyllum
Cotoneaster (looking to develop improved forms, fireblight resistance, and pink flowers)
Deutzia
Galtonia
Hibiscus (looking to develop new flower forms and growth habits)
Hydrangea
Ilex
Malus
Nyssa
Phellodendron (looking to develop sterility and variable forms)
Philadelphus (looking to develop flower fragrance, flower power and duration, and form)
Prunus
Quercus (looking to develop powdery mildew resistance in English oak)
Ribes
Sarcococca
Spiraea
Syringa (looking to develop better reblooming with disease resistance)
Thuja
Vaccinium
Zelkova (looking to develop new forms)

QUESTIONS

Voice: Do you ever get mixoploids?

Ryan Contreras: We absolutely do get mixoploids. We try to treat the tiniest meristem that we can, but it is challenging to treat a single cell. The other term for mixoploid is cytochimera, which refers to a single plant that has some cells that are diploid and some cells that are tetraploid. Some of these plants will stabilize at the diploid level and some will stabilize at the tetraploid level, and there are some that will stabilize at the mixoploid level.

Soil digestive system: functions and benefits of plant growth-promoting rhizobacteria©

S.J. Becker[a]

Tainio Biologicals, 4814 S. Ben Franklin Lane, Spokane, Washington 99224, USA.

INTRODUCTION

Plant growth-promoting rhizobacteria (PGPR) are soil bacteria that live on or around the root surface. Through their growth and activities, PGPR are directly and indirectly responsible for plant growth, development, and productivity through improvement of nutrient acquisition and uptake, plant hormone modulation, and competitive inhibition which decreases the inhibitory impacts of plant pests and pathogens.

The plant growth promoting rhizobacteria (PGPR), are characterized by the following inherent distinctivenesses: (1) they must be proficient to colonize the root surface; (2) they must survive, multiply, and compete with other microbiota, at least for the time needed to express their plant growth promotion/protection activities; and (3) they must promote plant growth (Kloepper, 1994).

Somers et al. (2004) classified PGPR based on their functional activities as: (1) biofertilizers (increasing the availability of nutrients to plant), (2) phytostimulators (plant growth promotion, generally through phytohormones), (3) rhizoremediators (degrading organic pollutants), and (4) biopesticides (controlling diseases, mainly by the production of antibiotics and antifungal metabolites) (Antoun and Prévost, 2005).

A great deal of research has been, and continues to be, conducted in the field of PGPR, as well as other beneficial soil and rhizosphere organisms. This research, combined with years of tests, trials, and sales, has led to the utilization of PGPR to stimulate production, quality, and sustainability for the agricultural community.

NITROGEN

While approximately 78% of the Earth's atmosphere is comprised of nitrogen, the atmospheric form, N_2, is not directly available to plants. The atmospheric N_2 must first undergo a process known as biological nitrogen fixation (BNF). The BNF process converts N_2 into an ammoniacal form of nitrogen, which can then be utilized by plants.

BNF is carried out through two basic processes: symbiotic, such as rhizobia creating nodules in leguminous plants and Frankia with non-leguminous trees; and free-living BNF undertaken by a number of organisms outside of the plant in the rhizosphere or rhizoplane. According to research conducted by Rubio and Ludden (2008), collectively, symbiotic and free-living nitrogen fixation accounts for well over half of all nitrogen fixed globally.

PHOSPHORUS

Phosphorus is another essential nutrient required for plant growth that is generally present in the environment, but unavailable to the plant. Both the phosphorus that is naturally present in the soil and phosphorus that is applied through fertilization tend to quickly dissipate through leaching into water, become biologically bound in organic forms, or become unavailable by forming insoluble complexes which the plant cannot access.

In order to overcome shortages of phosphorus, many PGPR produce enzymes, organic acids, and other chemical complexes to solubilize the bound organic or insoluble phosphorus from the soil or environment. The PGPR with this ability are known as phosphate solubilizing bacteria (PSB). PSB are considered as promising biofertilizers since they can supply plants with P from sources otherwise poorly available (Ahemad and Kibret, 2014).

[a]E-mail: steve@tainio.com

IRON

Iron, like phosphorus, tends to become insoluble in the soil environment, and therefore unavailable to plants and other living organisms. In plants, iron is critical for a variety of enzymes, structures, and for photosynthesis itself. When iron levels become low in the plant, iron chlorosis occurs and leads to reduced production, health, and plant viability.

To access unavailable iron, PGPR produce iron-chelating molecules known as siderophores. These siderophores have the ability to effectively detach iron from insoluble sources and increase bioavailability.

HORMONES

Hormones are signaling molecules utilized by organisms to control and regulate physiological, behavioral, and biochemical reactions. From cell division to control of flowering, hormones play a significant role in almost every aspect of plant growth.

Utilizing these signaling molecules and pathways, PGPR can affect many aspects of plant health and growth, for example, bacterial IAA increases root surface area and length, and thereby provides the plant greater access to soil nutrients (Ahemad and Kibret, 2014). It is reported that 80% of microorganisms isolated from the rhizosphere of various crops possess the ability to synthesize and release auxins as secondary metabolites (Patten and Glick, 1996), which helps highlight how closely the PGPR function in synchrony with the plant's growth systems.

ABIOTIC STRESS REDUCTION

Ethylene's utility as a signaling molecule is widespread throughout plants. It performs as a plant growth regulator and functions as a stress hormone. In general, when biotic and abiotic conditions for growth become less favorable for the plant, ethylene levels will increase and act as an "aging" signal, forcing the plant to mature more quickly for survival.

PGPR can help the plant through stressful times by helping alleviate the stress response and thus lowering the ethylene levels. Plant growth promoting rhizobacteria which possess the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase facilitate plant growth and development by decreasing ethylene levels, inducing salt tolerance, and reducing drought stress in plants (Nadeem et al., 2007; Zahir et al., 2008). Several forms of stress are relieved by ACC deaminase producers, such as effects of phytopathogenic microorganisms (viruses, bacteria, and fungi), and resistance to stress from polyaromatic hydrocarbons, heavy metals, radiation, wounding, insect predation, high salt concentration, draft, extremes of temperature, high light intensity, and flooding (Glick, 2012; Lugtenberg and Kamilova, 2009). As a result, the major noticeable effects of seed/root inoculation with ACC deaminase-producing rhizobacteria are plant root elongation, promotion of shoot growth, and enhancement in rhizobial nodulation and N, P, and K uptake, as well as mycorrhizal colonization in various crops (Nadeem et al., 2007; Shaharoona et al., 2008; Nadeem et al., 2009; Glick, 2012).

While barely scratching the surface, these benefits help to illuminate some of the many ways in which PGPR can help nourish, enhance growth, and alleviate stress for a wide variety of plants with agricultural, horticultural, silvicultural, and ornamental applications, as well as provide other benefits to both people and the environment.

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Highlights of the IPPS 2017 Western Region/New Zealand Region exchange and ornamental plant breeding in New Zealand©

D. Marinkovich[a]

Dr. Keith Hammett, Plant Breeder, 488C Don Buck Road, Massey, Auckland 0614, New Zealand.

TOURING THE PACIFIC NORTHWEST

When I found out that I had been awarded the IPPS Exchange scholarship, I had no idea how many places I would get to visit outside of the conference. My journey started in Vancouver, British Columbia, with Valerie Sikkema from Van Belle Nursery, and I was lucky enough to arrive on the day of the Cranberry Festival. Valerie and her husband, Arnold, took me sightseeing to Lynn Canyon and Stanley Park where I learned a lot about the native trees of the Pacific Northwest. I was able to attend a lecture by Douglas Justice at the University of British Columbia on woody plant identification which helped me feel less disoriented by the flora that was so different from New Zealand flora. I had an extensive tour of the UBC Botanical Garden and Japanese Tea Garden. I toured several nurseries around the Chilliwack area before crossing the border to stay with Todd Jones of Fourth Corner Nurseries near Bellingham, Washington. We then headed south and toured Sakata to see the breeding programmes for beets, broccoli, cabbage, and spinach; and Floret Flower Farm, a cut flower grower and mail order business. I then stayed with Sarah and Jim Brackman in Olympia, Washington, and toured Weyerhaeuser to see large-scale propagation of conifers. In Eugene, Oregon, I met Tony Shireman and toured Fall Creek Farm & Nursery and saw both their tissue culture laboratory and blueberry breeding programme. My last stops before the conference were at Oregon State University, the USDA National Clonal Germplasm Repository, and Dr. Ryan Contreras' ornamental breeding programme.

BECOMING AN ASSISTANT PLANT BREEDER

I was born in New Zealand and grew up in the country's largest city, Auckland (approximately 1.5 million people). Most Aucklanders live within a short drive to the ocean as the city sits between two harbours which lead to the Tasman Sea to the west and the South Pacific Ocean to the east. Auckland has a subtropical to temperate climate with mild winters (light frosts inland), humid summer temperatures around 30°C (86-90°F), and much rain throughout the year.

Auckland is home to around 52 volcanoes. As a brief glimpse into our flora and geography, I will mention Rangitoto Island, which erupted around 600 years ago. It is a beautiful place to spend the day walking, but also provides a great example of plant succession. After dust settled and bacteria colonised its a'a lava surface, organic matter formed and tough pioneering plant species such as pohutukawa (*Metrosideros excelsa*) landed and grew on the island. Rangitoto Island and Motutapu Island (behind it) now hold the largest forest of pohutukawa in the world. Pohutukawa is also known as the New Zealand Christmas tree, and many families go to the beach for Christmas and picnic under these trees!

I attended the University of Auckland and chose to study biology and classical studies because I could not decide between science and arts. Biology as a major was very broad, but I was drawn to the world of plants and completed a summer studentship studying the effects of different nutrient concentrations on the flowering time of the model legume, *Medicago truncatula*.

After graduating I spent 6 months at Seedling Systems, the biggest seedling propagation nursery in South Auckland. Seedling Systems supplies seedlings of vegetables, herbs, ornamental flowers, ginseng, native plants, tomatoes, and more. I was involved in

[a]E-mail: dharini@xtra.co.nz

watering several plastic houses, loading orders, and pricking out seedlings. With no practical horticultural background, this job was a bit of a challenge at first. My boss introduced me to Antony Toledo of Multiflora Laboratories (tissue culture), who talked to me about horticultural careers, plant breeding, and IPPS!

I decided to take two plant breeding papers (courses) at Massey University to gain some basic understanding of plant breeding theory. In July 2016, I began working with renowned ornamental plant breeder Dr. Keith Hammett.

Dr. Keith Hammett began his career as a trained plant pathologist, but was always interested in breeding and showing ornamental plants. Now, as a professional breeder of ornamental plants, he has recognised that he is a visual artist. Novel colour, flower form, plant habit, foliage shape, and foliage colour are all important in creating a piece of art that is three dimensional and living; plants change with time and in space.

FUNDAMENTALS OF PLANT BREEDING

Plant breeders sit in a network of people in the plant propagation industry. We rely on taxonomy and botanical science to understand the breeding systems and breeding possibilities of the species we deal with. Once we have a new cultivar, it needs to be made available to fellow plant enthusiasts; this requires growers, marketers, intellectual property agents, and retailers.

All plant breeders must always have a goal. Inspiration may come from looking at colours or flower forms of other genera, or the range of foliage or colour in wild species. On the path to improving or creating a new cultivar, a large population of offspring is usually produced each generation. It often takes decades to develop a new cultivar from beginning to commercial release, meaning that thousands of plants will be discarded during the selection process. Each breeding cycle must be a refining process that takes the breeder incrementally towards the clearly defined goal that was set at the beginning of the programme.

The strategy is the overarching plan – what is the germplasm available to you? Do you have to source seed or plant material from a seedbank or a national or international plant collection? In New Zealand, we have strict biosecurity rules under the Hazardous Substances and New Organisms Act of 1996, so it is now very difficult and expensive to bring in new species or plant material.

From among the available germplasm, the breeder must select plants to create a gene pool of parent plants to use in their specific programme. For example, dark-leaved, compact dahlia might be the goal, so all the dark-leaved plants below a certain height that we hold in our gene pool would be included in the parent block.

The breeding method relates to the reproductive cycle of the plant, and this is where botanical knowledge is useful. It is essential to understand the reproductive system of the plants you are working with. Is your plant an out-breeder or in-breeder, or can it be both? Can it hybridise with other closely related species? What is its chromosome number and ploidy?

POLYANTHUS BREEDING PROGRAMME

History

Polyanthus primrose (*Primula*) is a traditional florist flower. By the mid-1600s, plants were being specially raised for their aesthetic value and to certain criteria for showing and competing within 'florist' societies. Gold laced polyanthus was prized for certain characteristics by florists: the gold eye must be round, not hexagonal, and of a certain proportion; the gold lace must be the same colour tone as the eye; and the gold lace must be the same width all the way around.

Florence Bellis of Oregon started Barnhaven Primroses, supposedly buying seeds from an English catalogue of a friend. She ended up growing primula commercially, studying them at university, and founding the American Primrose Society in 1941.

Dr. Keith Hammett's original breeding goal was to breed a silver laced polyanthus with

a silver eye, as well as a silver laced blue polyanthus. This goal was achieved, but when I began work in 2016 there were few blue plants still alive. This year, my goal has been to revive the gene pool and preserve the blue ground colour silver picotee cultivar 'Blue Mountain' (a good plant breeding training exercise for me to practice on).

Breeding system

Polyanthus are out-breeders with two mechanisms of self-incompatibility. One method is spatial separation of the male and female organs. The pin form is when the female stigma is held visible and above the anthers. The thrum form is when the anthers are visible and above the stigma. This encourages cross pollination and is termed heterostyly. The second method is a difference in pollen grain size and stigma surface structure. Large pollen (from a thrum plant) gets caught on a stigma with long papillae/hairs (of a pin plant) and small pollen (of a pin plant) gets caught in the short hairs of the thrum plant's stigma.

Last year, I started by crossing three parents (one blue ground colour, the only blue plant left in our gene pool, and two crimson parents). The method of crossing is the same method Florence Bellis used over 50 years ago at Barnhaven Primroses in Oregon. Anthers are removed from the mother plant (emasculation) and pollen from the pollinator plant is dabbed onto the stigma (making sure the parents are a pin and thrum complementation). The outcome was plants with a mixture of flower colours from crimson to blue ground with silver picotee or lacing.

The next crosses will be using selections from the F_1 population to continue to improve the circularity and whiteness of the eye, revive the blue ground gene pool, improve the white eye on blue ground, increase the flower size of blue ground, and move full lacing onto blue ground from a red parent. I have made over 30 selections and crosses for various goals!

SWEET PEA BREEDING PROGRAMME

Breeding system

Sweet peas (*Lathyrus odoratus*) are obligate inbreeders; pollen is mature when the bud is still closed and fertilisation happens early on before the bud opens. *L. odoratus* can be made to outbreed with other *L. odoratus* cultivars (an intraspecific cross). This is done by emasculation at the bud stage – opening the bud and removing the anthers, coming back a few days later and transferring pollen of a different cultivar onto that flower's stigma. Careful labelling and recording is essential.

One of our long-term breeding programmes has been to produce a yellow flowered sweet pea. *Lathyrus belinensis* was introduced as a parent after it was first discovered in the late 1980s because it contains a yellow pigment; other species had so far been unsuccessful. The cross *L. odoratus* 'Mrs. Collier' × *L. belinensis* (an interspecific cross) was one of the few successful combinations. 'OB1' was the result – a smaller weaker plant than the parents, with flowers of intermediate size between the parents, and with pink standard and violet wings (the original sweet pea wild-type colours which are dominant traits). *L. belinensis* × *L. odoratus* 'Orange Dragon' produced 'A18', another pink and violet hybrid. Both 'OB1' and 'A18' were self-sterile, but produced some male pollen which could be used for further crossing with other cultivars of *L. odoratus*.

Challenges

Challenges include embryo abortion and seedling failure where weak, chlorotic plants fail to mature, and often produce inviable seed if they do. Embryo rescue and in vitro tissue culture is required. Close examination of the leaves of hybrids should show the characteristic pigmented spots of *L. belinensis*, a good phenotypic tool to indicate that the genetics are being carried in the plant.

In other subsequent results, backcrossing the F_1 hybrids to other *L. odoratus* cultivars produced a range of new commercial cultivars with new colour combinations never seen before. 'Blue Shift' is the first cultivar to morph colour as it ages from maroon/violet to blue.

'Porlock' has a distinctively large standard petal and marbling. 'Erewhon' is a distinctive reverse bicolour; the standard petal is paler than the wing petals. This was inspired as a goal by seeing the colour of another pea, *Pisum elatius*. Although you may have a set, long-term breeding goal, some tangent lines are worth pursuing along the way.

Seed yield of cultivars can vary widely between and within cultivars, years, and locations. Increasing the fecundity may have a genetic control component, but seed set and seed viability are also influenced by the environment, such as temperature and nutrition [phenotype (what you see) = genotype (nature) + environment (nurture)]. This year, challenges also included a lot of rain and some herbivory by rabbits and pukeko (a native wetland bird).

Contributions

On rainy days, I update pedigree family trees and breeding histories so that we have a clear understanding of the material available to us. We need a clear understanding of which lines are not worth continuing in a breeding direction.

Up-to-date records are essential to find accessions of seed in the freezer storage that might be useful, for example, looking at records of cultivars that have increased the fecundity (seed yield) of a cultivar in the past and sowing them for use as a parent again. This is especially relevant to those new cultivars with hybrid blood that do not produce a lot of seed and would benefit from crossing with a highly fecund cultivar.

DAHLIA BREEDING PROGRAMME

Breeding programme

Dr. Keith Hammett was inspired by the variety of foliage forms in *Dahlia* species as seen in their natural habitats in Mexico. As a flower exhibitor, foliage is not of interest as many dahlia shows exclude leaves from the display. However, gardeners like foliage and texture! We have a large collection of *Dahlia* species and cultivars stored as tubers and seed, with a range of flower and foliage forms, foliage colours, and plant habits.

Dahlias are out-breeders, so we use open pollination by bees (and butterflies and maybe others!) in randomised block designs. Each parent block contains a set of plants selected from our gene pool with the desired characteristics we want to cross. For example, parent plants might be selected for a combination of any of these: foliage colour, flower form, height, or foliage shape. Each parent block is separated by a reasonable distance so that most of the pollen is expected to have come from the neighbouring plants in that block. There is definitely cross-contamination, especially when erratic monarch butterflies are involved, but most seed would have developed from pollen within close proximity of that plant.

Collerette dahlias show huge potential for variation. The collar can be the same colour as the ray florets (self collerette), a paler colour (standard bicolour collerette), or darker than the ray florets (reverse bicolour collerette). Dr. Keith Hammett has also developed a darker disc colour; we have variation from yellow to amber to pink to red to black. When you think outside the box and move away from defined rules (e.g., those set by flower exhibitors), many possibilities open up. There are 72 possible categories for collerette dahlias based on grouping them into collar colour, foliage colour, foliage shape, plant height, and disc colour!

Contributions

I began my job in winter, so I was digging up tubers and washing them for storage over the winter (they get waterlogged in our rainy weather and heavy clay soil). I also clean seed using a homemade seed cleaner consisting of a vacuum cleaner, a heat pump, and a wooden slide. The heavy seed falls down the slide into the collecting container and the hot air blows the light plant material up the slide which can be vacuumed up. We deal with small quantities of seed, so we do not need anything fancy.

This year, we are evaluating over 120 plants that we selected from the field last

summer and planting the seed harvested from the parent blocks last summer. During the past month (early spring), I've been sowing seed and pricking out the dahlias that will be ready to be planted out when the weather is warmer.

Challenges

Viruses and disease can be obstacles in shipping dahlia material (both tubers and cuttings) overseas. Soil tests need to be done and tissue culture is required to clean up the cuttings. The plant breeder is also in a network of people that have different expectations. In large retail centres, where plants are sold in pots and in flower, a 1-m-tall dahlia will not be suitable. In contrast, the grower wants a uniform cultivar that will flower early and at the same time, and be a compact height so as many plants as possible will fit on shelves or trolleys for distribution. The gardener might want a nice, tall perennial border plant. It's a challenge to please everybody.

ACKNOWLEDGEMENTS

Thank you to the IPPS-Western Region and their Exchange Committee for organising and hosting my exchange. I am so grateful to my hosts who looked after me: Valerie and Arnold Sikkema, Todd and Allison Jones, Sarah and Jim Brackman, and Tony Shireman. Thank you to all the nursery owners and staff members for taking time out of your day to show me your nurseries and answer my questions.

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www.americanprimrosesociety.org

www.drkeithhammett.co.nz.

2017 New Zealand exchange experience©

K. Broadlick[a]

Fourth Corner Nurseries, 5652 Sand Road, Bellingham, Washington 98226, USA.

I was this year's lucky recipient of the IPPS-New Zealand exchange fellowship, sponsored by the IPPS-Western Region. It was an incredible trip. I spent the first week and a half visiting nurseries, followed by the New Zealand Region's annual conference, and then two additional weeks exploring the country. It's hard to sum up my experience in just a few words; there was no central theme, but so many little nuggets of wisdom. Here is a brief account of what I learned.

A VIEW OF NEW ZEALAND

The New Zealand landscape is beautiful and diverse. The country has everything from glacier-capped mountains to high desert tussocklands to subtropical forests, all within an area roughly the size of Oregon. The North Island is considered subtropical and is very green and lush. The South Island is more like the Pacific Northwest, wet and mountainous on the west side and flatter and drier on the east side, and with more agriculture. The North Island boasts an extensive forestry industry, with the California native *Pinus radiata* comprising 90% of the forestry trees in New Zealand. At one time, New Zealand had the largest continuous, non-native tract of forestry in the world. Many nurseries are producing *Pinus radiata* seedlings and cuttings. *Pinus radiata* can escape from cultivation (known as "wildlings"), and is often eradicated when it appears in conservation areas.

Botanically, New Zealand is fascinating. New Zealand has tree ferns, groves of *Nothofagus* (beech), and the southernmost-growing palm in the world, the Nikau palm (*Rhopalostylis sapida*). The vast majority of native plants are evergreen. Lancewood (*Pseudopanax crassifolius*) in its juvenile form has downward-pointing leaves with spines on the margins that are thought to be a defense mechanism against the now-extinct moa (a 12-ft-tall flightless bird). The silver fern (*Cyathea dealbata*), a tree fern, is the unofficial national emblem of the country and often appears on the jerseys of sports teams. The semi-deciduous tree fuschia (*Fuchsia excorticata*), the largest fuschia in the world, provides most of the fall color in the native bush. The average Kiwi thinks their native flora is quite boring, and is envious of our colorful perennials and deciduous trees. I would cut off my right arm to have such an extensive selection of evergreen native shrubs and groundcovers to recommend to landscapers and homeowners. The grass is always greener…

The native birds are fascinating (even to a plant person) and serve an equivalent role in New Zealand to salmon in the Pacific Northwest, focusing and driving much of the conservation work in the country. The keas were my favorite, but I also saw spoonbills, wood pigeons, and a few species of flightless birds, to name a few. Possums are a major threat to native birds. Different from our possums in the USA, these possums are native to Australia and were introduced to New Zealand in 1837 to establish a fur trade. They have no predators in New Zealand and are a major ecological pest. There are possum trapping and eradication programs throughout the country aimed at allowing the native bird populations to rebound.

THE NURSERY INDUSTRY IN NEW ZEALAND

I had the opportunity to visit 13 nurseries while in New Zealand, including The Native Plant Nursery in Taupo and Christchurch; Elliott's and Southern Woods in Christchurch; Multiflora, Lyndale, Nga Rakau, and Container Nurseries in Auckland; Kilmarnock Nurseries and Starter Plants Limited in Palmerston North; and Appleton's Tree Nursery, Waimea Nurseries, and Titoki Nursery in Nelson. Most of these container nurseries were small to medium in size (by USA standards). Each had their niche, but all were well cared for and

[a]E-mail: kelly@fourthcornernurseries.com

obviously run by talented propagators. Familiar themes were concerns about labor shortages and succession planning (how to find the right person to take over after retirement). A "number 8 wire mentality" (a.k.a. Kiwi ingenuity) was another obvious and common thread. I saw custom-manufactured harvesting machinery still being maintained by the same person that built it 20 years ago. Another nursery had planted sugarcane along all their irrigation ditches to soak up water, to act as a windbreak, and to provide the raw materials for hobby rum brewing. Some folks were even brewing their own rooting hormones and mycorrhizal inoculants!

MYRTLE RUST

All my tours and the New Zealand Region conference were colored by discussion of the disease myrtle rust, which showed up in New Zealand only 2 days before I arrived. It is suspected that spores blew over from Australia. Myrtle rust affects various species in the *Myrtaceae* family, primarily the new growth. The native pohutukawa (*Metrosideros excelsa*) may be susceptible, which would be a major blow to this iconic species both in landscapes and in its native setting. It remains to be seen whether feijoa (*Acca sellowiana*, also known as pineapple guava) will be susceptible.

The first positive identification of myrtle rust was at a nursery. As I travelled around the country, I learned that the disease was being identified at new locations almost every day. Confirmed cases ramped up as the conference began, and the nursery field trips were canceled at the last minute per a request from the federal government. The Executive Committee had to develop a new tour itinerary in less than 24 h, with the new tour including a kiwi fruit grading and packing house, an orchid nursery, and a cucumber greenhouse. A forum on myrtle rust was also added to the schedule and we had a very thoughtful and timely conversation about what this disease might mean for the nursery industry. My favorite quote from the forum was, "Without the movement of plants, we don't have a business. With the right to move plants comes a great responsibility."

CLOSING THOUGHTS

The last thing that really stood out from my trip was how willing everyone was to share information. I'm sure this is at least in part because Kiwis (and plant people) are inherently friendly folks, but I think it is also a reflection of IPPS membership. As an early-career propagator, I'm very excited about the access to knowledge and mentorship that IPPS will give me over the coming years.

ACKNOWLEDGEMENTS

Finally, I want to express my gratitude to the Western Region for sending me to New Zealand, my wonderful hosts (Juliette Curry, Antony Toledo, Philip Smith, and Mary Duncan) for taking such great care of me, and to all the other lovely folks I met along the way. Meeting everyone was the best part of the trip. Thanks to you all. And to any young propagators who fit the criteria, I strongly encourage you to apply. The program will be repeated next year, and it is truly a great experience.

The hordes: emerging pest threats to plants in the Western USA©

R. Rosetta[a]

Department of Horticulture, Oregon State University, North Willamette Research and Extension Center, 15210 NE Miley Road, Aurora, Oregon 97002, USA.

Numerous studies have shown that movement of horticultural products is a frequent pathway for invasive pests. This knowledge suggests there is an awesome responsibility that comes with moving plants from place to place. When it comes to new pests, the nursery industry is both at risk and a risk. Those propagating plants play a key role in the prevention and detection of invasive plant pests. Growers need to regularly update their knowledge of new exotic species risks as the topic of invasive species is dynamic with frequent changes. Scrutiny of nurseries by the government, public, and industry will continue to tighten. This paper highlights a few of the emerging invasive species of concern in the western US.

EMERGING INVASIVE PESTS

Hemerocallis gall midge, daylily gall midge (*Contarinia quinquenotata*)

The *Hemerocallis* gall midge is thought to have originated from Asia. It was detected in Vancouver, British Columbia, in 2001, and found in the state of Washington in 2007. In Washington, there are reports of this pest in Whatcom, Skagit Valley, Bellevue, Everett, Granite Falls, and the Puget Sound area (Rosetta, 2017b).

The *Hemerocallis* gall midge overwinters in the soil. The adult midge emerges from the soil and begins to lay eggs on the developing daylily buds in the late spring and early summer, usually from May through June. Tiny white maggots hatch from these eggs and can be found feeding within (and sometimes outside) the daylily buds. Feeding by the maggots on developing lily buds causes distorted growth. Buds become swollen and discolored. Damage may cause buds to shrivel and not completely form. Blossoms from affected buds are deformed and often have crinkled petal edges.

Cultural management has relied on avoidance of early-blooming cultivars (particularly yellow-colored selections) and removal and disposal (but not in compost) of infested daylily buds. Bringing in only bareroot plants, a strategy used with a similar midge, the rose midge (*Dasineura rhodophaga*), might help to reduce the risk of introduction of this midge via bringing in plants with the soil-based stages of the insect. Chemical management generally is timed to protect the new buds during the time adult midges lay eggs. Both contact and systemic insecticides have been used. A report by Halstead (2012) on insecticide management of *Hemerocallis* gall midge is available at the Royal Horticultural Society website.

Allium leafminer, onion leafminer (*Phytomyza gymnostoma*)

The *Allium* leafminer is a key pest of concern for *Allium* spp. (such as garlic, leek, and onion). It was first detected in Pennsylvania in 2015. *Allium* leafminer infestations have been found in Pennsylvania in 17 counties, in three New Jersey counties, and may have been found in one county in New York (Oregon Department of Agriculture, 2017a). Native to Germany and Poland, the *Allium* leafminer is now distributed more widely in Europe and more recently reported in Asia, Turkey, and Russia. This pest is considered a threat to Oregon's $125 million onion industry. The fly pupates within bulbs, including bulbs with no vegetative growth, which increases the risk of importation. Greatest risks are associated with importing from any infested area. The USDA has deregulated this new pest, and Oregon is considering a quarantine on *Allium* from infested states. The Oregon Department of Agriculture intends to eradicate this pest if it is detected.

[a]E-mail: robin.rosetta@oregonstate.edu

The *Allium* leafminer affects both ornamental species as well as native species of *Allium*. Economic hosts include onions, garlic, shallots, and green onions, with leeks and chives as preferred hosts. Larval feeding causes curled and twisted leaves. Small plants can succumb to larval feeding. Severe infestations can result in complete crop failure. *Allium* leafminers overwinter as pupae. There are two predicted generations. The spring generation occurs when adults emerge from the soil after overwintering and lay their eggs at the base of leaf stems, generally from March through April and possibly May. These larvae feed and eventually pupate and remain in diapause through the summer until fall, September to October, when adults emerge and lay eggs of the second generation. The larvae from these eggs emerge, feed, and then pupate to overwinter.

Damage from the *Allium* leafminer is most apparent as lines of feeding scars or punctures made by the female and the curling leaf damage from larval feeding. Adults are gray flies about 3 mm (1/8 inch) long with yellow heads, dark eyes, and yellow markings on the sides of their abdomen. Larvae are maggots and yellowish-to-white up to 8 mm (5/16 inch) long. They mine the leaf stalks toward the base of each leaf. They then pupate at the end of the mine, sometimes down in the bulb. The pupal stage is red to brown in color and approximately 3.5 mm (a little over 1/8 inch) long.

Some states may, like Oregon, choose to eradicate this pest if detected. Rutgers and Penn State have some cultural (row covers) and chemical management recommendations for both conventional and organic vegetable growers in the mid-Atlantic area (Rutgers University, 2017; Fleischer and Elkner, 2016).

Japanese flower thrips (*Thrips setosus*)

Japanese flower thrips were first detected in a nursery in Michigan in 2016. Hostas from this nursery were shipped to nurseries throughout the USA. Since then the pest has been detected in Rhode Island, Minnesota, Oregon (one location, under eradication), and possibly Colorado (not confirmed) (Oregon Department of Agriculture, 2017b). APHIS is no longer regulating this pest.

Japanese flower thrips feed on plants in at least 14 plant families. They are fond of solanaceous hosts, such as tomato, pepper, and eggplant. A partial list of hosts includes: camellia, chrysanthemum, cucumber, dahlia, hellebore, hosta, hydrangea, impatiens, iris, petunia, poinsettia, soybean, and strawberry. The list of hosts also includes several weed species, such as thistle and sow thistle (Vierbergen and Loomans, 2016). This pest can be a vector of *Tomato spotted wilt virus*. It can survive year-round in greenhouses and outdoors in USDA plant hardiness Zones 4 to 11, which includes all of Oregon. Their damage, seen as silvery streaks and spots and deformed leaves, is similar to damage caused by other thrips. Although called a flower thrips, this species is actually a leaf feeder and does not eat pollen.

Adult females are dark brown with a pale color on the basal quarter of the wing. Adult males are yellow and difficult to distinguish by non-experts. Their initial detection in Michigan was due to a thrips biocontrol program failure. An Oregon Department of Agriculture fact sheet has a list of insecticides that are known to be effective.

OTHER PESTS TO KEEP ON YOUR RADAR

Greenhouse thrips (*Heliothrips haemorrhoidalis*)

We are also concerned about introduced pests moving into natural areas. Greenhouse thrips have been found in damaging numbers on salal (*Gaultheria shallon*) in landscapes and natural areas in Oregon and Washington. Greenhouse thrips are not just greenhouse pests (Rosetta, 2017a).

Greenhouse thrips adults generally have dark-colored heads and thoraxes with a dark or orange abdomen. Larvae are light-colored with red eyespots. Damage from greenhouse thrips on salal resembles that of azalea lace bug, with silvering of the leaves and fecal spotting. Entire plantings can have a white or silver cast to them. Additional affected hosts in Washington and Oregon include viburnum, Oregon grape (*Berberis* syn. *Mahonia* sp.), Pacific wax myrtle [*Morella* (=*Myrica*) *californica*], rhododendron, and native fern (*Polystichum*

imbricans syn. *P. imbricans* subsp. *imbricans*).

Rose stem girdler (*Agrilus cuprescens*)

Rose stem borer has been trapped in the Portland area (2015) and found in crops in southwest Washington (2014), as well as east of the Cascade Mountains. It was identified in caneberries (*Rubus* species) in August 2017 at the North Willamette Research and Extension Center in Aurora, Oregon. This beetle borer has the potential to cause damage to important plants in the Northwest, including caneberries and roses.

A buprestid beetle, the rose stem girdler feeds in the cambium and girdles the plant. Damage symptoms include swollen stems, sometimes with spiraling tunnels in evidence. These galls may have dark coloration or have more woody epidermis. Bark or stem cracking or splitting is often seen. Wilting of infested stems is common. Areas of the stems with beetle tunnels are weak and break easily.

The adult beetles are small, copper-colored, and metallic with a bullet shape. The larvae are narrow, cream-colored and segmented with a large flat "head" (actually its pronotum). Adults are seen in the late spring and early summer (May through June) when they mate and lay eggs on roses and caneberries. Larvae hatch from these eggs and feed in the cambial area of the plant. The third instar larvae then move toward the pith of the stem. The beetles overwinter as a fourth instar larva. There is one generation per year.

Management includes cultural controls, such as pruning and disposing of infested canes and reducing plant stress. Chemical controls are timed to protect plants during the emergence and egg-laying of the adults. This often overlaps with bloom, so caution must be taken to protect pollinators (Alston, 2015).

Ash whitefly (*Siphoninus phillyreae*)

Ash whitefly was first detected in the USA in California in 1988. They were noted in Oregon in 2014. In the late summer and early fall, they can noticeably swarm as they search for preferred evergreen hosts on which to overwinter. Toyon (*Heteromeles arbutifolia*) was found to be the dominant overwintering host in California. In Oregon, they appear to be overwintering on firethorn (*Pyracantha* sp.). Also, in Oregon, preferred summer hosts on which they have been noted reproducing include pear, hawthorn, and Oregon ash (Rosetta, 2016c, 2017a).

All stages of ash whitefly remain on the leaf underside. Nymphs and "pupal" stages of ash whitefly are very distinctive and covered with white tufts of wax. They have long tubes around their edge that secrete copious waxy droplets.

Biological control agents for this pest are already known due to previous work by researchers at the University of California when this pest became established in California some years ago. A beetle, *Clitostethus arcuatus*, and a wasp parasite, *Encarsia inaron*, was found to be very effective in suppressing ash whitefly below economic and aesthetic thresholds. Those agents have been naturally introduced into many of the areas in which ash whitefly has established and appear to be very effective in those new locations, including Oregon. In general, chemical control is not recommended due to the success of the biological control program. On occasion, chemical treatment may be required if the pest is found on plants to be shipped.

Cabbage whitefly (*Aleyrodes proletella*)

Cabbage whitefly has also become a more widespread pest in the West, particularly on brassicas. It has been a pest in the northeast US since 1993. In the west, it was detected in California in 2001 and in Oregon in 2014 (Oregon Department of Agriculture, 2016; Rosetta, 2017a). It is important to note that cabbage whitefly is also hosted on non-brassicas, including common weeds such as sow thistle and milky thistle in the *Asteraceae* family and herbaceous plants such as columbine. In Oregon, kale has been the most noticeably infested plant. This pest may be an issue for local fresh market growers, perhaps outcompeting the cabbage aphid.

Adult cabbage whiteflies are small, white-winged insects with two pale markings on

each wing. Females lay small, white, oblong eggs, usually on the underside of the leaves, often in a circle or hemicircle with white powdery deposits commonly seen. Tiny nymphs emerge from the eggs and move and settle nearby to remain feeding in one place. The nymphs have three stages which are oval and slightly yellowish, then molt to a "pupal" stage. The red eyes become noticeable in that stage, which is immobile as well (Oregon Department of Agriculture, 2016; Rosetta, 2016c).

Banded-winged whitefly (*Trialeurodes abutilonea*)

Banded-winged whitefly has been found on the east side of Oregon, and has a host range of approximately 140 species in 33 plant families. It has been intercepted in shipments to the United Kingdom from the USA on *Acacia* sp., *Banisteriopsis caapi*, *Brugmansia* sp., and *Hibiscus rosa-sinensis* plants. Where it has been detected, it is considered an occasional pest and it can transmit at least four viruses (Rosetta, 2017a).

This whitefly is named for the two distinctive zigzag bands on its wings. The puparium of this whitefly also has a wide, dark, longitudinal band.

Biological control agents associated with banded-whitefly include *Eretmocerus staufferi*, the fungus *Orthomyces aleyrodes*, minute pirate bugs (*Orius insidiosus*), and several species of lady beetles (Malumphy et al., 2010).

Viburnum leaf beetle (*Pyrrhalta viburni*)

Viburnum leaf beetle is thought to have been introduced from Europe to North America in the 1890s, having been detected in Nova Scotia in 1924 and first detected in the USA in Maine in 1994. It has since spread to many northeastern states in the USA. It was found in British Columbia in 2001 and confirmed in the state of Washington in 2004 (Murray et al., 2016; Rosetta, 2016a).

Both adult and larval stages of the viburnum leaf beetle feed on a number of *Viburnum* species. The adult beetle lays eggs in the late summer into rows of holes it chews into the stems. As viburnum leaf beetle inserts its eggs into the plant stems, it is critical that propagators check their plant material before collecting cuttings. The beetle overwinters in this egg stage from which larvae emerge in the spring. There are three larval instars and one generation per year. Susceptibility varies by *Viburnum* species (Rosetta, 2017a).

QUESTIONS

Dharam Sharma: Is there biocontrol for rose stem girdlers?

Robin Rosetta: I am not aware of any. It will be a while before we see a good list of management tools. Caneberry growers may not know they have this pest until they hear about it; then they go back and realize that this is what they have been seeing in their fields.

Voice: How do you get rid of thrips on edible crops?

Robin Rosetta: I don't work with edible crops. However, for some thrips, like Western flower thrips, there are some very good biocontrol programs, both microbial biopesticides and augmentation with parasitic wasps. In addition, minute pirate bugs and various predatory mite species can be applied. Thrips are a challenge because they get into inaccessible places. It is important to determine which type of thrips you are dealing with.

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What's your problem? Diagnosing plant disease for nursery growers©

L. Santamaria[a]

Department of Botany and Plant Pathology, Oregon State University, North Willamette Research and Extension Center, 15210 NE Miley Road, Aurora, Oregon 97002, USA.

Production of healthy plants is the goal of any plant propagator. When it comes to producing healthy plants, all activities and practices at the nursery are connected and must be considered in order to prevent plant diseases. There are occasions when plant pathogens find a way to infect plants even when we apply good practices at each stage of plant production.

WHAT IS A PLANT DISEASE AND WHAT ARE THE POSSIBLE CAUSES?

Plant disease may be generally described as any change or alteration in the normal development of a plant. The causes of plant diseases can be either living or non-living factors. Non-living factors are also referred to as "abiotic factors". Abiotic factors that can cause plant injury include: low or high temperatures, changes in pH, nutrient deficiencies, air pollution, water stress, excess water, and various chemicals. There is no organism to reproduce or spread from plant to plant. Symptoms may appear suddenly (i.e., following cold temperatures), but usually show up over time. Herbaceous plants can show damage immediately, whereas some woody plants may display damage weeks later. Usually, the problem does not get worse over time.

Living causes of plant disease, referred to as "biotic factors", are any living organisms that cause damage to a plant. In this category, we can include insects, nematodes, weeds, and microorganisms. Plant-disease-causing microorganisms are called "pathogens" and are the main cause of plant diseases. Pathogens can spread from a diseased plant to a healthy plant, causing disease on susceptible hosts. The problem generally gets worse over time under the same environmental conditions if we do not employ control measures. Some diseases can even spread over a wide area if we have not initiated a disease management plan.

Plant pathogens (disease-causing organisms) are microscopic and not visible to the naked eye, and include bacteria, fungi, and viruses. All these microorganisms have characteristics that allow them to infect a plant and reproduce on or inside a plant. Bacteria can colonize plants by growing between the cells and absorbing plant nutrients. Bacteria may build up to such high numbers that they plug the vascular system, and are sometimes visible when they ooze out of the plant tissue. Fungi are the largest group of plant pathogens and produce fruiting bodies with thousands of spores that help them to spread. Viruses are extremely small and can only be observed under an electron microscope. Viruses can be transmitted by insects and nematodes, are easily carried on dirty tools, and may be transmitted by workers' hands from one plant to another.

THE DISEASE TRIANGLE

There are three elements that must be present at the same time for a plant disease to occur, and we refer to this as the "disease triangle". These elements are: 1) the pathogen, 2) a conducive environment for the pathogen, and 3) a susceptible host (a plant that allows penetration and establishment of the pathogen). Different pathogens find different environments most suitable. Wet weather is favorable for downy mildew, leaf spots, rusts, and root rot diseases. Cool, humid weather is favorable for gray mold (*Botrytis*). Hot, humid weather is conducive for *Rhizoctonia* diseases.

DIAGNOSING PLANT DISEASES

When it comes to identifying a plant disease, early detection and correct diagnosis are

[a]E-mail: luisa.santamaria@oregonstate.edu

important. A correct diagnosis is useful information for a nursery manager, helping to reduce losses and prevent the spread of a problem. This information will also help in development of management strategies and better production decisions. The first step in diagnosing plant problems is to examine all plant parts for signs and symptoms of disease. Look at the plant closely for clues and consider the possible causes or agents of the problem. Observations are key.

SYMPTOMS OF DISEASE

A symptom of disease is a visible change in the normal appearance of a plant. Carefully observe the affected plants and the general environment. Symptoms of disease can include: leaf spots and leaf blight, wilt, galls, cankers, rots, necrosis, chlorosis, and general decline. Some symptoms caused by bacteria, fungus, virus, or even abiotic causes can look similar. Do not jump to conclusions when a plant problem is first noticed, as disease may not be the cause. Sometimes we can use information to determine the type of pathogen based on specific characteristics. For example, leaf spots caused by bacterial pathogens may have an angular shape, may have a chlorotic halo, or may appear as streaks on monocotyledonous plants. Leaf spots caused by fungi may appear as necrotic or chlorotic spots, whereas viruses often produce a mosaic pattern, showing chlorotic areas that alternate with green areas of leaf tissue. Plant stems may show external symptoms, such as stem cankers, or internal symptoms, such as dark rings in the wood caused by the presence of fungal fruiting bodies seen when you cut a stem and observe the cross section. Symptoms of disease on plant roots may appear as root rot, caused mainly by fungal pathogens, or abnormal tissue growth (e.g., knots), caused by nematodes.

SIGNS OF DISEASE

A sign is the physical evidence of the pathogen, and includes fungal fruiting bodies (such as mushrooms or pycnidia), mycelia, bacterial slime, or presence of nematodes. Mycelium (plural: mycelia) is the vegetative part of a fungus, consisting of a mass of branching, thread-like hyphae. Signs of rust disease are rusty-red spots on the underside of the leaf. Keep in mind that plants kept in the greenhouse or field throughout the year may act as reservoirs of pathogens and insects, and should be scouted regularly and kept under strict disease control.

OTHER DIAGNOSTIC TOOLS

Signs and symptoms are not the only way to diagnose a plant disease. Other tools include molecular techniques, such as PCR (polymerase chain reaction) and immunological tests (such as immune-strips and agglutination tests). Pocket diagnostic test kits are available and useful in a nursery setting for detecting of several plant pathogens, such as *Phytophthora* species.

SOME EXAMPLES OF CHALLENGING DISEASES IN NURSERIES AND LANDSCAPES

Boxwood is susceptible to several diseases. Currently, boxwood blight (caused by *Cylindrocladium pseudonaviculatum*) is of major concern. This disease is characterized by stem lesions and leaf spots, with defoliation occurring soon after the leaf spots are first observed. Infected plants may lose most of their foliage. Some plants may recover, but become infected again and finally die. The pathogen only infects the aerial parts of the plant, not the roots. The pathogen may also infect species of *Pachysandra* and *Sarcococca*. Boxwood blight is sometimes confused with *Volutella* blight (caused by *Volutella buxi*), with the latter characterized by salmon-pink-colored fruiting bodies on the leaves. Boxwood is also susceptible to root rot caused by *Phytophthora citrophthora* and *P. cinnamomi*.

Symptoms of downy mildew on garden impatiens are blossom drop and lack of flowers. A sign of downy mildew is the white mycelium, which may be observed on the undersides of the leaves. Sporangia, which are sac-like structures with motile spores (called zoospores), may also be seen. Oospores are the survival/overwintering structures of the fungus. Oospores are formed in the stems and leaves of infected plants and can survive for

several years in the soil.

A SUMMARY OF PLANT PROBLEM DIAGNOSIS STEPS

1. Consider the possible causal agents:
   - Biotic disease—symptoms progress and nearby plants become infected.
   - Abiotic problem—generally a lack of symptom progression; does not spread.
2. Ask questions such as:
   - When was the problem noticed?
   - Was the damage sudden or gradual?
   - How old are the affected plants?
   - What percentage of plants are affected?
3. Observe patterns:
   - Large area/all plants—generally abiotic.
   - Scattered, localized—generally biotic
4. Check for distribution of symptoms:
   - Uniform—generally abiotic.
   - Random—generally biotic.
5. Review cultural practices:
   - Is proper planting technique being used?
   - Is there an overapplication of fertilizers and/or pesticides?
   - Is there an irrigation problem?
6. Review environmental conditions:
   - Recent extreme temperatures?
   - Drought or excess rain?
   - Soil type and conditions?
7. Check for signs and symptoms.
8. Consult literature resources for possible diseases and disorders:
   - Indices listing hosts and their pathogens.
   - Websites providing information.
   - Books with background info and host/pathogen lists.
9. If you do not find an answer and the problem continues to grow, send a sample to a plant diagnostic laboratory, or consult with an Extension specialist.

ADDITIONAL RESOURCES

Diagnosing plant diseases

https://ohioline.osu.edu/factsheet/plpath-gen-2.
https://www.apsnet.org/edcenter/intropp/topics/Pages/PlantDiseaseDiagnosis.aspx.
http://edis.ifas.ufl.edu/mg441.

Bacterial pathogens

https://www.apsnet.org/edcenter/intropp/PathogenGroups/Pages/Bacteria.aspx.

Nematodes

http://edis.ifas.ufl.edu/in138.

Nuggets of knowledge©

D. Takao[1,a] and L. Rupp[2,b]

[1]Takao Nursery, 2665 N. Polk Avenue, Fresno, California 93722, USA; [2]Department of Plants, Soils and Climate, Utah State University, 4820 Old Main Hill, Logan, Utah 84322, USA.

Moderator: What percentage of production costs is electricity in a tissue culture laboratory?

Dharam Sharma: Ours is about 10% in central California. Costs depend on the type of lighting and air conditioning system.

Gayle Suttle: Our cost is about 3.5% in Oregon. HVAC is a major user of electricity.

Steve McCulloch: Generally, electricity can be less than 5% of your costs, depending on how efficient your systems are. Many labs are now looking at LED lighting. That is going to have a profound effect on our electrical bills. A lot of the electricity goes toward lighting, air conditioning, and autoclaving.

Sam Huang: Electricity is 3 to 5% of costs at our laboratory in Oregon. When we moved our lab from California to Oregon, we were able to take advantage of cooler weather to reduce our electrical costs.

Moderator: If someone finds a new plant, what is the procedure followed by a tissue culture lab to get the plant initiated?

Steve McCulloch: The first thing we do is have a conversation with the customer. Often, we will get an email inquiry, but we have found that it is best to sit down in person or talk over the phone to thoroughly understand what the customer's goals are with the plant, so we can best help them. After that, laboratory procedures are fairly straightforward. We also need to have a good familiarity with the plant because there can be some inherent and important things about the plant. The plant may have disease problems or there may be viral problems present in the stock. So, the process starts with a conversation and involves our doing some background work to understand the horticulture and the propagation difficulties with that plant.

Moderator: What is the cost to get a plant into tissue culture?

Gayle Suttle: Unfortunately, that is the first question most people ask us, along with "How quickly can we get the plants?" The time involved may be one year, it may be five years, or may be never. We always begin with the end in mind. What is the customer's goal? Based upon our experience, we must decide whether the project makes sense and whether the customer's company is likely to be in business one, five, or ten years in the future. At our company, we have exclusive and non-exclusive contracts. For an exclusive plant, there is a cost involved that is direct to that customer. If we start a non-exclusive plant, we can sell the plant to anyone else, and we do not charge for that. We must evaluate the opportunity for success. We know there are certain plants that we are never going to be successful with (as with plants that have a slow multiplication rate). In all cases, we charge the culture initiation fee, which is just a partial cost of getting a plant into culture, and then we figure out what it is going to cost us. We base our prices on how many hood hours it takes us to produce the plants. We have a very simple financial model that relates the cost of everything in our company to the number of dollars per hood hour, and everything ties to that.

Dharam Sharma: The greater the quantity being ordered and the easier the plant is to micropropagate, the lower the price will be. The harder the plant is to propagate and the lower the number needed, the more expensive the plant can be.

[a]E-mail: dtakao@takaonursery.com

[b]E-mail: larry.rupp@usu.edu

Moderator: What are the hormone rates used for cannabis cuttings?

Melanie Miller-Gonzalez: Many growers will use Wood's Rooting Compound at a softwood rate, whereas others will use a powdered hormone. As with other crops, the choice is grower-specific. In my experience, every grower has a preference in what rate they like to use. I am not aware of different rates being used for different cultivars.

Katy Cunningham: Cuttings will often root without a hormone, but we do use one at Dark Heart Nursery.

Gene Blythe: During our tour of Aroma Cannabis, they were using Clonex Rooting Compound, which is the only EPA-registered product that is available as a gel. This product contains 3000 ppm IBA. Of course, you can take any of the liquid rooting solutions and make them into a gel yourself using a gelling agent.

Moderator: Is there a list of the different rooting hormones that are available for use by nurseries?

Gene Blythe: Yes, just a few years ago Cheryl Boyer, Jason Griffin, Brenda Morales, and I put together a leaflet listing all root-promoting products registered for commercial use in the USA, along with the pros and cons of different methods of application and instructions for preparing gel formulations of liquid auxin solutions. The leaflet is available online as a free download at: www.ksre.ksu.edu/bookstore/pubs/MF3105.pdf.

Moderator: At some of the nurseries we have visited on our tours, a lot of the propagation is done on ground beds or on cement pads. Are the nurseries worried about *Phytophthora* as the trees are placed on the propagation beds?

Jason Julian: Before setting down new plants, we remove all plant debris and wash down the beds. Then we do a preventative Physan application between crops. We also use new or pasteurized containers (cans, flats, and pots) and follow a set of best management practices for all *Phytophthora*-susceptible crops.

Sam Huang: At Monrovia's central California location, propagation and production of camellias is done in a separate part of the nursery to prevent *Phytophthora* contamination. Also, our technical services department is continually testing recycled water during the year, as well as testing SOD-susceptible hosts twice each year, for presence of *Phytophthora*. Chlorine is injected into the irrigation water as a preventative treatment.

Moderator: Is there a good time card system for tracking hours, and specifically hours spent doing propagation, watering, planting, etc.?

Gayle Suttle: We are moving to a digital timeclock system. The system we think is going to work for us to use for job costing is called T Sheets.

All-America Selections winners for 2017: outstanding ornamentals and edible crops for producers and home gardens©

D. Blazek[1,a] and E.K. Blythe[2,b]

[1]All-America Selections, 1311 Butterfield Road, Suite 310, Downers Grove, Illinois 60515-5625, USA; [2]Mississippi State University, Coastal Research and Extension Center, South Mississippi Branch Experiment Station, Poplarville, Mississippi 39470, USA.

Abstract

Seventeen cultivars became All-America Selections (AAS) National Award Winners for 2017. AAS includes a network of over 80 trial grounds across the United Stated and Canada where new, never-before-sold cultivars are "Tested Nationally and Proven Locally®" by skilled, impartial AAS Judges. Only the best performers are declared AAS Winners. Once these new cultivars are announced as AAS Winners, they are available for immediate sale and distribution. An additional seven cultivars were selected as AAS Regional Award Winners for 2017. Regional winners undergo the same trialing process as national winners, but are recognized as cultivars that exhibit outstanding performance in specific regional climates.

AAS NATIONAL WINNERS FOR 2017

***Abelmoschus esculentus* 'Candle Fire' (F_1 okra)**

A high-performing, unique red okra with pods that are round, not ribbed, and a brighter red color than the reddish-burgundy okras currently available. Plants thrive in the heat. Fruit are suitable for both kitchen and ornamental uses. Aged fruit can be used in flower arrangements and dry seed can to brew caffeine-free coffee. Bred by Known-You Seed.

***Capsicum annuum* 'Chili Pie' (F_1 pepper)**

This unique, miniature bell pepper is mildly hot when fruits turn red. Plants are compact, easy to grow, and adapt well to containers or small gardens. Foliage is dark green, and plants can set fruit under hot, humid conditions. Bred by Clover Seed Co., Ltd.

***Capsicum baccatum* 'Aji Rico' (F_1 pepper)**

This hybrid hot pepper matures early for short-season production. The large plants produce many thin-walled, crunchy peppers with a narrow, conical shape. The peppers mature from green to red and can be eaten at any stage, having a refreshing citrus flavor and warm heat level, perfect for eating fresh or use in salsas or hot sauces. Bred by PanAmerican Seed.

***Capsicum baccatum* 'Mad Hatter' (F_1 pepper)**

'Mad Hatter' peppers have a novel, three-sided shape and a refreshing, citrusy floral flavor that remains sweet, only occasionally expressing mild heat near the seeds. Plants are vigorous, robust, and easy to grow. The abundant fruits may be used raw in salads, pickled, or stuffed with cheese. Bred by PanAmerican Seed.

***Catharanthus roseus* 'Mega Bloom Orchid Halo' (F_1 vinca)**

'Mega Bloom Orchid Halo' vinca produces huge, bright, rich purple blossoms with a

[a]E-mail: dblazek@aaswinners.com
[b]E-mail: blythe@pss.msstate.edu

wide white eye. Plants maintain a nice, dense habit with flowers staying on top of the foliage. Plants withstand heat and humidity without succumbing to disease. Growers will like the early bloom time, compactness in the greenhouse, and plant uniformity. Bred by AmeriSeed.

***Catharanthus roseus* 'Mega Bloom Pink Halo' (F_1 vinca)**

'Mega Bloom Pink Halo' vinca produces huge, soft pink flowers with a wide white eye. Plants maintain a nice, dense habit with flowers staying on top of the foliage. Plants tolerate heat and humidity and are resistant to disease. Growers will like the early flowering, compact habit in the greenhouse, and plant uniformity. Bred by AmeriSeed.

***Celosia argentea* 'Asian Garden' (spiked celosia)**

Asian Garden displays good branching with an almost bushy growth habit and early to bloom flower spikes. Plants continue to produce spikes on sturdy stems, keeping their bright pink color all summer long. Flowers are a magnet for pollinators. Bred by Murakami Seed Co., Ltd.

***Citrullus lanatus* 'Gold in Gold' (F_1 watermelon)**

The outer color of the 11- to 16-pound fruit of 'Gold in Gold' is yellow with golden stripes, while the inner flesh is an attractive orange/gold. Plants are high yielding, disease resistant, and have a strong rind that resists cracking and bursting. Bred by Asia Seed Co., Ltd.

***Citrullus lanatus* 'Mini Love' (F_1 watermelon)**

The shorter vines (3-4 ft) of 'Mini Love' produce up to six fruits, so plants can be grown in smaller spaces. This personal-sized, deep red-fleshed Asian watermelon has a high sugar content with a thin, but strong, rind. Bred by HM·Clause.

***Dianthus* 'Supra Pink' (F_1 interspecific dianthus)**

Compact, bushy plants (less than 1 ft in height) are prolifically in producing flowers with novel mottled pink flowers sporting frilly petal edges that hold up from spring through fall. No deadheading is required. Bred by Hem Genetics.

***Foeniculum vulgare* 'Antares' (F_1 bulb fennel)**

'Antares' fennel may be used as an edible bulb, for its ornamental fronds, as a seed producer, or as a food source for caterpillars of the swallowtail butterfly. The bulbs are uniform and pure white with a much improved, almost sweet, licorice/anise flavor in comparison with other market varieties. Plants are also slower to bolt. Bred by Bejo Seeds, Inc.

***Pelargonium* Calliope® Medium Dark Red (interspecific geranium)**

Calliope® Medium Dark Red geranium is an interspecific hybrid with zonal-type flowers and leaves. Plants have a mounded, semi-spreading growth habit with strong stems supporting the flower heads that are loaded with deep red flowers. Plants are more heat and drought tolerant than older geraniums. Plants are vegetatively propagated. Bred by Syngenta Flowers.

***Phaseolus vulgaris* 'Seychelles' (pole bean)**

'Seychelles' pole bean produces high yields of long (5- to 6-in.), uniform, straight, stringless pods with an excellent flavor. Whether grown in the garden or in a patio container, 'Seychelles' grows 7 to 9 ft tall on vigorous dark green vines and should be grown on supports. Bred by Bakker Brothers/Pure Line Seeds, Inc.

***Solanum lycopersicum* 'Midnight Snack' (F_1 tomato)**

This unique indigo-type cherry tomato ripens to red with a beautiful glossy black-purple overlay when exposed to sunlight. The indeterminate vines produce an abundance of

healthy, antioxidant-containing fruit. Bred by PanAmerican Seed.

***Solanum lycopersicum* 'Patio Choice Yellow' (F_1 tomato)**

This compact, determinate tomato was developed specifically for small spaces and container gardens. Short vines (only 18 in. tall) produce large yields of one-half-ounce, bright yellow, mild flavored cherry tomatoes. Bred by Seeds by Design.

***Verbena peruviana* EnduraScape™ Pink Bicolor (verbena)**

Vigorous plants are sturdy spreaders that display abundant, soft pink flowers that darken in intensity toward the center of the flower. Plants can tolerate drought and heat, plus survive cooler temperatures down to the low teens. Plants are vegetatively propagated. Bred by Ball FloraPlant.

***Zinnia hybrida* 'Profusion Red' (zinnia)**

The original Profusion zinnias were ground-breaking plants because of their compact form, disease resistance, earliness, continuous flowering through the season, and ease in growing. The true red color of this latest Profusion zinnia does not fade in the summer sun. Uniform plants and outstanding greenhouse and garden performance will be important for growers producing 'Profusion Red' zinnias for retail sales. Bred by Sakata Seed Corporation.

AAS REGIONAL WINNERS FOR 2017

***Capsicum annuum* 'Sweetie Pie' (F_1 pepper) (Regions: Southeast, Heartland, Northeast)**

'Sweetie Pie' is a miniature bell pepper that is easy to grow with excellent fruit set even under hot and humid conditions. The small, 3-ounce peppers are thick-walled, sweet, and flavorful. Bred by Clover Seed Co., Ltd.

***Cucurbita moschata* 'Honeybaby' (F_1 winter squash) (Regions: Heartland)**

The short, wide fruits of 'Honeybaby' are sweet and nutty, and slightly larger and meatier than similar cultivars. The vines grow 2 to 3 ft in a semi-bushy habit. Bred by Seeds by Design.

***Cucurbita pepo* 'Sugaretti' (F_1 winter squash) (Regions: Southeast)**

This new spaghetti winter squash produces a generous crop of mid-sized, orange-fleshed, striped fruit on semi-bushy, determinate vines with good powdery mildew resistance. The hard shells protect the flesh for a long shelf life. Bred by Seeds by Design.

***Penstemon barbatus* 'Twizzle Purple' (F_1 penstemon) (Regions: Southeast, Heartland)**

Vibrant purple blooms present a new and unique color in penstemon. This North American native blooms profusely with 1-inch tubular flowers on long, slender stalks that grow up to 35 in. high, making this cultivar a magnet for pollinators from mid- to late summer. Bred by Van Hemert & Co. Seeds.

***Petunia ×atkinsiana* 'Evening Scentsation' (F_1 petunia) (Regions: Heartland, Great Lakes, West/Northwest)**

'Evening Scentsation' is a medium-sized multiflora petunia that produces fragrant flowers with notes of hyacinth, sweet honey and rose. The scent is stronger in the evening hours. Bred by Takii & Co., Ltd.

***Pisum sativum* 'Patio Pride' (pea) (Regions: Southeast)**

This compact pea produces sweet, uniform pods that are very tender when harvested early. This cool-season crop needs only 40 days to maturity. Succession plantings yield a consistent harvest over many weeks. Bred by Terra Organics.

***Solanum lycopersicum* 'Chef's Choice Yellow' F_1 (tomato) (Regions: Southeast)**

'Chef's Choice Yellow' is the fourth addition to the popular Chef's Choice tomato series, producing hearty beefsteak-type tomatoes with a showy yellow color. Disease-resistant plants produce 30 or more 10-ounce fruits on 5-ft, indeterminate vines. Bred by Seeds by Design.

In summer 2017, the first three AAS National Winners for 2018 were announced:

***Capsicum annuum* 'Onyx Red' (ornamental pepper)**

Compact, well-branched plants display dark black foliage that contrasts well with a multitude of shiny red fruits. Bred by Takii & Co., Ltd.

***Solanum lycopersicum* 'Red Racer' (F_1 tomato)**

Cocktail-sized tomatoes with great taste are produced on determinate plants that perform well in small gardens and containers. Bred by EarthWork Seeds and distributed by Garden Trends Wholesale.

***Zea mays* 'American Dream' (sweet corn)**

Vigorous, healthy plants produce ears with very tender, super sweet, bicolored kernels with good tip fill. Bred by Illinois Foundation Seeds, Inc.

More information on AAS and AAS winners is available at: www.all-americaselections.org

Vegetable propagation by grafting and its importance©

P. Devi[a], A.S. Attavar and C. Miles

Department of Horticulture, Washington State University, Northwest Washington Research & Extension Center, 16650 State Route 536 Mount Vernon, Washington 68273, USA.

Abstract

Grafting vegetable plants onto specific rootstocks that are resistant to soilborne diseases such as verticillium wilt and fusarium wilt has become a common practice, attracting interest among intensive vegetable crop producers as well as organic growers. It is a unique horticultural technique that involves the joining of two plants through their vascular tissues in order to take advantage of their combined characteristics. There is documentation that grafting originated in China in 1560 BC. However, vegetable grafting was started in Japan in the 1920s to overcome soilborne diseases. Vegetable grafting was introduced to Europe in the late 20th century, and was brought to the USA almost 20 years ago. Today, grafting accounts for about 97% of watermelons, cucumbers, and eggplants that are grown in greenhouses. With the loss of the soil fumigant methyl bromide, the potential of grafted plants for disease control and the costs and labor needed for grafting have become important topics of study. Grafting has the potential to increase commercial cucurbit and solanaceous crop production in the USA by overcoming soilborne pathogen impediments by providing a more vigorous root system, increasing fruit quality, and improving water and nutrient uptake efficiency. For grafting to be a viable alternative pest management strategy in the US, efficient cost and labor-saving grafting methods are needed. Our current research studies are investigating how to optimize the success rate for grafting vegetable transplants utilizing the one-cotyledon grafting and splice grafting methods to reduce labor requirement. Additionally, we are also testing grafted plants to control verticillium wilt caused by *Verticillium dahliae* in Washington.

[a]E-mail: pinki.devi@wsu.edu

Enhancing perennial stock plant production through the use of plant growth regulators©

S. Markovic[a] and J. Klett[b]

Department of Horticulture & Landscape Architecture, Colorado State University, 301 University Ave., Fort Collins, Colorado 80523, USA.

Abstract

Our research group is working with two perennial plants, *Heuchera sanguinea* 'Snow Angel' and *Epilobium canum* subsp. *garrettii* (syn. *Zauschneria garrettii*) 'Pwwgo1s', Orange Carpet® creeping hummingbird trumpet, due to production problems with these plants in greenhouses and nurseries throughout the Mountain West region. Growers had identified these two and a few other Plant Select® brand plants for propagation research. Four variables (growing medium, container size, fertilizer, and plant growth regulators) are being studied for stock plant production. The PGRs (Fascination (gibberellic acid), Verve (ethephon), and Configure (cytokinin)) are being studied at a high and low rate based on label rates, grower recommendations, and prior research. Six PGR treatments and a control are being used. The first repetition of this experiment was conducted at the Horticulture Center greenhouses at Colorado State from December 2016 to March 2017. PGR applications were made once a month with data collected at 2-week intervals. Data were collected on the number, fresh weight, and dry weight of cuttings taken, and height, width, and number of breaks (branches) on the stock plants prior to cuttings being taken. The second repetition of the experiment is under way and two rounds of data collection have been done starting in August 2017, with the remaining two rounds of data collections to be completed in November 2017. The data collected in the first repetition have been statistically analyzed with results showing increases in some treatment groups in comparison to the control and other treatments. The increase in vegetative production for the two perennials in this study lead to the belief that using PGR treatments on stock plant production will lead to an increase in vegetative growth and more overall success for the propagator trying to produce these varieties of perennials.

[a]E-mail: sean.markovic@colostate.edu
[b]E-mail: jim.klett@colostate.edu

Selecting salt tolerant pistachio rootstocks using tissue culture©

D.P. Sharma[a]

Dry Creek Laboratories, Duarte Nursery, 1618 Baldwin Road, Hughson, California 95326, USA.

Abstract

The presence of excessive amounts of salts in soil or irrigation water hinders plant growth and productivity. The salts responsible are chlorides, sulfates, carbonates, and bicarbonates of sodium, calcium, and magnesium. The presence of large amounts of boron is also a problem in certain locations. Over 300 million acres of land in the world are affected by this malady. In the Central Valley of California, the fruit and nut bowl of the world, land suitable for cultivation and fresh irrigation water are becoming increasingly scarce; thus, there is a need to extend cultivation to areas that are high in salinity and/or have brackish water available for irrigation. Pistachio is an important crop in the Central Valley and the gradual increase in demand is extending its cultivation to soils or irrigation water with higher salt content. Therefore, there is a need for a pistachio rootstock that can withstand high salts and supports a productive scion cultivar. Seeds of a popular pistachio rootstock, UCB-1 (*Pistacia atlantica* × *P. integerrima*; which came out of controlled crosses at the University of California, but has shown genetic variation within seedlings), were procured, stratified at 40°C for 6 weeks, surface sterilized, and germinated in vitro in the dark. About 5-mm sections of the hypocotyl and epicotyl were excised and placed on a defined medium and grown in an aseptic environment under 30 µM of fluorescent light and at 25±2°C. Individual sections developed into shoots and were multiplied as separate clones and were grown on media containing differential range of salts from 0 to 10,000 mg L^{-1}. Shoot growth was evaluated on a visual scale from 0 to 10. Clones that showed better growth under high salts were selected, multiplied, and acclimated for field trials. Four of the clones, namely UCB-D71, UCB-D90, UCB-D110, and UCB-D154, outperformed others in the field over 2 years in multilocational trials. These clones were selected and patented before public release. The field trials are still ongoing to evaluate fruit yield and quality with different scion cultivars grafted onto them.

[a]E-mail: dharam@drycreeklab.com

Optimized micropropagation protocol to establish high-yielding true-to-type plantations of elite genotypes of *Tinospora cordifolia* for consistent production of therapeutic compounds©

V. Srivastava and R. Chaturvedi[a]

Department of Biosciences and Bioengineering, Indian Institute of Technology Guwahati, Guwahati-781039, Assam, India.

Abstract

***Tinospora cordifolia* (family: *Menispermaceae*) is an ancient medicinal plant and is commonly known as amrita, giloy, and guduchi. This woody liana is a large, deciduous, climbing shrub with heart-shaped, membranous, cordate leaves. The ayurvedic charisma of the plant is by virtue of its succulent stem and aerial roots. It is widely distributed in the Asian and African subcontinents and grows to an altitude of 300 m. The plant is characterized by being a therapeutic amalgamation of secondary metabolites including alkaloids, terpenoids, glycosides, steroids, and other classes of secondary products. Therefore, it is known as a natural immune-modulator against jaundice, skin diseases, constipation, tuberculosis, leprosy, cancer, malaria, dengue, and diabetes. Tremendous usage of this plant has made it a threatened species and a need for its conservation is focused on plant tissue culture technology, allowing micropropagation of the plant throughout the year and providing elementary material for pharmaceutical research. The current investigation presents a successful method for large-scale clonal propagation of the plant using nodal segment explants taken from field-grown parent plants and initiated on MS medium (Murashige and Skoog, 1962) supplemented with 6-benzylaminopurine (BAP). An average of 8-fold shoot multiplication of *T. cordifolia* was obtained within 5 to 6 weeks of culture for those explants exhibiting multiple shoot proliferation. The in vitro leaves from established elite clonal lines were utilized to generate high-yielding callus cultures of *T. cordifolia* for enhanced production of protoberberine alkaloids. In vitro callus cultures were obtained on MS medium supplemented with 6-benzylaminopurine (BAP) and 1-naphthaleneacetic acid (NAA) at varied concentrations. The identification and purification of alkaloids was performed via thin layer chromatography, high performance liquid chromatography, and mass spectrometry from in vitro-raised cell cultures of *T. cordifolia*. Therefore, present research highlights the suitable strategies for conserving the parental characters of the plant and superior production of medicinally important alkaloids, devoid of any seasonal and regional variations, in minimal space and time.**

[a]E-mail: rakhi_chaturvedi@iitg.ernet.in

Decreasing blue light increases growth of four diverse species©

B.V. Swan[a] and B. Bugbee

Crop Physiology Laboratory, Department of Plants Soils and Climate, Utah State University, 4820 Old Main Hill, Logan, Utah 84322-4820, USA.

Abstract

Light quality (wavelength) and quantity (intensity) play an integral role in plant growth and development. It is understood that both red and blue light are necessary for plant growth, and it is thought that green light may be beneficial for lower leaf photosynthesis. Photobiology studies using LEDs are primarily executed at low light levels (photosynthetic photon flux (PPF) lower than 200 µmol m^2 s^{-1}). This was because of the inefficiency of LEDs at high light levels. In this study, we investigated the effects of decreasing blue light on lettuce and kale, and the interactions between high light (PPF; 500 µmol m^2 s^{-1}, 11.5 mol m^2 d^{-1}) and low light (200 µmol m^2 d^{-1}, 28.5 mol m^2 d^{-1}). Eight treatments with varying levels of blue light where used to analyze the effect of decreasing blue light on lettuce. The treatments included: cool, neutral, and warm broad-spectrum LED lights; 30, 20, and 10% blue light (red light as a background); 20% blue with 10% green light and 10% blue with 20% green light (red light as a background). 'Siberian Dwarf' kale growth (fresh mass, dry mass, and leaf area) increased with decreasing blue light, but the effect was not statistically significant. Leaf length was the only parameter in lettuce that significantly increased with decreasing blue light. Growth of 'Red Salad Bowl' lettuce increased significantly with decreasing blue light. Lettuce leaves were very sensitive to changes in light quantity, and showed a foliage color change at high light. 'Boston' cucumbers were sensitive to both light quality and quantity. These results suggest that increasing blue light has a negative effect on plant growth, and that there are interactions between high and low light levels.

[a]E-mail: bostonvswan@gmail.com

What is a "good" root system?©

C.E. Whitcomb[a]

Lacebark, Inc., PO Box 2383, Stillwater, Oklahoma 74076, USA.

Abstract

Lush green foliage and bright flowers continue to hold most of the attention of landscapers and homeowners purchasing nursery plants. Recently, roots have finally been getting some attention. However, there is a great deal of misinformation about just what constitutes a "good" root system. Often, what is touted is unnecessarily flawed. Based on numerous container research studies, I provide six examples of "good" root systems compared with flawed root systems.

Example 1: oak seedlings at three days after germination. A seedling with a good root system has already responded to air root pruning and formed many new roots. A seedling grown without air pruning continues to put all its energy into "one basket" by extending a single taproot downward.

Example 2: propagation containers with and without air pruning. A seedling root system in a container with air pruning will be branching at all levels along the container column. Without air pruning, a seedling has a few new roots near the bottom which will already be showing the problem of root circling.

Example 3: aeration and drainage. A well branched fibrous root system is produced in substrate with good aeration and drainage. However, poorly aerated substrate and inadequate drainage result in a poor root system.

Example 4: a tree after transplanting and growth in 3-gallon containers. A round container designed with ledges, directing ribs, and holes breaks the cycle of circling and stimulates new roots throughout the container column. Unfortunately, trees grown in conventional containers without ledges, ribs, and holes show the standard pattern of circling roots.

Example 5: trees after 3 to 5 years of production. A tree grown in a unique root-tip-trapping, fabric container shows internal branching with so many tiny, active root tips that it is difficult to count them all. However, when roots of trees grown using traditional ball and burlap systems are revealed, there are just a few large roots present, so there are few roots to support the tree and extend into surrounding soil after transplanting.

Example 6: the finishing stage of production of large specimen trees. Even at 5-inch diameter, trees grown using systems that promote root branching continue to show their fibrous root system potential. However, field-grown trees produced and harvested mechanically using conventional production methods show a meager support system with only a few large roots.

In nursery production, the ultimate growing site of a plant is not the container in which it is grown. Rather, plants are to be transplanted and expected to establish and grow. Often unknowingly, insufficient, non-branching, circling root systems created by standard container methods complicate the health of a plant for many years. However, with the proper growing techniques, roots can be produced that are fibrous, oriented for extension in all directions, and capable of helping the plant reach its full potential in an efficient manner.

[a]E-mail: carl@lacebarkinc.com

Evolution of plant production in containers©

C.E. Whitcomb[a]

Lacebark, Inc., PO Box 2383, Stillwater, Oklahoma 74076, USA.

Abstract

This paper highlights some of the historical research that led to containers that can improve the root system, rather than just acting as root packaging. Prior to 1968, plant containers, which had once been metal cans, were mainly smooth, injection-molded, plastic pots that created circling, congested roots. To this day, many nurseries fail to provide their customers with root systems without these problems.

In 1968, Dr. Whitcomb grew trees in bottomless milk containers. This created root pruning, but only at the bottom of the containers, so additional designs were tested. In 1970, a "slotted" container with openings in the sidewall was tested, but the side pruning was minimal and water loss was excessive.

Experiments on pot-in-pot production were evaluated in 1973 and showed root circling and escape using this production method. Also that year, copper was tested as a root pruning method, but results revealed stunting and nutritional interference.

In 1983, a porous, aboveground fabric container was tested. It would later earn a patent in 1985. However, with inconsistent pruning, some root escape, and water loss when used above the ground, additional designs were needed.

Based on additional studies, an injection-molded, plastic container that created root tip trapping without holes was patented in 1984. A container with a V-shaped rib for air root pruning was patented in 1985. A unique, 4-pack design of a propagation container that created root pruning throughout the container was patented in 1988. This engineering led to the design being applied to 1-gal and 3-gal injection-molded containers in 1989. Similarly, a patent was awarded for an improved design of 60-cell, 32-cell, and 18-cell propagation trays in 1996.

A new and improved "tree bag" design with precise openings and more consistent pruning was released in 1990. (Later, in 1997, this fabric container would be sewn to fit cinder blocks as an additional, stable method of production). Also in 1990, a patent was awarded for an expandable, air-root-pruning container.

In 2003, a white, soft-sided, bilayer fabric was tested, resulting in a root-branching, water-conserving container. In 2010, this design earned a patent, with a faster-draining design earning a second patent in 2011. 2004 brought the release of an improved design of the expandable root-pruning container, which was awarded a patent in 2009.

Research conducted during this 40-year period not only revealed flaws in designs, but proved that root pruning can be achieved in containers via several methods: air root pruning, constriction pruning, and root-tip trapping. With these multiple methods, containers were designed that efficiently create better root systems, whether above the ground, on the ground, below the ground, or on benches. These patented containers reduce production times for growers, conserve water and nutrients, and produce plants with a higher success rate after transplanting and during establishment.

[a]E-mail: carl@lacebarkinc.com

Improved air layering system for tropical hardwood ornamentals in Hawaii©

J. DeFrank[a]

Department of Tropical Plants and Soil Science, University of Hawaii at Manoa, 3190 Maile Way, Room 102, Honolulu, Hawaii 96822, USA.

Abstract

The USA patent literature contains many forms of air layering devices. Hard structures with hinged sides can be found in the form of orbs, ellipses, and multichambered plastic pots. Additionally, pre-cut plastic sheets with attached gauze pads as the rooting medium and hydrophilic polymer tubes provide alternatives to pre-sized, hard enclosures. A new air layering system was developed in Hawaii that provides for wide variation in stem diameters and rooting medium volume. In our air layering system, rooting medium (high quality, long-stranded sphagnum moss) is encased in a tubular plastic net sack with length dependent on stem diameter and desired rooting medium volume. Large, woody stems (4- to 8-cm diameter) of a sterile, ornamental shade tree (*Cassia* × *nealiae* 'Wilhelmina Tenney', or rainbow shower) were the study structures used for refinement of the net sack air layering device.

To maximize success in rooting air layers on large stems of *Cassia* ×*nealiae* 'Wilhelmina Tenney' (rainbow shower), several aspects of the air layering technique needed to be optimized. Large, woody stems need freely slipping bark for easy girdling to stimulate root initiation. Once a 4- to 5-cm section of bark is removed, the underlying cambium layer must be thoroughly removed to prevent reconnection during the root initiation phase. A serrated knife is used to make a tangential cut from the outer bark to the hardwood stem section to expose the proper area of the cambium. Knife serration produces a ridged area that maximizes the surface area receiving Hormodin 3 (0.8% indole-3-butyric acid powder). A stiff textured brush (i.e., a new toothbrush) is best for inserting the hormone powder deep into these stem ridges.

Net sacks filled with rooting medium are treated with ready-to-use insecticide powder (5% carbaryl dust) prior to stem attachment to prevent ant colonization of the layer. Application of the moistened net sack begins at the top of the girdle and is tightly wound in a spiraling fashion around the stem. Increased rooting medium volume is achieved with overlapping layers of the netted medium. Once the desired rooting medium volume is obtained, an S-shaped fastener (an expanded metal paper clip) is used to secure the rooting sack to the stem.

When rainfall is expected during the root initiation period, drainage of the netted medium is enhanced by placing a wooden chopstick between the stem and the rooting medium. The entire netted sack is tightly covered with overlapping layers of 12-cm-wide black plastic shrink wrap, ensuring a loose fit at the top of the air layer and exposure of the drainage chopstick at the bottom. It is important to allow for swelling at the top of the air layer to prevent phloem restriction at the root initiation zone. The loose-fitting plastic wrap allows stem swelling as well as ant entry, hence the need for insecticide within the rooting medium. A properly applied net sack of rooting medium will allow for drainage, swelling above the root initiation zone, and insect exclusion.

In Hawaii, an actively growing tree will produce abundant roots in 2 to 3 months. Optimum time of year for air layering the 'Wilhelmina Tenney' rainbow shower stems is October to February, when winter rains stimulate growth and flowers are absent.

[a]E-mail: defrenk@hawaii.edu

Technical sessions, Monday morning, 30 October 2017©

K. Gantt[a]

Hefner's Nursery, 4135 Springs Road, Conover, North Carolina 28613, USA.

The 42nd Annual Meeting of the International Plant Propagators' Society-Southern Region of North America convened at 7:30 am at the Omni Park West Hotel, Dallas, Texas with President Kevin Gantt presiding.

PRESIDENT KEVIN GANTT

President Gantt welcomed everyone to Dallas, Texas for the 42nd Annual Meeting of the International Plant Propagators' Society-Southern Region of North America (SRNA). He thanked Local Site Committee Chair, Benjamin Berry and his committee and volunteers for the long hours in arranging the excellent tours, hotel, other planning activities and all their attention to detail.

He welcomed students, first time attendees and new members, asking them to stand and be recognized. Gantt thanked the Executive Committee, and Elliott Hallum's Sponsorship Committee, which raised $39,000 in cash sponsorships - which was outstanding. Gantt encouraged the membership to visit and show their support of our sponsors during the meeting. He encouraged all members to make new members and first-time attendees feel welcome—share with them and seek from them. He called for good questions and enthusiastic participation at the Tuesday night question box.

Gantt announced that the SRNA has just initiated the Southern Region Educational Endowment, which will be discussed in greater detail later in the program. It will greatly enhance our region's ability to support students and early career professionals – and ensure continued quality of the outstanding educational programs our region is known for.

Gantt announced that this is the fifth year our region has participated with the European Region in the *Early-Career Propagator Exchange* program between the two regions. He recognized Sophie Lewis from Great Britain (European Region), who was hosted by Judson LeCompte, Charles Parkerson and the SRNA. Lis Meyer of the SRNA was our designee to the European Region. Both of these early-career professionals had an incredible exchange experience in our respective regions. This is the sixth year we are doing the *Vivian Munday Young Horticultural Professional Scholarship Work Program* (*Vivian Munday Scholarship*). We currently have four young professionals: Alexis Anthony (Clemson), Connor Ryan (University of Georgia), Carlee Steppe (University of Florida) and Madison Hindsley (North Carolina State University)—who are making a strong contribution to this year's program. Gantt thanked Program Chair and 1st Vice-President, Dr. David Creech, for the excellent program and slate of speakers he assembled.

PROGRAM CHAIR DR. DAVID CREECH

Program Chair Dr. David Creech welcomed all members, guests and students. He thanked the membership for the opportunity to serve them, and then reviewed the scheduled program. The Question Box, scheduled for Tuesday evening, was to be chaired by Three Wise Old Men on Stools: Drs. Mike Dirr, Carl Whitcomb and David Creech. He then introduced the first moderator, Dr. Andrew King.

[a]E-mail: kevingantt@charter.net

Nursery innovation on a budget-making every penny count©

J.C. Harden Jr.[a]

Mortellaro's Nursery, Ltd. 16946 IH 35 North, Schertz, Texas 78154, USA.

INTRODUCTION

Today's nursery business faces increasing expenses and operating costs on a daily basis. Increased expenses include: labor, supplies, shipping and taxes. Improving efficiency of operations through innovations is one of the best ways to increase profitability. The first step for innovations is a willing attitude for change. Innovations in a business need not cost a large amount of money—in order to enhance efficiency and save money in the long run. Innovations entail improving the nursery site layout, changes in organization of supplies and products, addition or modification of equipment, changes in supply management—and enhancing and streamlining organization and communication with personnel.

NURSERY SITE LAYOUT

The nursery site layout is something that many businesses never consider until they change locations. The layout of a nursery should maximize efficiency in the movement of people and materials—including sales, chemical applications, irrigation and drainage, shipping and supply management. A curvilinear layout is often considered one of the most efficient designs for a nursery (Figure 1). There is no need to wait to improve your layout for efficiency.

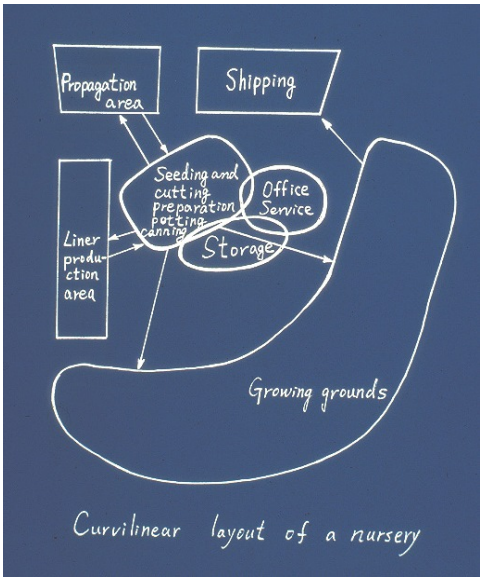

Figure 1. A curvilinear layout is one of the best designs for nursery production.

Placement of crops is something that many people overlook. There is more to plant placement than just light or winter protection requirements. Laying out an operation includes grouping: (1) plants nearest to the sales area, (2) commonly sold plants together, (3) plants with the same chemical requirements for one stop spraying, (4) high or low water usage plants together—based on irrigation needs, and (5) low water use plants in drainage areas when capture of water runoff is not feasible.

Location and control of highway vehicles on the nursery is becoming more important.

[a]E-mail: jamesharden@hardentx.com

Locating the receiving, shipping and customer pickup in the same area—allows crews to assist each other and reduces traffic flow of non-company vehicles on the property. Many nurseries are changing their customer and delivery areas to meet quarantine requirements.

SIGNAGE: PLANT AND SEASONAL QUOTAS, SOIL MIXES, HORMONE RATES

Using signage to enhance efficiency is often overlooked. Many companies are concerned at the initial cost of signs or that people will steal their production information. Most production info is only relevant for that particular company and crop mix. Signage cost can be minimal—while significant savings in time, money and accuracy are gained in the long run.

Mortellaro's Nursery, Ltd. uses signs for hormone rates, standard and seasonal production numbers, soil mixes, pictures of insects and disease, and scheduled chemical treatments. At our nursery, we post signs on blocks and greenhouses that list quantities of each crop in the block or greenhouse (Figure 2). The signs list year-round and seasonal quantities needed. This allows production crews to do quick visuals of what crops need to be potted—and allows managers to prioritize crop varieties rather than worry about needed production numbers on a daily basis. The same signage is used on propagation tables so that the propagation department fills a production need as soon as it appears. Colored signs are used for different propagation soil mixes and those colors are also used for the colored saran that is wrapped around pre-filled pallets (Figure 3). The color system solves any language or literacy problems with our crews.

Figure 2. Production signage lists for greenhouse bow space usage.

Figure 3. Colored signage for soil mixtures, including color-coded shrink wrap of media on pre-filled pallets.

TOOL TRANSPORT AND STORAGE

Small, 2-cycle gas engines are used extensively in our nursery. We find it easier to store these machines in our shop on a pallet and set it outside daily for crews to sign-out and sign-in, as needed (Figure 4). This method reduces traffic flow in our shop area and avoids disturbing our mechanic. Storing of handheld power tools was also an issue until we created two different methods of storing them along with batteries. We utilize locked cabinets for tools used by field employees and unlocked storage for maintenance and mechanics in our shop (Figure 5).

Figure 4. Gas powered tools are stored and transported with racks attached to pallets.

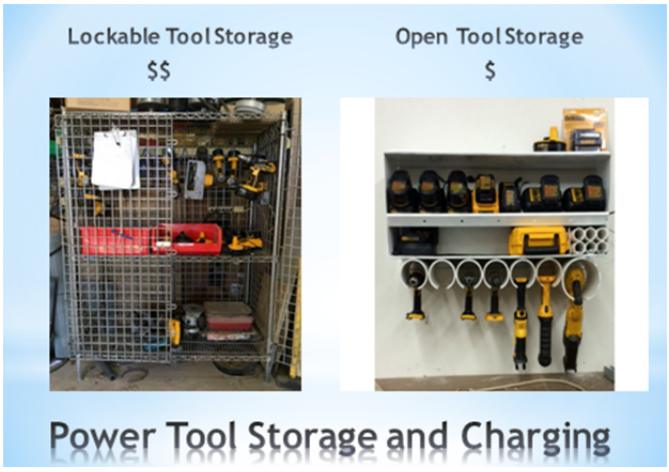

Figure 5. Lockable and open tool storage and charging area.

USING PALLETS AND BARRELS FOR ORGANIZATION

Many nurseries receive all of their supplies on pallets, but do not consider reusing those pallets for other uses. We use metal racks/pallets for storing our used pots and to transport those pots between our two business locations. We also use the metal frames from pallet totes to store material and supplies. All shade cloth and frost blankets are stored in metal tote frames when not in use. During winter, the pallet totes are placed next to the blocks where they may be used and covered with plastic.

We use cardboard and plastic barrels to hold our poly lock, nails, and staples for winterizing. The barrels and all supplies are stored in a tote frame until needed. We use small 1-gal blue sealed barrels to hold nails or bailing twine to protect it from the weather

and keep it in usable condition (Figure 6).

Figure 6. The $20 tote pallets can be placed where needed.

We store all totes in cargo containers to keep them protected from rodents and the elements. We also use the tote frames for storing load locks, blocks and cardboard shipping supplies on our dock.

MOBILE HOME ANCHORS AS TREE ANCHORS

There are many methods for anchoring trees. We utilize three techniques to anchor trees at our operation. Our most recent method utilizes mobile home anchors and mule tape to secure large containers from blowing over (Figure 7). We anchor the pot to the ground rather than anchoring the trunk. We created a steel frame to hold the anchors in place so that one person can install the anchors.

Figure 7. Tree staking with mule tape, hose, scrap carpet and mobile home anchors.

HANDHELD WARN WINCH FOR INSTALLING GREENHOUSE HEATERS

In the past, we used two men with ladders and a rope hoist to raise and support greenhouse heaters until they were bolted to the greenhouse bows. The time needed was about 45 min per house. Two years ago we started using a 110 volt Warn handheld winch (https://www.warn.com/utility/portable_winches.jsp) to raise heaters from the ground to

their mounting points in the greenhouses (Figure 8). We also created custom muffler clamp brackets for each heater. Each heater can be mounted using just a 1 cm (0.5 in.) wrench and four nuts. It currently takes one man on a ladder and one man on the ground about 15 min to raise and mount each heater.

Figure 8. A Warn winch can lift heaters with little employee effort.

PLUMBING TRAILER

We purchased a used US Air Force jet support trailer many years ago. We stripped the trailer of its hose reels and stocked it with all of our plumbing supplies including a water pump, a generator, and a compressor (Figure 9). We haul the trailer to plumbing or construction projects on our property. This allows us to have the supplies needed at the worksite—rather than inefficiently running back and forth for supplies. A used utility truck body could be utilized for the same purpose.

Figure 9. A portable plumbing trailer converted from a US Air Force surplus jet support trailer.

CONVEYORS

We have purchased used roller conveyors and modified them for different uses. We utilize small 0.3 m^2 (3 ft^2) square rollers to move 95-gal and 200-gal trees on customers' trailers (Figure 10). We use 1.2-1.8 m (4-6 ft) long roller conveyors to load 30-gal and 45-gal

containers from and onto trailers. The conveyors not only reduce potential employee injuries, but also eliminate the need for equipment for larger trees and shrubs.

Figure 10. Used, portable conveyors for moving large containers.

TRACTOR WEIGHTS

Rather than purchase brand specific weights for tractors and skid steers—custom weights can be fabricated. We have used large idler rollers, large used sprockets, old tractor wheel weights, or even concrete filled pipes for weights. Any style of weight will work with the correct method of attachment. Custom weights can cost from \$0.22 kg^{-1} (\$.10 lb^{-1}) with concrete or older weights—rather than \$2.2-4.4 kg^{-1} (\$1-2 lb^{-1}) with new factory weights.

IPAD TABLETS

IPad tablets are used extensively at Mortellaro's Nursery (Figure 11). We supply tablets to all managers, supervisors, drivers, and chemical applicators. We purchase used IPad Air Tablets from Apple and protect them with a lifeproof case. This is a cost of only about \$450 per IPad. The cost is minimal with the benefits gained. The IPads are used for group texting, tracking drivers' locations and hours, multiple inspections and reports, email, shared calendars for each department, reference for customers, plant info, and chemical applications.

Figure 11. Apple IPad tablets are used extensively at Mortellaro's Nursery.

Managers use a custom written app for the following uses and reports are automatically delivered to the appropriate person:

- Insect and disease scouting
- Equipment repair tickets
- Employee warning reports
- Monthly on site equipment inspections

Drivers use the IPads for Google maps to route deliveries, check for delivery vehicle access problems, and traffic or construction delays. The IPads are also used as an Electronic Logging Device for DOT record keeping. We are able to track the drivers through Apple at no cost using "Find My Friends" as well as the ELD software. The ELD software provides all management a current list of hours available for each driver daily. We are able to communicate with drivers for upcoming deliveries, safety meetings, corrected invoices or other customer issues at any time.

Supervisors and chemical applicators receive group texts, insect and disease scout reports, production changes and any other relevant information as needed. They also have access to any production or chemical treatment info or history at the nursery.

CARGO CONTAINERS FOR WORK AND STORAGE

Cargo containers are excellent as an inexpensive building option for shop use, storage and secure office space (Figure 12). Two cargo containers can be placed with a roof between them to provide covered and even lockable storage inside and outside the containers for equipment repair and storage, fertilizer or chemical storage, or a field or sales office. Better still: using cargo containers allows the construction of an office or storage area that is classified as temporary structure and avoids the need for building permits and increased taxes for structures. Currently cargo containers can be purchased for about $2500 each for a 12 m (40 ft) unit with double doors.

Figure 12. Cargo containers can be utilized as inexpensive building options for shop use, storage and secure office space.

CONCLUSION

An open attitude to change is a necessity for innovations to work. Change needs to be

welcomed rather than feared. Innovations come in many forms such as new ideas, different styles of communication, different work methods, modified or new equipment, and new technology. Innovation needs to be encouraged not only from top down, but also bottom-up—from the people working every day. Your employees can have great ideas for changes—if you encourage their input.

Foodscaping: revolution or evolution?©

B.G. Arthur[a]

7624 Troy Stone Drive, Fuquay-Varina, North Carolina 27526, USA.

Marketing horticultural relevance is the best way to describe my passion of foodscaping. The idea is simple: add purpose to landscapes in developed areas such as suburban neighborhoods, office parks, school campuses and retirement communities—and engage landscape professionals to manage these properties. With an education in design, an enthusiasm for ornamental horticulture and a hunger for local, organically raised produce—I see potential to grow food in every cultivated space. From simple plants like garlic to low maintenance cover crops and grains—open mulch space is an opportunity for green industry professionals to develop recession-proof services for long term gains.

Cultivating food is more than a trend; it is a tremendous opportunity for the greenhouse and landscape industry to meet a demand that will not be going out of style. People have to eat! Moreover, local food sales in the US grew from $5 billion to $12 billion between 2008 and 2014 (Food Industry Research Firm Packaged Facts, 2017) (https://www.packagedfacts.com/about/release.asp?id=3717). The same study predicted local food sales will jump to $20 billion in 2019—leading to new consumer recognition of the potential value of their home landscape.

Foodscaping is simply the integration of edibles in a traditional ornamental landscape. It is a means of covering open mulch space to reduce weeds and chemical usage—while contributing to the local food movement. This design strategy is meant to empower the green industry by positioning the products and services provided as a necessity rather than a luxury.

This is not a new idea; it is a modern take on the way past generations utilized land. Foodscaping is just a new term for a logical and easy way to grow meaningful amounts of food in landscapes that already exist. Thanks to experts like Rosalind Creasy the groundwork has been set for homeowners to understand how their yards could be used to grow beauty and bounty. By connecting the expertise of growers and landscapers to the local, sustainable food movement, horticulture professionals are poised to play a critical part in the literal food chain.

Woody ornamentals are a key component of foodscape design. Regionally appropriate flowering trees and shrubs offer structure and year round interest while representing the biological diversity needed to attract beneficial insects. The maintenance of the traditional (and often existing) plant pallets of trees, shrubs and perennials is well understood by landscape contractors. Ornamentals make up more than 70% of a designed foodscape (Figure 1).

The addition of perennial edibles such as ground covers of strawberries, blueberries hedges and living grape walls provide bounty with similar maintenance requirements as commonly used landscapes plants like hollies, azaleas and roses. Fruit and nut trees offer long-term harvests while contributing habitat for wildlife and shade. Herbaceous perennials, including asparagus and figs create seasonal bounty and textural contrast. Herbs have long been utilized in landscapes for their heat and drought tolerant qualities. By growing oregano, rosemary and thyme a landscape can offer high culinary impact and nectar for beneficial pollinators.

[a]E-mail: brienne.gluvna@gmail.com

Figure 1. Foodscapes start with a professional landscape plan drawn to scale illustration by Preston Montague.

Seasonal edibles enhance landscapes by displaying recognizable plants that engage the public in a unique capacity. They also offer a multitude of health and economic benefits that positively impact communities. The inclusion of flashy annual crops like tomatoes, peppers, kale and chard add brilliant colors that blend beauty and abundant harvest. Growers and retailers can shape the foodscaping movement by offering interesting edible plants including heirloom varieties and AAS award winning selections. Choose plants that thrive in your region and promote the unique qualities that make your area the perfect climate for a specific collection of edibles and ornamentals. This will result in increased consumer confidence and success. With thousands of edibles to choose from—growers have the ability to promote a diverse collection of annuals, perennials, trees and shrubs, making every landscape an authentic space of beauty and bounty (Figure 2).

Figure 2. Foodscapes at Epcot are used to produce food for park restaurants.

Landscapes that present nutritional, ecological and aesthetic value, meet the needs of the evolving consumer. As the Millennial generation rises to be the largest group of American home buyers, now 34% for the fourth consecutive year (National Association of Realtors, 2017) (https://money.usnews.com/money/personal-finance/articles/2015/08/05/why-millennials-are-dominating-the-housing-market), meeting their landscape needs has become a profitable endeavor. However, it is not just the millennial age consumer that is demanding evolved products and services from the green industry. Many baby boomers, like my parents, are retiring and downsizing. They are approaching landscape services with a different sensibility and have a desire to make the most of less square footage. They are steering away from large lawns, high maintenance hedges and spray regiments. What they are looking for now is "garden-landscape fusion" with fresh tomatoes alongside the boxwood hedge and a ground cover of fresh salad greens adjacent to the knock-out rose. And they want all of this without the risk of exposure to herbicide and pesticide. They have grandkids and pets to protect!

Sustainable management in the form of weekly or monthly visits is the profitable, long term component of a foodscape. Following in line with the increased value created by the "Local and Organic" labeling of produce—foodscape maintenance is worth more than traditional "mow and blow" services. When the customer has the expectation of eating from the landscape they are willing to pay more – upwards of 50% higher!

Successful plantings always start with healthy soil. The addition of organic matter is

essential to ensure the plantings will thrive. Transitioning from salt based fertilizers and hard chemistries (fungicides, herbicides and pesticides) can seem overwhelming, but there are effective organic products and bio-control programs that can easily be applied to every landscape ensuring a safer world courtesy of green industry services.

With more than 110 million acres of suburban development in the USA, (USDA Extension Service Data, 2017) (https://cfpub.epa.gov/roe/indicator_pdf.cfm?i=51) it is important that as we nurture this emerging market. We need to recognize that there are misconceptions revolving around how to grow food in modern landscapes. Many homeowners believe property values will go down with a rogue farmer on the cul de sac, hence restrictive HOA covenants. It is important to communicate and recognize that landscapes are not meant to be farms. Instead, the goal of a foodscape is to cultivate supplemental amounts of produce while meeting the aesthetic standards of the surrounding community.

Start by thinking "outside the box". Lumber encased beds are NOT the only way to grow food. In fact, these infamous raised beds are generally the cause for the "no food in the front yard" mantra of suburbia. Boxed beds can cause decreased production due to over planting which invites insect and disease to wreak havoc. Additionally this method of containing edibles creates monocultures, as our food crops lack bio-diversity. Home gardeners generally grow edibles from only four plant families: (1) *Amaranthaceae*: beats, quinoa, spinach and Swiss chard; (2) *Brassicaeae*: cool season crops such a broccoli, cabbage, cauliflower and kale; (3) *Fabaceae*: beans, peas and peanuts; and (4) *Solanaceae*: warm season crops like eggplant, peppers, potatoes and tomatoes.

Instead, look at the bed edges of common areas like foundation plantings and property borders. This is an ideal place to grow edible plants that help deter mammal browse. Arugula, basil, garlic, onions and potatoes are candidates for this open square footage. The bed edge location provides easy access for watering and harvesting. It is likely free of the woody ornamental root systems and is often not utilized. Most importantly, EVERY SINGLE landscape has a bed edge. This adds up to millions of square feet that could be used to grow something consumable.

This approach of engaging green industry professionals in food production offers a solution to the food miles crisis while helping eliminate food deserts around the country. A newly emerging market revolves around the harvesting, processing and distribution of the crops grown in professionally managed foodscapes. Commonly designed like community supported agriculture (CSA), produce can be handled in a number of ways including weekly crop shares distributed to paying members. Another effective approach is partnering with local restaurants. Programs such as Ample Harvest (http://ampleharvest.org) can be utilized to donate produce directly to food banks serving the community.

As professional horticulturist I strive to meet the needs of a growing population and focus on ways to extend horticultural relevance in the American society. I am proud to see plants being recognized for all of the attributes they represent: beauty, ecology, health, wellness, nutrition and lifestyle. Foodscaping is a design technique that embraces the heritage of home gardening while developing a new level of sophistication for modern day living. Green industry professionals are poised to become more essential than ever by designing, installing and maintaining foodscapes that will feed our communities in a sustainable way. Join the Foodscape Revolution and harness the sun, soil and irrigation systems of the everyday landscape and start using your skills to nourish community while setting a high standard for beautiful, ethical land care!

Biography: Brie Arthur is an author and public speaker residing in Fuquay Varina, North Carolina (Figure 3). Her debut book, *The Foodscape Revolution* was published in 2017 by St Lynn's Press. Formerly the grower and propagator at Plant Delights and Camellia Forest Nurseries, she is nationally recognized for her work with the PBS television show: *Growing A Greener World*. Brie studied landscape design at Purdue University and works as a consultant to landscape contractors and wholesale growers. She is the national director of GWA Region IV, sits on the board of the North Carolina Botanic Garden Foundation and is on the executive committee of IPPS SR.

Figure 3. Brie Arthur is an author and public speaker residing in Fuquay Varina, North Carolina. Photo credit: Elizabeth Galecke.

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Commentary on woody plant breeding opportunities©

M.A. Dirr[a]

1849 Heather Lane, Bogart, Georgia 30622, USA.

INTRODUCTION

I have assembled a short list of opportunities for breeders and growers to consider. The big three—*Hydrangea, Rhododendron* (azalea) and *Rosa*—have been explored to their genetic core. However, there is still room for improvement, and I list a few hydrangea options. Reblooming and sterility are important breeding goals for many trees and shrubs.

DESIRABLE BREEDING NEEDS OF SELECT WOODY SPECIES

- *Abelia* × *grandiflora*. Compact green like 'Rose Creek'. There are improved root systems for variegated cultivars.
- *Aesculus* spp. breeding work is being done in Europe. *Aesculus californica* × *A. pavia*? There is a need for a pink form of *A. parviflora.*
- *Amorpha*. At Plant Introductions, Inc. (PII) (http://www.plantintroductions.com) we did some breeding work with *A. canescens,* a pretty grey foliaged, blue-purple flowered, compact shrub. *Amorpha fruticosa* is native to the Southern USA.
- *Aronia*. Excellent work by Dr. Mark Brand at the University of Connecticut - incorporating *Aronia* and *Sorbus.* His Low Scape® is a *Rhus aromatica* 'Gro-Low' alternative.
- *Calycanthus*. The sweetshrubs are a wide open frontier. The new *C. floridus* 'Burgundy Spice' is one of the best maroon foliage shrubs I have observed. *Calycanthus chinensis* × *C. floridus* offers potentially larger flowers plus stunning foliage. There is a need for compact versions of 'Aphrodite' and 'Hartlage Wine'.
- *Ceanothus*. Still room for a heat-tolerant, blue-flowered hybrid. *Ceanothus* × *delileanus* 'Henri Desfossé' was the best performer in the University of Georgia Arboretum (UGA) and PII evaluations.
- *Cercis*. North Carolina State and Drs. Denny Werner and Tom Ranney have bred a palette of foliage, flower, and habits that I never thought was possible. Their best work is yet to come.
- *Chimonanthus praecox*. Many unique flower selections in China. Could this be hybridized with *Calycanthus*?
- *Clethra barbinervis*. Fragrant flowers and Stewartia-like bark, large shrub/small tree status. PII breeders worked on hybridizing this with *C. alnifolia.* I swapped plants/seeds with a friend from Nova Scotia. He has a compact selection with beautiful maroon-red fall color.
- *Cornus elliptica* (formerly *C. kousa* var. *angustata), C. hongkongensis, C. capitata*. It has a terribly confused pedigree. Small dogwoods with kousa-like flowers borne later than *C. kousa.* Considered a Zone 7 and 8, 9 plant on the US West Coast. Leaves turn maroon in winter, semi-evergreen to evergreen. *Cornus elliptica* is easy to root from cuttings. *C. elliptica* 'Elsbry', Empress of China® dogwood is an outstanding selection.
- *Corylus*. Dr. Tom Molnar at Rutgers is revolutionizing filberts. He is breeding for fruit production and resistance to Eastern filbert blight (EFB); there are many beautiful ornamental types. Molnar spoke to the SR-IPPS last year.
- *Distylium*. Ten years ago—who knew or cared? It is becoming mainstream and all the brands are seeking new genetics. There is a need for a true Zone 6 selection. In China, there are numerous selections with red, yellow, variegated foliage and larger red flowers.
- *Euonymus myrianthus*. Evergreen small tree/large shrub with large yellow capsules, red seeds. I have rooted cuttings. No scale was observed. There are some 142

[a]E-mail: michirr@aol.com

Eunonymus species, offering many breeding opportunities.

- *Fothergilla*. *Fothergilla* × *intermedia* 'Mount Airy' dominates the market. New material collected from the entire range of *F. gardenii* and *F. major* is promising.
- *Hydrangea macrophylla*. Where do breeders go for new traits? I have sought legacy/heirloom genetics for unique traits: 'Brestenburg', 'Green Mantle', 'Maréchal Foch', and 'Madaket'. There is need for developing stem and flower bud hardiness. I have purple leaf selections. Remontancy (reblooming) is still the most important trait.
- *Ilex glabra*. Don't laugh. This is a remarkably adaptable native species ranging from Nova Scotia to Florida. It is used everywhere in Middle Atlantic and New England states. *Ilex glabra* 'SMNIGAB17', Gem Box® inkberry holly and 'Peggy's Cove' (wild-collected in Nova Scotia) are the smallest. Both are female. 'Peggy's Cove' is available through the Griffith Propagation Nursery. Both cultivars would function as worthy boxwood substitutes.
- *Ilex virginica*. We can do better. We did breeding work at PII.
- *Jasminum nudiflorum*. It is hardy to Rhode Island. Used as ground cover, but does not appear to fruit.
- *Lindera*. Some 100 species, with two found in the US. Has anyone grown spicebush? *Lindera glauca* (var. *angustifolia*), *L. obtusiloba,* and *L. triloba* have exceptional yellow, orange, red, and/or purple fall color. *Lindera glauca* is cold, heat, drought, sun, and shade tolerant.
- *Photinia*. Any hope? *Photinia serratifolia* × *Rhaphiolepis* or *Eriobotrya* × *Raphiobotrya* 'Coppertone'.
- *Planera aquatic*. Who knows? Who cares? Small native Southeastern US elm-like tree favoring moist to wet habitats. Could it be a sleeper urban tree? There is even a weeping selection!
- *Ptelea trifoliata*. I have always loved this small tree/large shrub with trifoliate leaves. It is an excellent shade plant. 'Aurea' is a yellow-foliage form that comes partially true from seed. Color fades to green in heat.
- *Syringa*. PII accessioned 50 breeding lines with the idea of breeding reblooming, heat-adapted lilacs for the South. After evaluating thousands of hybrid seedlings, there was nothing to show except the best parent was 'Red Pixie'—an exceptional flowering lilac; Griffith Propagation Nursery sells it.
- *Viburnum*. I have asked visitors to the garden/nursery what they envision for their plant mix. Viburnums are frequently mentioned with caveats like fragrance, evergreen foliage, easy-to-root and overwinter, etc. I have worked on viburnums my entire career and am still in the hunt. *Viburnum odoratissimum* var. *awabuki* is an excellent screening evergreen and the new Copper Top™ from Southern Living adds pretty foliage color. My son found a wine-red branch sport of *V. odoratissimum* var. *awabuki. Viburnum utile* is an underutilized evergreen species with white flowers and red to black fruits. I have five clones in the garden. There is no cold damage and excellent heat tolerance.

A FEW EVERGREEN THOUGHTS

- In the Southeastern USA. Leyland cypress, *Cryptomeria,* and *Thuja* 'Green Giant' dominate. Are there other options?
- *Thuja koraiensis* and *T. standishii* are unique. Can *Thuja* be hybridized with *Thujopsis?* They are closely related.
- *Taiwania cryptomerioides* is a prickly evergreen that I see sporadically in the USA Southeast.
- *Keteleeria davidiana, K. evelyniana,* and *K. fortunei*. They are related to fir (*Abies*), but have heat tolerant. Trees in Quincy, Florida, Raleigh, North Carolina and Savannah, Georgia landscapes attest to their adaptability to the Southern USA adaptability. Propagation by seed and cuttings are difficult. A young professor, with time, is needed to address these challenges!

How scary is this? Two emerging pests: emerald ash borer and crapemyrtle bark scale©

M.E. Merchant[a]

Texas A&M AgriLife Research and Extension Center, Dallas, Texas 75252-6599, USA.

INTRODUCTION

I am fully aware that an entomologist in a plant propagation meeting is likely to be only seen as a bearer of bad news. At the risk of being *that* entomologist, I was asked to update you on two emerging insect pests—one that threatens the future of ash trees (*Fraxinus* spp.) in the USA, and one that has the potential to damage the economic viability of crapemyrtle (*Lagerstroemia* spp.). Besides the obvious bad news, however, I want to inject some hope. The good news is that we are discovering more effective tools that should help manage the negative impacts of both pests.

EMERALD ASH BORER

The emerald ash borer (*Agrilus planipennis* Fairmaire (*Insecta*: *Coleoptera*: *Buprestidae*) (EAB) was probably introduced into the US in the early 1990s, but was first found attacking trees in Michigan in 2002 (Herms and McCullough, 2014). Little was known about this insect prior to its discovery in the USA, as it was considered only a minor pest in its native China at the time (Wei et al., 2004). In North America, however, the impact of this species on native ash populations has been unprecedented, with five of the six most prominent ash tree species recently being listed as critically endangered as a direct result of borer attack (IUCN, 2017). Since 2002, the EAB has spread to 31 states and killed hundreds of millions of ash trees in the USA and Canada. Last year, in the spring of 2016, EAB was first detected in Texas (USDA/MSU, 2017).

Emerald ash borer attacks trees in both forested and urban sites, including otherwise healthy and vigorous trees. Larval feeding in phloem girdles and kills trees as small as 2.5 cm diameter breast height, leading to death within 5 years of initial infestation. The EAB causes virtually 100% mortality of most of the major ash species in areas where it invades (IUCN, 2017). In addition to ash, EAB has been found infesting white fringetree and cultivated olive (Cipollini, 2015; Cipollini et al., 2017), though with lower survival rates than in susceptible native *Fraxinus*.

Three factors hold some promise that EAB impacts may be somewhat mitigated in Texas and the South. First, density of urban and forest *Fraxinus* is lower in Texas (and presumably other southern states) than in the Midwest states where EAB impact has been severe. Whether patchy distribution of *Fraxinus* populations in our area will allow isolated populations of *Fraxinus* to escape EAB mortality, however, is yet to be determined.

Second, releases of classical biological control agents have shown promise for long-term suppression of EAB. Classical biological control efforts against EAB began in 2007 after release of three species of exotic parasitoid wasps by USDA/APHIS. Since that time at least one other exotic agent has been released and other native species with impact on the borer have been identified. It will take years to assess the long-term success of these releases, and of the ability of native predators to respond to EAB, but initial results have been encouraging (Bauer et al., 2015; Duan et al., 2017). Ultimately, researchers believe that biological control offers the greatest promise for economically sustainable control, and survival of native ash.

Third, effective insecticide control strategies have been developed over the past 15 years, preparing the way for practical management of EAB as it reaches Texas and the other southern states. Emamectin benzoate is a highly effective treatment and can provide ash protection for up to 3 years under high EAB pressure. This product is usually injected into the tree trunk. Other systemic insecticides, including imidacloprid, dinotefuran, and azadirachtin—are in widespread use and providing effective control for 1 to 2 years

[a]E-mail: m-merchant@tamu.edu

(McCullough et al., 2011). Prophylactic treatment of trees is generally not recommended until EAB is detected within 15 miles of a location.

CRAPEMYRTLE BARK SCALE

Crapemyrtle, (*Lagerstroemia indica* and hybrids; *Myrtales*: *Lythraceae*) is an important flowering tree widely used in horticultural plantings throughout the southern USA, and in temperate coastal areas. In 2004 an unidentified scale was discovered feeding on crapemyrtle trees in a commercial landscape in Richardson, Texas. Heavy infestations of the scale insects at this site had coated upper tree branches turning them white, while lower parts of the plants were black with honeydew and sooty mold.

Initially identified as azalea bark scale (*Acanthococcus azalea*), DNA sequence analysis of mitochondrial and nuclear regions, completed in 2015, confirmed this scale as (*Acanthococcus* (=*Eriococcus*) *lagerstroemiae* Kuwana) (*Sternorrhynca*: *Eriococcidae*), a species native to Asia and previously unknown from the USA. Subsequently, morphological features have been identified that allow systematists to physically identify the two species. Last year the Entomological Society of America approved the official common name of this insect as crapemyrtle bark scale (CMBS).

While CMBS infestations are not normally fatal to the plant, we have consistently observed that the scale significantly reduces the quality of crapemyrtle appearance via sooty mold and reductions in bloom size and abundance.

We have been conducting research on insecticide control of this scale since 2008. Soil applied neonicotinoid insecticides have been the most consistently effective in our trials. Imidacloprid applied to the root zone of the tree is a standard treatment and provides 1-2 years of control. Foliar and trunk sprays with neonicotinoids provide some suppression, but are not as effective as root treatments. Horticultural oil sprays alone have not provided effective or long-lasting scale control.

Lady beetles are frequently noted on infested crapemyrtles in our study plots. After multiple years of insecticide trials, we suspected that high numbers of lady beetles on untreated control trees contributed to difficulty maintaining high scale numbers in our untreated (control) plots. So in 2006 we attempted to exclude beneficial insects from our research plots by spraying the canopies early in the season with low and high rates of either carbaryl or cypermethrin. Significantly lower numbers of lady beetles, and higher scale numbers, were observed in plots treated with carbaryl and cypermethrin, suggesting that these insecticides kill predator insects with little or no impact on scale abundance. This research suggests that lady beetles do play a significant role in CMBS suppression, and has given us a tool to ensure consistently high scale numbers in our field trials.

The geographical range of CMBS continues to expand. While larger metropolitan areas in Texas, Arkansas, Louisiana and Tennessee are most heavily infested, CMBS is now verified from Virginia Beach, Virginia, to Seattle, Washington. A website has been developed by the Southern Region IPM Center that allows us to record scale sightings from anywhere in the country (http://www.eddmaps.org/cmbs/). Anyone who observes this scale for the first time is asked to take photos of the scale and submit it to the EDDmaps site for confirmation. This will allow us to track the spread of this scale to new areas.

Texas, Arkansas and Louisiana all have publications on CMBS describing the insect and outlining best control recommendations:

- Texas http://www.agrilifebookstore.org/Crape-Myrtle-Bark-Scale-p/eht-049.htm
- Arkansas https://www.uaex.edu/publications/pdf/fsa-7086.pdf
- Louisiana http://www.lsuagcenter.com/NR/rdonlyres/0C57CFE2-CAA2-444B-A1AB -DED45AFC5009/103115/Pub3440BugBizCrapeMyrtleBarkScale_FINAL.pdf

In my last bit of good news, this year Texas A&M AgriLife Extension and additional cooperating states received a $3.3 million grant to from the US Department of Agriculture's National Institute of Food and Agriculture for the specialty crop industry (SCRI). This grant will fund ongoing CMBS research and outreach for the next 3 years. Among the areas to be addressed in the project are study of chemical and non-chemical control methods, host plant resistance, consumer preferences and impacts of insecticide control methods on pollinators.

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Hartmann and Kester's Principles and Practices of Plant Propagation: a sneak preview of the 9th edition©

S.B. Wilson[1,a], F.T. Davies, Jr.[2] and R.L. Geneve[3]

[1]University of Florida, Department of Environmental Horticulture, Gainesville, Florida, 32611, USA; [2]Texas A&M University, Department of Horticultural Sciences, College Station, Texas, 77843, USA; [3]University of Kentucky, Department of Horticulture, Lexington, Kentucky, 40546, USA.

INTRODUCTION

The first edition of *Plant Propagation: Principles and Practices* was published in 1959. Dr. Hudson Hartmann envisioned writing a comprehensive plant propagation text in 1955 and invited his colleague Dr. Dale Kester at the University of California, Davis to be his co-author. Hudson and Dale taught or co-taught plant propagation together at UC Davis from 1945 until 1987 and both were active members of the International Plant Propagator's Society formed in 1951. Together, they co-authored five editions of their foundational textbook that has become the standard reference for teaching plant propagation at most colleges and universities. In 1990, Dr. Fred T. Davies, Jr. from the Texas A&M University joined as a third author for the 5th edition and in 1997 Dr. Robert L. Geneve from the University of Kentucky became the fourth author for the 6th edition. In recognition of the contributions of the initial authors, the textbook was renamed *Hartmann and Kester's Plant Propagation: Principles and Practices* for the 7th edition published in 2002. As the textbook marked its 50th anniversary in 2011, the 8th edition was printed with full color figures throughout the chapters. For the newly revised 9th edition, Dr. Sandra B. Wilson from the University of Florida became the fifth author for the textbook. With the 9th edition Davies, Geneve and Wilson strived to continue the tradition and original intent expressed by Hudson Hartmann and Dale Kester in the preface of the first edition that "This book provides a source of information concerning the fundamental principles involved in plant propagation and serves as a manual that describes useful techniques for propagating plants".

The 9th edition continues the tradition of presenting paired chapters where the principles underlying the science of propagation alternate with the technical practices and skills utilized for commercial plant propagation. As with previous editions, the amount of material between editions has increased substantially (Table 1), and many aspects of plant science and horticultural production systems have been integrated into each relevant chapter. The references have been updated substantially to help the reader delve deeper into these subjects depending on their interests and research needs. The majority of figures have been reconfigured and updated for the new edition (Figures 1-3). In addition, this is the first edition that presents a compiled glossary of propagation terms as a separate section following the subject matter chapters.

As in previous editions, the book is organized into five basic parts (Table 2). The initial three chapters are introductory chapters meant to support general aspects of propagation including a historical perspective, basic plant biology concepts, and the environmental control of facilities associated with propagation and nursery practices. Part two provides a discussion of seed propagation from the initial aspects of seed development through seed production, dormancy, and germination. Part three covers important aspects of vegetative propagation. This reorganized section begins with a basic discussion of clonal selection followed by the major chapters describing vegetative propagation by cuttings and grafting. It concludes with chapters covering layering and propagation by specialized structures, including bulbs and tuberous roots. The fourth part of the textbook is a discussion of propagation utilizing tissue culture techniques. This section has been reorganized to reflect the importance of micropropagation in horticultural crop production. The principles and techniques of micropropagation from meristematic tissue (axillary shoot proliferation) are discussed in Chapter 17 whereas the principles and techniques of plant tissue culture from

[a]E-mail: sbwilson@ufl.edu

nonmeristematic tissue (adventitious origin) are discussed separately in Chapter 18. The final section includes separate chapters on specific propagation techniques for fruits and nuts, woody perennial nursery crops, and annual and herbaceous perennial crops for the greenhouse and nursery. These final chapters have been updated, new species added and nearly 1,420 references have been compiled to support propagation practices.

Table 1. A timeline representing each of the nine editions, publication year, total pages, figures, references and authorship.

Edition	Year	Pages	Figures	References	Chapters	Authorship and content
1	1959	531	201	986	18	Hartmann and Kester
2	1968	659	232	1464	19	Hartmann and Kester Addition of chapter on micropropagation methods
3	1975	664	249	1497	19	Hartmann and Kester
4	1983	716	282	2104	20	Hartmann and Kester Addition of chapter on micropropagation principles
5	1990	631	315	2390	20	Hartmann, Kester, and Davies Addition of Fred Davies as 3rd author
6	1997	757	462	2930	21	Hartmann, Kester, Davies and Geneve Dedication to Hudson Hartmann; addition of Bob Geneve as 4th author; addition of chapter on biology of propagation; instructors manual with transparency masters
7	2002	840	490	3225	21	Hartmann, Kester, Davies, and Geneve Renamed "Hartmann and Kester's Plant Propagation: Principles and Practices"; CD included; color included in layout
8	2011	869	622	3292	21	Hartmann, Kester, Davies and Geneve Dedication to Dale Kester; color images; study questions at the end of chapters; instructors resource website
9	2018	945	679	3798	21	Davies, Geneve, and Wilson Addition of Sandy Wilson as 5th author; illustrations designed by Geneve; complete reorganization of tissue culture chapters; 500 term glossary

Table 2. New chapter organization of the ninth edition (Davies et al., 2018).

Plant Propagation Principles and Practices			
1	How plant propagation involved in human society	13	Techniques of grafting
		14	Techniques of budding
2	Biology of plant propagation	15	Layering and its natural modifications
3	The propagation environment	16	Propagation by specialized stems and roots
4	Seed development	17	Principles and practices of micropropagation from meristematic tissue
5	Principles and practices of seed selection		
6	Techniques of seed production and handling	18	Principles and techniques of plant tissue culture from nonmeristematic tissue
7	Principles of propagation from seeds	19	Propagation of fruit and nut species
8	Techniques of propagation by seeds	20	Propagation of ornamental trees, shrubs, and woody vines
9	Principles and practices of clonal selection		
10	Principles of propagation by cuttings	21	Propagation of ornamental annuals and perennials
11	Techniques of propagation by cuttings		Glossary- 500 terms
12	Principles of grafting and budding		

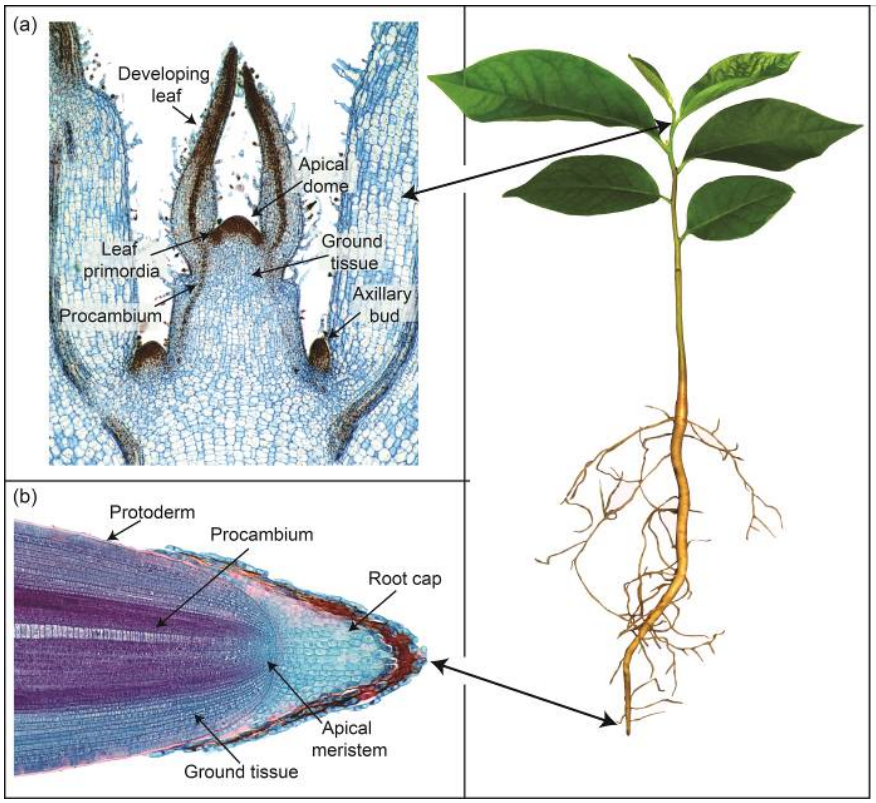

Figure 1. Photomicrographs of (a) shoot and (b) root meristems (Davies et al., 2018).

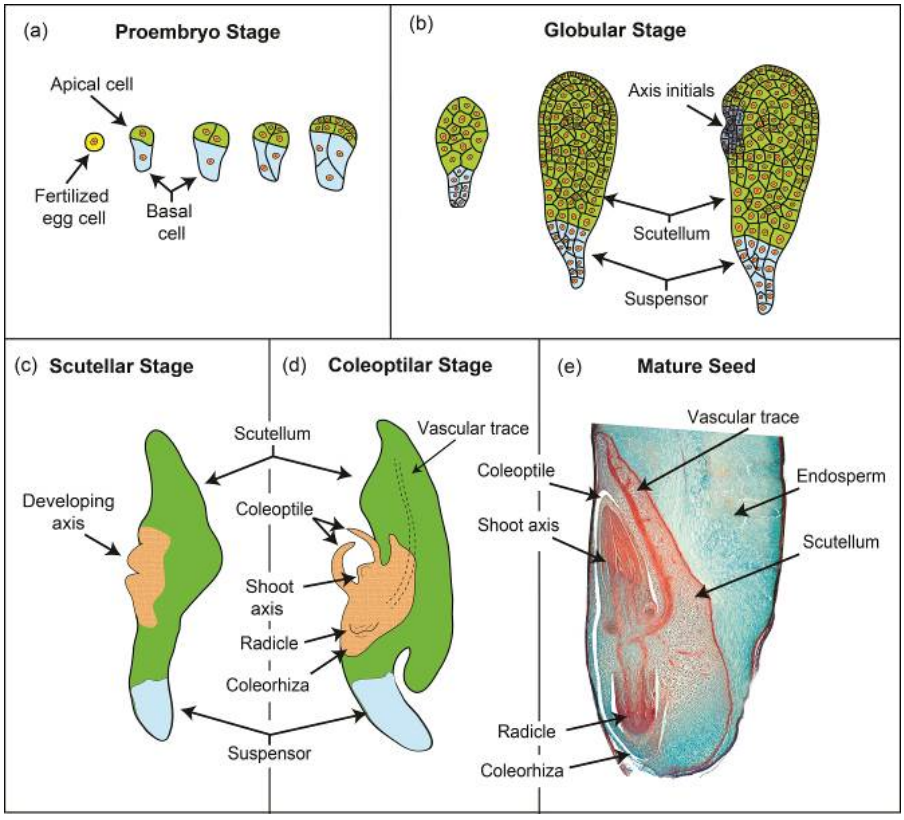

Figure 2. Embryo development in a typical monocot (corn) (Davies et al., 2018).

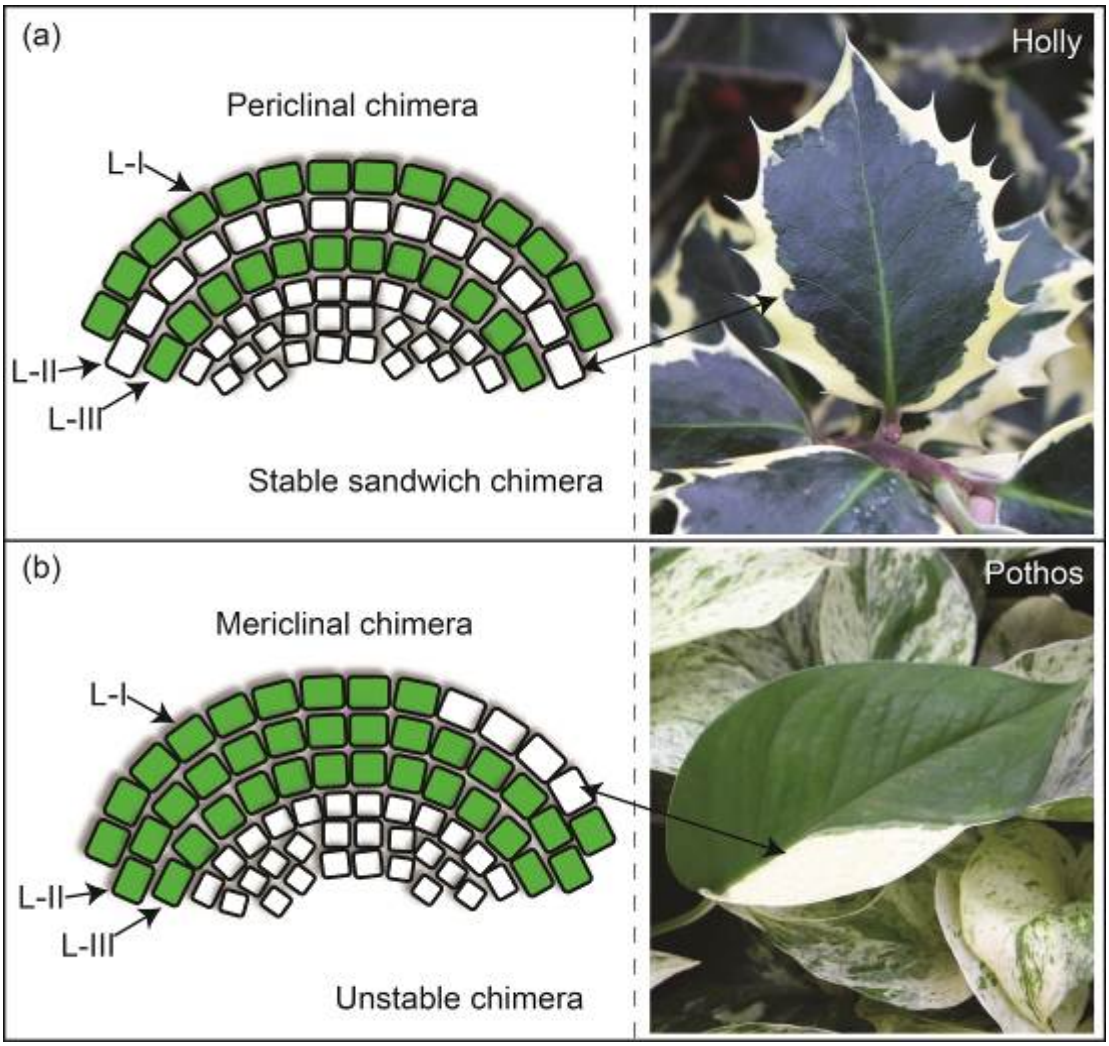

Figure 3. Two types of chimeras in variegated leaves are (a) periclinal and (b) mericlinal (Davies et al., 2018).

INTERACTIVE LEARNING RESOURCES

Supplemental to the text, there are a number of online resources available to assist instructors and students. These include an animated life cycle of angiosperms, online self-review quizzes, a web application for glossary terms, instructor PowerPoints for each chapter, and a test bank of useful questions and answers.

Plant life cycle

Sexual reproduction (fusion of male and female gametes) occurs in the flower. The sexual cycle of plant reproduction starts with the development of a pollen microspore mother cell and a female megaspore mother cell, which undergo meiotic cell divisions (Figure 4). This eventually leads to functional male pollen cells within the pollen sac and female cells within the embryo sac. Within a typical angiosperm, the steps to pollen development (microsporogenesis), ovule development (megasporogenesis), pollination, fertilization, and embryo development have been fully illustrated and narrated to enhance student learning. These concepts are discussed in detail in Chapter 4 of the text (Davies et al., 2018) and can be viewed online at: http://irrecenvhort.ifas.ufl.edu/creative_tools.html.

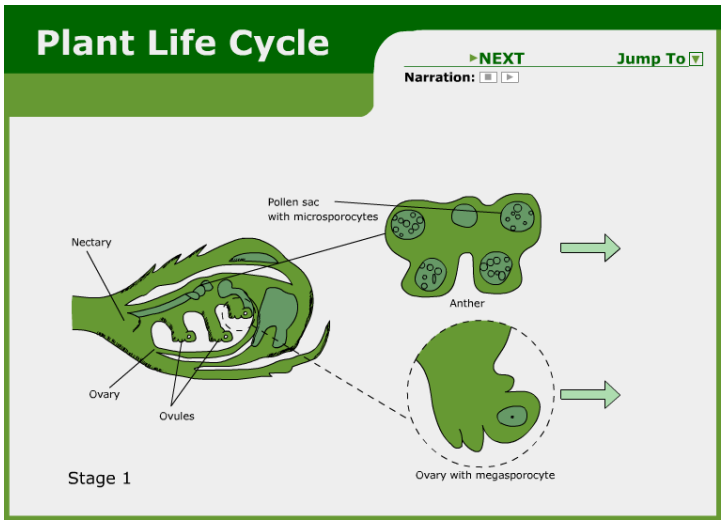

Figure 4. Screen capture of a representative angiosperm life cycle beginning with the development of microspore and megaspore mother cells. The user can advance to any stage of development using a drop down menu that is synchronized with audio narration.

Online self-review quizzes

A series of online interactions was created for students to review concepts introduced in the text (Figure 5). These were developed for each of 18 chapters and include a variety of exercises including: multiple choice, true/false, drag and dropping the correct term to its description, and identifying the correct sequence of events. For example, using a drop down menu, the user could be asked to identify the correct sequence of events that occurs in a successful graft as illustrated in Chapter 12 of the text (Davies et al., 2018). The questions are automatically graded for each chapter, allowing instant feedback. Self-review quizzes can be found at: http://irrecenvhort.ifas.ufl.edu/creative_tools.html.

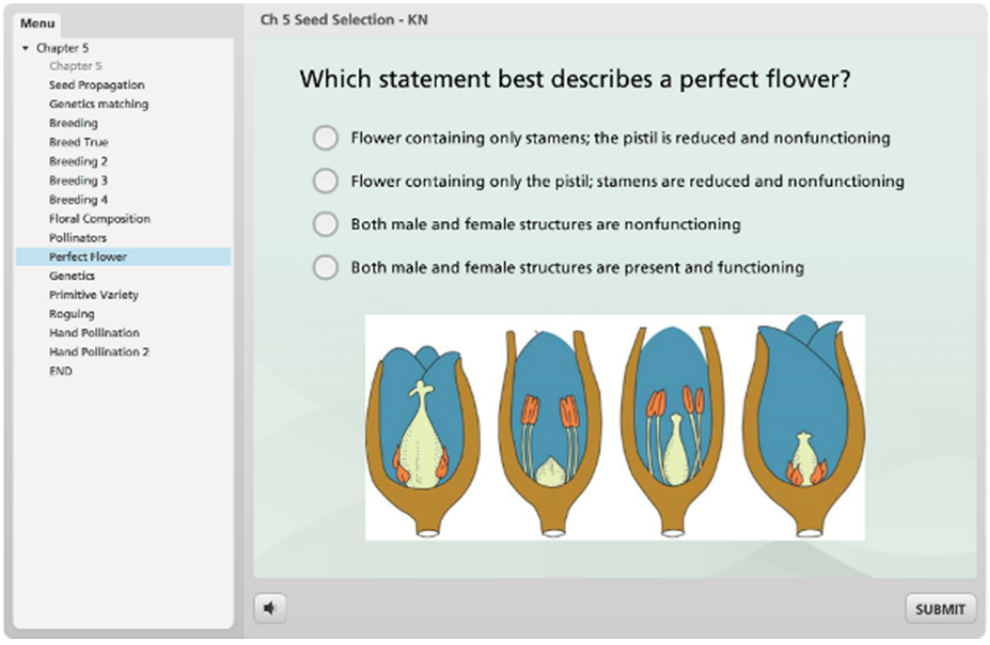

Figure 5. Illustration of a multiple choice question from chapter 5 asking the user to select the statement that best describes a perfect flower.

Web glossary

Throughout the first 18 chapters of the text (Davies et al., 2018), nearly 500 glossary terms appear in orange bold the first time they are defined. As a reference, a cumulative list of all glossary terms can be found at the end of the text. This is new to the 9th edition. In addition, a web application has been built using an alphabetical collection of glossary pages, a navigational menu system organized by topic categories, and an internal search function. This allows the glossary terms and corresponding images to be readily available on any computer or mobile device by clicking on the following link: http://irrecenvhort.ifas.ufl.edu/creative_tools.html. For example, if interested in seed terminology, the user could select 'seed propagation' from the menu, and then select from four choices: development, technology, germination, and dormancy. If the user selects 'dormancy', then another menu appears listing the types of dormancy to choose from. Exogenous seed dormancy is described and illustrated with a cross section of a seed showing the macrosclereid layer in the seed coat when this glossary term is selected (Figure 6).

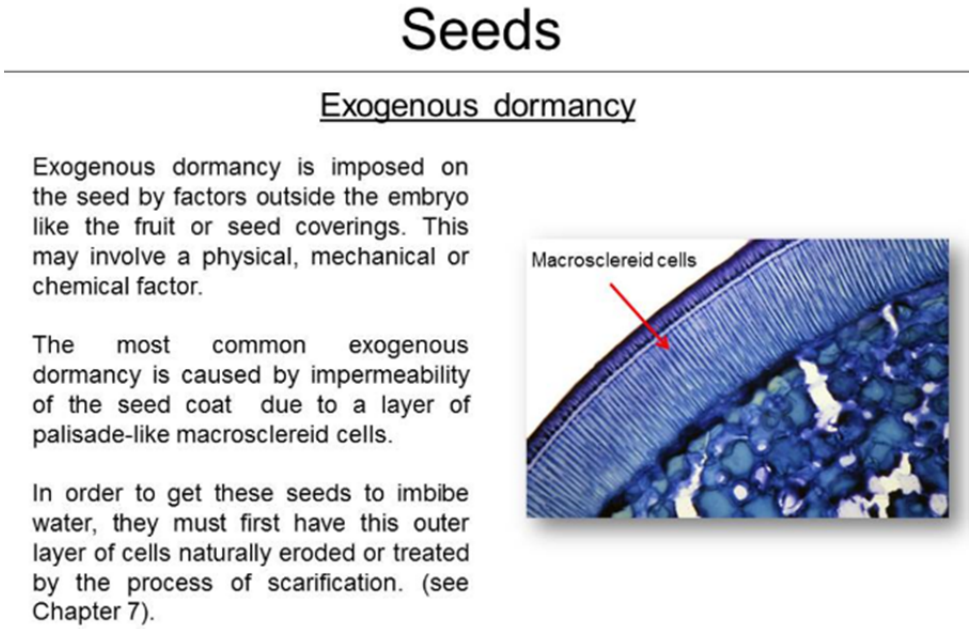

Figure 6. Cross section of a seed showing the macrosclereid layer in the seed coat when this glossary term is selected.

Online instructor resources

To access supplementary materials online, instructors need to request an instructor access code at www.pearsonhighered.com/irc. Within 48 h of registering, instructors can enter their access code, locate the textbook in the online catalog, and select the instructor resources button to find PowerPoint slides containing all of the figures for each of the chapters. There are also nearly 450 test questions (and answers) including multiple choice, true/false, fill in the blank, and short answer that students should have an understanding of upon completion of the chapters.

Literature cited

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Mulching for weed control: influence of type, depth, herbicide formulation and activation irrigation level on germination and growth of three container nursery weed species©[a]

D. Saha[1], C. Marble[1,b], B.J. Pearson[1], H.E. Perez[2], G.E. Macdonald[3], D. Odero[4] and A. Chandler[1]

[1]Environmental Horticulture Department, Mid-Florida Research and Education Center, University of Florida, 2725 S. Binion Road, Apopka, Florida 32703, USA; [2]Environmental Horticulture Department, PO Box 110670, University of Florida, Gainesville, Florida 32611, USA; [3]Agronomy Department, 2089 McCarty Hall D, University of Florida, Gainesville, Florida 32611, USA; [4]Agronomy Department, Everglades Research and Education Center, University of Florida, 3200 E Palm Beach Road, Florida 33430, USA.

Abstract

This research was conducted to assess the impact of herbicide formulation, mulch type and depth, and activation moisture on germination and growth of crabgrass (*Digitaria sanguinalis*), garden spurge (*Chamaesyce hirta*), and eclipta (*Eclipta prostrata*). Granular or liquid formulations of indaziflam, prodiamine, and dimethanamid-P + pendimethalin were evaluated for control of these weed species by in combination with either pinestraw, pinebark, or hardwood mulch at depths of 0, 2.5, or 5.1 cm (0, 1 or 2 in.) followed by herbicide activation irrigation levels (one-time irrigation level following treatment) of either 1.3, 2.5, or 5.1 cm (0.5, 1, or 2 in.). Weed seed placement (below or above the mulch layer) and light penetration through different types and depths of 0, 1.3, 2.5, 5.1, and 10.2 cm (or 0, 0.5, 1, 2, and 4 in., respectively) of mulches were also analyzed. Results showed when using herbicides, mulch depth and herbicide formulation had a greater effect on weed control compared with mulch type or herbicide activation irrigation level. Mulch depths of 5.1 cm (2 in.) and liquid formulations generally provided the highest degree of weed control. There were no differences in light penetration or weed counts when mulch was applied at levels of at least 2.5 cm (1 in.).

INTRODUCTION

Mulch can control weed growth, moderate soil temperature, and increase water availability to container-grown plants. Herbicide placement in regards to the mulch layer (i.e., above or below the mulch) is an important factor to be considered because different mulch materials interact differently with various types of herbicides (Marble, 2015). For preemergence herbicides to be effective they must be incorporated into the soil after application; this typically involves application of 0.6 to 1.3 cm (0.3 to 0.5 in.) of irrigation within 3 to 4 days or a few weeks after application to "activate" the herbicide. It is unknown if more irrigation is needed to move the herbicide down to soil when being applied over mulch. No information is available on how different mulch materials and herbicides interact with each other and there is a lack of label recommendations for the use of preemergence herbicides in the mulched nursery containers. The objective of this research was to assess the impact of the mulch type and depth, herbicide formulation, and activation irrigation levels on germination and growth of three container nursery weed species.

MATERIALS AND METHODS

Greenhouse experiment

Research was conducted at the Mid-Florida Research and Education Center, University

[a]First Place – Graduate Student Research Paper Competition

[b]E-mail: marblesc@ufl.edu

of Florida, in Apopka, Florida in 2016 and repeated in 2017. Nursery containers (946 mL or 1 qt.) were filled with a pinebark:peat substrate and amended with Osmocote® Plus 15-9-12 at the rate of 4.7 kg m^{-3} (or 0.03 lbs $gal.^{-1}$). After filling containers, approximately 35 seeds of either crabgrass (*Digitaria sanguinalis*), garden spurge (*Chamaesyce hirta*) or eclipta (*Eclipta prostrata*) were sown to the surface of each container. Following seeding, three different types of mulch materials including pinestraw, pinebark mini-nuggets, or hardwood chips (*Eucalyptus*) were added on top of each container at depths of 0, 2.5 or 5.1 cm (0, 1 or 2 in.). Liquid or granular formulations of indaziflam (Marengo® 0.622 suspension concentrate and Marengo® 0.0224 G, Bayer Crop Science, Research Triangle Park, North Carolina), prodiamine (Barricade® 4 FL, Syngenta Crop Protection, Greensboro, North Carolina and RegalKade® 0.5 G, Regal Chemical Co., Alpharetta, Georgia), and dimethenamid-P + pendimethalin (Tower® 6 EC + Pendulum® 3.3 EC and Freehand® 1.75 G, BASF Corp., Research Triangle Park, North Carolina) were applied on August 17, 2016 (Round 1) and April 2, 2017 (Round 2) at their labeled rates to eclipta, crabgrass, and garden spurge respectively. Liquid formulations were applied with a CO_2 backpack sprayer calibrated to deliver 178 L ha^{-1} (or 20 gal. $acre^{-1}$) using a 8004 flatfan nozzle (TeeJet Technologies, Wheaton, IL) at a pressure of 30 psi. Granular formulations were applied using a hand-shaker. On the day after treatment, each container was irrigated 1.3, 2.5, or 5.1 cm (0.5, 1, or 2 in.) by hand watering. Following the initial hand watering, pots were kept dry for 3 days inside a greenhouse. After 3 days, all containers were irrigated via overhead sprinkler and received 0.5 cm (0.2 in.) total per day via two separate irrigation cycles. The experiment consisted of a factorial treatment arrangement of the two-herbicide formulations, three types of mulch materials, three types of mulch depths, and three levels of activation moisture levels with eight replications per treatment. Non-mulched, no-herbicide treatment was also included for each weed species for comparison. Data collection included weed counts at 30 and 60 days after treatment (DAT). At 60 DAT, all weed species were cut at the soil line and shoot fresh weights were determined for each weed species. Shoot fresh weights were converted to percent control using the formula: Percent control = [((non-treated control – treated)/non-treated control)*100]. All percent control data were subjected to ANOVA using the PROC GLM procedure in SAS® (SAS 9.4, SAS Institute, Inc., Cary, North Carolina). Fisher's least significance difference test was used to compare between individual means of experimental variables. All differences were considered significant at $p \leq 0.05$ and each weed species was analyzed separately. Significant differences observed in monthly weed counts were reflected in fresh weight data; therefore, for the sake of brevity only percent control of shoot fresh weight data will be discussed.

Field experiment

In addition to the above experiment, another study was conducted in Summer 2017 where weed seed placements (above or below mulch layer) and light penetration through the different types and depths of mulches were evaluated. Nursery containers (11.4 L or 3 gal.) were filled with substrate and amendments as previously described. Approximately 35 seeds of crabgrass or garden spurge were sown to the surface of one-half of each container (representing seeds below the mulch layer). Following seeding, three different types of mulch materials including pinestraw, pinebark or hardwood chips were added on top of each container at depths of 0, 1.3, 2.5, 5.1, and 10.2 cm (0, 0.5, 1, 2, and 4 in.). Containers without mulch (control) were also included. Another 35 seeds of crabgrass or garden spurge were sown to the surface of mulch layer on the other half of each container (representing seeds above the mulch layer). Square transparent plastic tube of 30.5 cm (12 in.) × 3.8 cm (1.5 in.) × 3.8 cm (1.5 in.) (Sinclair & Rush Inc.) was inserted at the middle of each container containing the crabgrass seeds, below the mulch layer. All the containers were kept under full sun condition and received 1.3 cm (0.5 in.) of irrigation per day via overhead sprinkler. Data collection included biweekly weed counts and light intensity measurements in terms of photosynthetic photon flux density (PPFD) under the mulch layers at different depths using a light measuring sensor (LI-191R Line Quantum Sensor, LICOR®, Inc. Environmental, 4421 Superior Street, Lincoln, Nebraska 68504) by inserting into the transparent plastic tubes.

The experiment was a randomized complete block design with four different mulch types, five different mulch depths, with four replicates in each treatment. Light measurements data and weed counts data were analyzed (in SAS®) similarly as discussed in the previous experiment. Data from both years were combined for analysis. Due to minimal interactions between the treatment variables and for the sake of brevity, only treatment main effects are discussed.

RESULTS

Greenhouse experiment

There was no significant difference in the percent control of crabgrass, eclipta and garden spurge at three different irrigation levels (data not shown). In crabgrass and garden spurge, there was no difference in percent control among mulch types. For eclipta, the hardwood chips provided greater control (81.1%) compared to pine bark (67.5%) and pinestraw (64.8%) (Table 1). Mulch depth of 5.1 cm (2 in.) provided greater control than depths of 0 or 2.5 cm (1 in.) for all three weed species (Table 1). Liquid formulations provided greater control of all three weed species compared with granular formulations (Table 1).

Table 1. Main effects of mulch types, depths and herbicide formulations on three container weed species.

Mulch type	Percent control[1]	Mulch depth (cm)	Percent control	Herbicide formulations	Percent control
		Crabgrass			
None	84.5b[2]	0.0	84.5b	None	27.7c
Pinestraw	87.5ab	2.5	84.6b	Granular	91.1b
Pinebark	87.2ab	5.1	91.3a	Liquid	98.2a
Hardwood	89.1a				
		Eclipta			
None	54.3c	0.0	54.3b	None	41.3c
Pinestraw	64.8b	2.5	55.4b	Granular	60.3b
Pinebark	67.5b	5.1	86.8a	Liquid	80.9a
Hardwood	81.1a				
		Garden spurge			
None	89.3b	0.0	89.3b	None	66.5c
Pinestraw	96.1a	2.5	92.1b	Granular	94.8b
Pinebark	93.2a	5.1	97.5a	Liquid	99.1a
Hardwood	95.1a				

[1]Percent control = converted shoot fresh wt using the formula: [((non-treated control - treated)/non-treated control)*100].

[2]Means followed by the same letter are not significantly different based upon Fisher's protected LSD test ($p<0.05$).

Field experiment

Pinebark and pinestraw provided greater crabgrass control than hardwood as shown by weed counts (Table 2). In pots seeded with garden spurge, all mulch types provided at least a 40% reduction in weed counts up until week 6 (17.4 weeds per pot or less in mulched pots compared with 29.5 in non-mulched pots). After week 6, pinebark and pinestraw continued to provide greater spurge control than the hardwood mulch. For both crabgrass and garden spurge, seeds placed below the mulch showed less germination from week 2 until week 12, with the exception of crabgrass seeds placed below pinestraw mulch (Table 2). Mulch depths of 2.5, 5.1, and 10.2 cm (1, 2, and 4 in.) excluded over 99.5% of light and there was no difference in mulch type at depths greater than 1.3 cm (0.5 in.) (data not

shown).

Table 2. Weed counts for crabgrass and garden spurge.

	Below[2]	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below	Above
	2WAS[1]		4WAS		6WAS		8WAS		10WAS		12WAS	
						Crabgrass						
Mulch type												
Pinebark	1.3c	1.7c	1.6c	1.8c	1.5c	2.1c	1.1c	1.9c	1.1c	1.7c	1.1c	1.6c
Pinestraw	1.5c	1.2c	2.1c	1.4c	2.1c	2.0c	1.9c	1.9c	2.0c	1.8c	2.0c	1.6c
Hardwood	4.8b	6.0b	5.1b	7.4b	5.1b	7.9b	5.1b	7.4b	4.6b	6.8b	4.6b	6.2b
Control	8.5a	12.5a	8.8a	12.8a	10.0a	12.8a	10.0a	13.0a	10.0a	13.0a	10.0a	13.0a
Mulch depth (cm)												
1.3	7.9a	7.1b	8.3a	7.6b	8.3a	8.1b	7.9a	7.6b	7.3b	7.1b	7.2b	6.7b
2.5	2.0b	2.1c	2.6b	2.8c	2.8b	3.4c	2.8b	3.3c	2.8c	3.7c	2.8c	2.9c
5.1	0.2b	1.6c	0.5c	2.1c	0.3c	2.6c	0.1c	2.3c	0.1d	1.4c	0.1d	1.3c
10.2	0b	1.1c	0.3c	1.6c	0.3c	1.8c	0.1c	1.8c	0.1d	2.1c	0.1d	1.7c
0.0	8.5a	12.5a	8.8a	12.8a	10.0a	12.8a	10.0a	13.0a	10.0a	13.0a	10.0a	13.0a
						Garden Spurge						
Mulch type												
Pinebark	2.5b	5.0b	2.6b	6.3b	4.1c	7.4c	11.9c	17.4c	13.2b	19.4c	54.5c	69.9b
Pinestraw	3.6b	3.4b	5.1b	7.1b	5.7bc	7.5c	15.9c	20.0c	18.4b	22.8c	64.3c	79.9b
Hardwood	4.1b	3.8b	4.5b	5.1b	9.6ab	17.4b	40.4b	52.3b	53.2a	68.1b	174.8b	223.1a
Control	18.0a	34.0a	14.5a	29.5a	14.5a	29.5a	60.8a	97.0a	60.8a	97.0a	245.3a	254.8a
Mulch depth (cm)												
1.3	11.8b	15.0b	13.0a	17.2b	13.8a	17.8b	43.4a	56.3b	44.4ab	59.1b	166.0b	199.3b
2.5	0.8c	1.1c	1.2b	5.3c	5.3b	11.3bc	24.2b	31.6c	32.1bc	40.5bc	107.5c	137.3c
5.1	1.0c	0c	2.0b	2.2cd	4.9b	9.0c	13.7b	20.3cd	19.6c	26.8c	60.8d	93.6d
10.2	0c	0c	0b	0d	1.9b	5.1c	9.8b	11.4d	17.0c	20.7c	57.1d	67.1d
0.0	18.0a	34.0a	14.5a	29.5a	14.5a	29.5a	60.8a	97.0a	60.8a	97.0a	245.3a	254.8a

[1]WAS = Weeks after seeding.

[2]Weed counts followed by the same letter are not significantly different based upon Fisher's protected LSD test ($p<0.05$).

DISCUSSION

Herbicides need to be irrigated after application to be incorporated or "activated" (Altland et al., 2003), but very little research has been conducted to examine whether more irrigation is needed to improve efficacy in mulched areas (Marble, 2015). The result from this trial showed that when using herbicides, activation irrigation levels of 1.3, 2.5, and 5.1 cm (0.5, 1, or 2 in.) had no impact on efficacy when applied on mulched surfaces. Mulch type had no impact in crabgrass and garden spurge control. However, hardwood performed better than pinebark and pinestraw in controlling eclipta. Placement of herbicides (above or below a mulch layer) can be an important aspect to examine along with the different mulch types. Case and Mathers (2006) showed oryzalin provided better weed control when applied under hardwood bark while flumioxazin performed better when applied on top of the pinebark nuggets (Case and Mathers, 2006). A mulch depth of 5.1 cm (2 in.) improved weed control efficacy in all the three weed species. This result is in accordance with previous findings of Somireddy (2012) where mulch depth alone can provide sufficient weed control. Our data also showed that liquid-formulations performed better than granulars. Further examination of how these formulations move and bind with organic mulch is needed, but previous research suggests that liquid formulations typically provide greater control than granulars due to increased coverage (Wehtje et al., 2015).

Mulch can reduce weed seed germination and growth near the soil surface by reducing photosynthetic capability due to light exclusion (Crutchfield et al., 1986; Teasdale and Mohler, 2000). Additionally, many mulch materials such as pinebark nuggets have hydrophobic properties and quickly dry following rainfall or irrigation, which reduces water availability to germinating weeds (Richardson et al., 2008). Data suggest that an application of mulch at a depth of 5 cm (2 inches) or more can effectively control the weeds by acting as a physical barrier to the weed seed germination and growth. Based upon results from this trial, it can be concluded that mulch depth and herbicide formulation will affect weed control efficacy to a greater degree than activation moisture or mulch type. Future work will be conducted in field soils and will utilize different weed genera. We are also currently

investigating the water holding capacity of various mulches to determine which type(s) may be more suitable in a nursery environment. Additional research will also focus more closely on herbicide formulation and movement through various mulch types.

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Are cuttings a viable alternative to seeds for sweet basil production?©[a]

D. Haijie[1,b], G. Mengmeng[2] and N. Genhua[3]

[1]Department of Horticultural Sciences, Texas A&M University, College Station, Texas 77843, USA; [2]Department of Horticultural Sciences, Texas A&M AgriLife Extension Service, College Station, Texas 77843, USA; [3]Texas A&M AgriLife Research and Extension Center at El Paso, 1380 A&M Circle, El Paso, Texas 79927, USA.

INTRODUCTION

Sweet basil (*Ocimum basilicum*) is an herbaceous annual plant originating in India and tropical Asia, and now widespread in Asia, Africa, North America, South America, and the Mediterranean region (Pushpangadan and George, 2012; Wogiatzi et al., 2011). Sweet basil is one of the most commonly grown herbs in the United States with great flavor, antioxidative, and antibacterial properties due to its enhanced content of essential oils and phenolic compounds (Chiang et al., 2005; Fischer et al., 2011; Kruma et al., 2008). Thus, the concentration of essential oils and phenolic compounds in basil are important for their culinary and clinical practices.

The conventional basil production is via seed, which could be affected by poor germination rate, slow seedling growth, delayed yield production, and varied content of phytochemicals due to genetic and biochemical heterogeneity (El-Keltawi and Abdel-Rahman, 2006; Heywood, 1978; Lim and Eom, 2013). Cutting propagation is a common practice and an important tool for the production of many herbaceous and woody plant species, owing to relatively faster plant growth, high progeny uniformity, and ease of the process (El-Keltawi and Abdel-Rahman, 2006; Lim and Eom, 2013). Many studies have been conducted to test the viability of vegetative production on basil, using different explants, including nodal segments and axillary buds (Begum et al., 2002; Siddique and Anis, 2008), shoot tip explants (Siddique and Anis, 2007), leaf explants (Phippen and Simon, 2000), young inflorescences (Singh and Sehgal, 1999), and cotyledons (Dode et al., 2003). However, little is known of the differences between using cuttings and seedlings as starter plants in basil production. This trial was designed to characterize the effects of cutting and seed propagation, as well as effects of four different planting densities, on root formation, length of growth period, and biomass accumulation of basil - to evaluate the feasibility of using cuttings as starter plants in basil production.

MATERIALS AND METHODS

Plant materials and culture

Two greenhouse experiments were conducted in College Station from September 9 to October 30, 2016 (Experiment 1) and in El Paso from April 30 to May 31, 2017 (Experiment 2), respectively. 'Genovese' sweet basil (Johnny's Selected Seeds, Winslow, Maine) was used in both experiments.

Treatment and experimental design

In Experiment 1, 10 cm (4 in.) long basil cuttings were cut from mother plants and trimmed to two leaves, dipped in rooting hormone (Hormodin 2; OHP Inc., Mainland, Pennsylvania) and stuck into one plug cell of 72 cell trays with vermiculite (Vermiculite Premium Grade; Sun Gro Inc., Bellevue, Washington). Two basil seeds were sown in one plug cell of 72-cell trays with propagation mix (Propagation mix; Sun Gro Inc., Agawam, Massachusetts). All trays were put under mist in a greenhouse on day 0 after initiation (0 DAI). When roots were visible on the outside of the plug root ball, seedlings were transplanted into 15.3 cm (6 in.) BM7 pots (Berger, Watsonville, California, USA). Plants

[a]Second Place – Graduate Student Research Paper Competition

[b]E-mail: haijiedou@tamu.edu

were harvested when growth reached 30 cm height. All plants were irrigated with a nutrient solution containing 1 g L^{-1} (150 ppm N) 15N-3.3P-12.5K fertilizer (Peters Professional, Everris NA Inc., Dublin, Ohio).

In Experiment 2, 10.2 cm (4 in.) long basil cuttings were cut from mother plants and trimmed to two leaves, then immediately dipped in diluted liquid rooting concentrate with 1,000 ppm concentration (indole-3-butyric acid, Dip'n Grow, Oregon, USA), and four planting densities of 1, 2, 3, or 4 cuttings (C1, C2, C3, or C4) were stuck into one plug cell of 72 cell trays with vermiculite (Thermo-O-Rock West Inc., Chandler, Arkansas, USA). Four planting densities of 5, 10, 15, or 20 seeds (S5, S10, S15, or S20) were sown in one plug cell of 72-cell trays with Metro-Mix 360 (SunGro Hort., Bellevue, Washington, USA). Plant management was the same as in Experiment 1.

Data collection and measurement

In Experiment 1, root fresh weight (FW) was measured before transplanting. Plant height and two perpendicular widths were measured after transplanting on 21, 31, 38, 45, and 51 DAI. Shoot FW and dry weight (DW) of basil were measured before harvest.

In Experiment 2, root FW and DW were measured before transplanting. Plant height, two perpendicular widths, and relative chlorophyll content (SPAD) of basil leaves were measured after transplanting on 27, 34, 41, and 48 DAI. Shoot FW and DW were recorded before harvest. Only the new growth of cutting plants was measured in both experiments. An analysis of variance was conducted using software JMP (Version 12, SAS Institute Inc., Cary, North Carolina, USA).

RESULTS AND DISCUSSION

Root formation

In Experiment 1, basil plants from cuttings were transplanted on 14 DAI when roots developed to root ball surface, compared with 21 DAI for seedlings. Basil plants from cuttings developed to a transplantable stage earlier than seedlings, which is in agreement with El-Keltawi and Abdel-Rahman (2006). For cuttings, a 100% rooting was observed, whereas seed germination rate was 90%. On 14 DAI, root FW of plants from cuttings and seedlings were 0.48 and 0.04 g, respectively.

In Experiment 2, basil plants from cuttings and seedlings with four planting densities developed to transplantable stage at the same time on 20 DAI. Plants from cuttings had greater root mass than seedlings, and the root FW and DW were the highest for C4, C3, followed by C2, and were the lowest for C1, S20, S15, S10, S5 (Table 1). Propagation of basil by either tip or middle stem cuttings resulted in similar root patterns with approximately 100% rooting. The faster root formation and growth of cuttings, compared to seedlings could be explained by translocated carbohydrate from leaves and stems for root development, as well as a higher concentration of endogenous root-promoting substances from apical tissues (Hartmann et al., 2011).

Plant growth and shoot biomass accumulation

In Experiment 1, plants from cuttings and seedlings reached to approximately 30 cm tall on 38 and 51 DAI, respectively. With similar height and growth index, shoot FW of seedlings were higher than plants from cuttings, while there was no significant differences on shoot DW or shoot FW accumulation rate. On the other hand, the shoot DW accumulation rate of plants from cuttings was 50% higher than seedlings, due to 13 days shorter of growth period (Table 2).

In Experiment 2, rooted cuttings and seedlings reached approximately 30 cm height on 46 and 41 DAI, respectively. After transplanting, plant height and growth index of plants were the highest for S20, S15, S10, followed by S5, and was the lowest for C4, C3, C2, and C1. However, the SPAD in plants from cuttings was approximately 12% higher than seedlings (data not reported).

Table 1. Root fresh weight (FW) and dry weight (DW) of basil plants from cuttings and seedlings on 20 DAI in Experiment 2.

Treatment	Density	Root FW (g)	Root DW (g)
Cuttings	C1	0.45 c[1] B[2]	0.050 c B
	C2	1.57 b A	0.111 b A
	C3	1.96 ab A	0.129 ab A
	C4	2.13 a A	0.146 a A
Seeds	S5	0.39 c D	0.028 c C
	S10	0.51 c C	0.030 c AB
	S15	0.70 c B	0.038 c AB
	S20	0.85 c A	0.043 c A

[1]Means followed by the same lowercase letters are not significantly different at $P<0.05$ between plants from cuttings and seedlings.
[2]Means followed by the same uppercase letters are not significantly different among four planting densities within plants from cuttings or seedlings.

Table 2. Growth index, shoot fresh weight (FW) and dry weight (DW), and shoot accumulation rate of basil from cuttings and seedlings in Experiment 1.

Treatment	Growth index (cm)	Shoot FW (g)	Shoot DW (g)	Shoot accumulation rate (g d^{-1}, FW)	Shoot accumulation rate (g d^{-1}, DW)
Cuttings	21.7a	18.4b	2.36a	0.48a	0.063 a
Seeds	22.6a	22.8a	2.17a	0.45a	0.042 b

Different lowercase letters indicate significant differences at $P<0.05$.

With similar plant height, shoot FW and DW of plants from cuttings were 49 and 71% higher than seedlings when plants were harvested on 48 and 41 DAI, respectively, which probably was associated with enhanced root formation (Lim and Eom, 2013). Shoot FW accumulation rate of S5 was much lower than the other treatments, and high planting density of seedlings such as 10 to 20 seedlings per pot compensated for low shoot biomass accumulation rate of low planting density and achieved similar biomass accumulation rate as cutting treatment (Table 3). Similarly, shoot DW accumulation rate was the lowest for S5 and increased by four cutting treatments, resulted in higher shoot dry matter content of plants from cuttings (Table 3). Shoot biomass accumulation of 10 seedlings per pot was similar or higher than 15 or 20 seedlings per pot, probably due to the inter-plant competition for sunlight and nutrients at higher densities.

Table 3. Shoot fresh weight (FW), dry weight (DW) and shoot accumulation rate of basil plants from cuttings and seedlings in Experiment 2.

Treatment	Density	Shoot FW (g)	Shoot DW (g)	Shoot accumulation rate (g d^{-1}, FW)	Shoot accumulation rate (g d^{-1}, DW)
Cuttings	C1	103.0 ab[1] A[2]	10.35 ab A	1.93 a A	0.19 abc A
	C2	100.3 a A	9.47 ab A	1.93 ab A	0.18 abc A
	C3	117.1 a A	11.02 a A	2.26 a A	0.22 a A
	C4	97.1 a A	9.42 a A	2.02 ab A	0.20 ab A
Seedlings	S5	53.7 d C	4.45 d C	1.31 c C	0.11 e C
	S10	77.7 b A	6.35 b AB	1.89 a A	0.16 cd AB
	S15	68.6 c B	5.77 c B	1.68 b B	0.14 de B
	S20	79.6 b A	7.03 b A	1.94 a A	0.17 bcd A

[1]Means followed by the same lowercase letters are not significantly different at $P<0.05$ between plants from cuttings and seedlings.
[2]Means followed by the same uppercase letters are not significantly different among four planting densities within plants from cuttings or seedlings.

CONCLUSION

Rooting of basil plants from cuttings was stronger and faster, and plants from cuttings achieved higher shoot FW yield, as well as higher dry matter content compared with seedlings at similar plant height. High planting density of 10-20 seedlings per pot achieved similar biomass accumulation rate as cuttings, and density of 10 seedlings per pot would be recommended due to savings on seeds and resource competition at higher densities. In conclusion, cutting propagation provided viable alternative for starting plants for sweet basil production.

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Isopropyl alcohol and auxin application method affect phytotoxicity of herbaceous stem cuttings©[a]

J.T. Ray[1,b], E.K. Blythe[2], Guihong Bi[1], P.R. Knight[2], D.B. Reynolds[1] and G.R. Bachman[3]

[1]Mississippi State University, Department of Plant and Soil Sciences, Starkville, Mississippi 39762, USA; [2]Mississippi State University, Coastal Research & Extension Center, South Mississippi Branch Experiment Station, Poplarville, Mississippi 39470, USA; [3]Mississippi State University, Coastal Research & Extension Center, Biloxi, Mississippi 39532, USA.

Abstract

In response to commercial propagators' inquiries regarding potential phytotoxicity of alcohol used in root-promoting solutions for cutting propagation, three experiments were conducted using stem cuttings of three herbaceous plant taxa. Solutions were prepared with three rates of isopropyl alcohol (0, 25 or 50%) in combination with three rates of indole-3-butyric acid (IBA): 0, 1000, or 2000 ppm (Exp. 1); 0, 100, or 200 ppm (Exp. 2); or a mixture of IBA and 1-naphthalene acetic acid (NAA): 0+0, 500+250, or 1000+500 ppm IBA+NAA, respectively (Exp. 3) and applied to cuttings using the basal quick-dip method (Exps. 1 and 3) or total immersion method (Exp. 2). No stem or leaf burn occurred using the basal quick-dip method, whereas foliar and stem burn occurred on cuttings of *Pelargonium* 'Mary Helen' using the total immersion method with solutions containing alcohol (regardless of IBA rate). Results indicate that solutions containing up to 50% alcohol can be used safely when applied using either basal quick-dip or total immersion methods for stem cuttings of *Chrysanthemum* Mammoth™ and *Impatiens* 'Coral'.

INTRODUCTION

Plant propagation by asexual methods (cuttings, grafting, layering, division, tissue culture, or other methods) is a fundamental activity in nursery plant production (Hartmann et al., 2011). Asexual propagation allows growers to produce new plants from production stock, maintain genetic characteristics of clonal plant selections, and meet consumer demand. The stem cutting method involves promoting initiation of adventitious roots on leafy (and sometimes leafless) stem pieces during the growing season (herbaceous, softwood, or semi-hardwood cuttings) or dormant season (hardwood cuttings) (Hartmann et al., 2011). Auxins are one of several naturally occurring phytohormones in plants and are involved with many plant responses, however, their most important role in plant propagation is to induce adventitious rooting in cuttings (Crawford, 2005). Commercial formulations of indole-3-butyric acid (IBA) and 1-naphthalene acetic acid (NAA), are used in nursery production to initiate rooting, increase rooting percentage, and increase quality and number of roots. These auxin-containing products (commonly referred to as "rooting hormones") are available in liquid, powder (talc), and water-soluble salt form (Blythe et al., 2007). The basal quick-dip method of auxin application is used most often due to its ease of application (Crawford, 2005). Immersion of whole cuttings has been reported to promote excellent rooting on herbaceous and other plant taxa when compared to powder formulations (Hartmann et al., 2011). Translocation of applied rooting hormones has been reported to occur acropetally in xylem with the transpiration stream, then laterally into surrounding tissues (Blythe et al., 2007). Isopropyl alcohol or ethyl alcohol can be used as solvents or carriers for IBA and/or NAA formulations to increase auxin intake. The acid form of auxin is relatively insoluble in water, but can be dissolved in a cosolvent, such as alcohol, before adding water (Blythe et al., 2007). There have been anecdotal reports that use of alcohol can cause "stem burn" on cuttings; however, no formal research has been reported to

[a]Third Place – Graduate Student Research Paper Competition.

[b]E-mail: tim.ray@msstate.edu

adequately establish occurrence of tissue damage on stem cuttings with use of alcohol-based auxin solutions. The objective of this research is to assess potential phytotoxic effects of alcohol on stem cuttings from various plant taxa using methods of applications used in the nursery and floriculture industry. Presence and extent of tissue burn on cuttings of selected commonly grown, herbaceous crops treated with alcohol-based solutions were examined.

MATERIALS AND METHODS

Plant material for cuttings of *Impatiens* L. (interspecific) 'Coral' and *Pelargonium* 'Mary Helen' were obtained from production plants at the South Mississippi Branch Experiment Station in Poplarville, Mississippi. Cuttings of *Chrysanthemum* L. Mammoth™ 'Yellow Quill' were obtained from Ball Horticultural Company (West Chicago, Illinois). All cuttings were freshly prepared to a uniform size appropriate for the taxon (Table 1) and the lowest basal leaves were removed from each cutting. All flowers and flower buds were removed from cuttings of *I.* 'Coral'. All cuttings received a 1-s basal dip to a uniform depth (Exps. 1 and 3) or a 5-s total immersion (Exp. 2) in a solution at ambient temperature containing IBA (Hortus IBA Water Soluble Salts®; Phytotronics Inc., Earth City, MO) at 0, 1000, or 2000 ppm IBA (Exp. 1); 0, 100, or 200 ppm IBA (Exp. 2); 0 + 0, 500 + 250, or 1000 + 500 ppm IBA + NAA (as Dip 'N Grow) (Exp. 3) prepared with isopropyl alcohol to final rates of 0, 25, or 50% (by vol.) (Table 2), for a total of nine treatment combinations with 0% alcohol plus 0 ppm IBA or IBA + NAA as the control. Treated cuttings were inserted to a uniform depth into a peat moss and pine bark-based potting mix (Fafard 3B; Conrad Fafard, Agawam, Massachusetts) in individual cells of 50-cell propagation trays (PROP-50-RD; T.O. Plastics, Inc., Clearwater, Minnesota) set in carrying trays (FG1020A; J&M Plastics Inc., Royse City, Texas). Treated cuttings were assigned to cells using a completely randomized design with 33 cuttings per treatment and placed under intermittent mist (10 s every 10 min during daylight hours) in a climate controlled greenhouse.

Table 1. Taxa of herbaceous ornamental crops used to provide stem cuttings, with specifications on cutting preparation, propagation, and harvest.

Botanical name	Cutting type	Cutting length (cm)	Cutting source	Exp. No.	Propagation date	Avg. daily min./max. temps (°C)	Depth (cm)[1]	Harvest date
Chrysanthemum Mammoth™ 'Yellow Quill'	Herb., terminal	5	Purchase from supplier[2]	1	1/13/16	62±3 - 68±4	1	2/13/16
				2	1/13/16	62±3 - 68±4		2/13/16
				3	1/13/16	62±3 - 68±4		2/13/16
Impatiens 'Coral'	Herb., terminal	5	Container-grown stock	1	7/8/15	72±4 - 88±5	1	9/4/15
				2	7/8/15	72±4 - 88±5		9/4/15
				3	12/11/15	62±3 - 68±4		1/28/16
Perlargonium 'Mary Helen'	Herb., terminal	12.5	Field-grown stock	1	10/26/15	63.3±3 - 72±4	1	12/19/15
				2	10/26/15	63.3±3 - 72±4		12/19/15
				3	10/26/15	63.3±3 - 72±4		12/19/15

[1]Depth of insertion of the cutting into the rooting substrate.
[2]Ball Horticultural Company, West Chicago, Illinois.

Table 2. Prepared solutions containing three rates of alcohol (0, 25 or 50%) in combination with three rates of IBA: 0, 1000, or 2000 ppm (Exp. 1); 0, 100, or 200 ppm (Exp. 2); or a mixture of IBA and NAA: 0+0, 500+250, or 1000+500 ppm IBA+NAA, respectively (Exp. 3) and applied to cuttings using the basal quick-dip method (Exps. 1 and 3) or total immersion method (Exp. 2).

Treatment. no.	Basal quick-dip (Exp. 1)		Total immersion (Exp. 2)		Basal quick-dip (Exp. 3)	
	Alcohol[1] (%)	IBA-water soluble salts (ppm)	Alcohol (%)	IBA-water soluble salts (ppm)	Alcohol (%)	IBA (ppm) from Dip 'N Grow® (IBA+NAA)
1	0	0	0	0	0	0
2	0	1000	0	100	0	500
3	0	2000	0	200	0	1000
4	0.25	0	0.25	0	0.25	0
5	0.25	1000	0.25	100	0.25	500
6	0.25	2000	0.25	200	0.25	1000
7	0.5	0	0.5	0	0.5	0
8	0.5	1000	0.5	100	0.5	500
9	0.5	2000	0.5	200	0.5	1000

[1]0.91% isopropyl alcohol.

Maximum photosynthetically active radiation at the level of the cuttings was 310 µmol m^{-2} s^{-1} during the winter and 522.5 µmol m^{-2} s^{-1} during the summer. Daily minimum and maximum temperature range varied depending on time of year cuttings were taken (Table 1). Temperature and humidity were monitored with a HOBO Pro RH/Temp data logger (Onset Computer Corp., Bourne, MA) placed with the cuttings. Rooted cuttings of *C.* Mammoth™ 'Yellow Quill' were harvested 30 days after treatment (DAT) and cuttings of all other taxa were harvested 50 to 55 DAT (Table 1). After cuttings were harvested, rooting substrate was removed from roots with water and individual cuttings were visually assessed for stem and leaf burn [presence of tissue necrosis (yes/no) and extent (percentage of tissue affected)] and mortality. When limited mortality occurred within a treatment, only surviving cuttings were assessed for stem and leaf burn. Root systems were dried individually in a horizontal air flow oven (Model 1680; VWR International/Sheldon Manufacturing, Inc., Cornelius, Oregon) for a minimum of 48 h at 50°C to constant weight and the root (or shoot) dry weight recorded. Data were analyzed using linear models (for continuous response data) and generalized linear models (binary response data) using the GLIMMIX procedure of SAS (version 9.4; SAS Institute Inc., Cary, North Carolina), with auxin rate and alcohol rate as qualitative treatment factors. If the interaction term was not significant ($p \geq 0.20$), the main effects were evaluated; otherwise, simple effects were evaluated. Comparisons of least squares means among three rates of alcohol and three rates of IBA (main effects) or comparisons among the three levels of one treatment factor at each level of the other treatment factor (simple effects) were made using the Shaffer-Simulated adjustment for multiple comparisons ($\alpha=0.10$). A significance level of 0.10 was selected to reduce the chance of a Type II error.

RESULTS AND DISCUSSION

Chrysanthemum Mammoth™ 'Yellow Quill'

There was no stem burn or leaf burn observed on any of the chrysanthemum cuttings in all experiments, regardless of alcohol or IBA rate (Table 3). Root dry weight (RDW) varied with alcohol and IBA concentrations in Exp. 1, with the one or two lowest IBA rates tending to produce the greatest RDW, particularly in solutions containing 0% or 25% alcohol, whereas neither treatment factor nor their interaction significantly affected RDW in Exps. 2 and 3. However, in Exp. 3, the greatest mean RDW was produced by cuttings treated with a solution containing no alcohol or IBA + NAA, but there was no consistent pattern (Table 3).

The greatest mortality (~15%) occurred in Exp. 1 using 50% alcohol with 0 ppm IBA and 2000 ppm IBA compared to no mortality using 50% alcohol with 1000 ppm IBA (Table 3). Results indicate that solutions containing up to 50% alcohol can be used safely when applied using either basal quick-dip or total immersion methods for stem cuttings of *C.* Mammoth™ 'Yellow Quill'.

Table 3. Stem (SB) and leaf burn (LB) (%), mortality (M) (%), and root dry weight (RDW) (g) of *Chrysanthemum* Mammoth™ 'Yellow Quill' observed using a basal quick-dip with selected rates of alcohol and IBA (Exp. 1) or IBA and NAA (Exp. 3) or using total immersion with selected rates of alcohol and IBA (Exp. 2).

Experiment 1				Experiment 2				Experiment 3			
SB%	LB%	M%	RDWg	SB%	LB%	M%	RDW%	SB%	LB%	M%	RDWg
Significance of treatment factors (P values)				Significance of treatment factors (P values)				Significance of treatment factors (P values)			
-	-	<.0001	<.0001	-	-	0.2292	0.5097	-	-	0.3462	0.4367
-	-	0.1859	<.0001	-	-	0.8095	0.1468	-	-	0.0151	0.6767
-	-	0.0119	<.0001	-	-	0.079	0.2347	-	-	0.3743	0.009
Treatment means grouped by alcohol rate				Treatment means grouped by alcohol rate				Treatment means grouped by alcohol rate			
0	0	0.0a[1]	0.196a	0	0	0.0b	0.179	0	0	6.1	0.179a
0	0	3.0a	0.182a	0	0	6.1a	0.172	0	0	0.0	0.146b
0	0	0.0a	0.163b	0	0	0.0b	0.179	0	0	0.0	0.160ab
0	0	0.0a	0.238a	0	0	3.0ab	0.185	0	0	6.1	0.141a
0	0	0.0a	0.154b	0	0	0.0b	0.184	0	0	0.0	0.155b
0	0	0.0a	0.169b	0	0	6.1a	0.184	0	0	0.0	0.170ab
0	0	15.2a	0.117a	0	0	0.0a	0.168	0	0	0.0	0.147a
0	0	0.0b	0.135a	0	0	0.0a	0.16	0	0	0.0	0.162a
0	0	15.2a	0.090b	0	0	0.0a	0.199	0	0	0.0	0.150a

[1]When the interaction term in the model is significant ($p \leq 0.20$), simple effects means followed by the same letter are not significantly different using the Shaffer-Simulated adjustment for multiple comparisons (α=0.10); otherwise, the treatment means are presented without letter groupings for informational purposes. When the interaction term in the model is not significant ($p > 0.20$), main effects means for rates within each treatment factor followed by the same letter are not significantly different using the Shaffer-Simulated method for multiple comparisons (α=0.10).

Impatiens 'Coral'

There was no stem burn or leaf burn present on any cuttings of *I.* 'Coral' in any experiment, regardless of alcohol or IBA rate (Table 4). Shoot dry weight (SDW) was greatest in Exp. 1 using 0% alcohol with 2000 ppm IBA, but differences were not great enough to suggest that use of IBA has much, if any, impact on crop production. In Exp. 2, SDW was greatest on transplants grown from cuttings treated with solutions containing 50% alcohol compared to 0 and 25% alcohol, regardless of IBA rate. These results are consistent with Boyer et al. (2013) and Crawford (2005) who reported that alcohol allows for improved absorption of auxin, with increased rooting resulting in increased shoot growth. Root dry weight were greater on cuttings treated with the highest rate of IBA + NAA in Exp. 3, and also greater when treated with solutions containing 25% and 50% alcohol compared to solutions containing no alcohol (Table 4), results also consistent with Boyer et al. (2013) and Crawford (2005). Neither treatment factor nor their interaction had any significant effect on mortality in any of the treatments. After 28 days, cuttings in Exp. 1 and Exp. 2 were transplanted to 10-cm square pots (SVT-450; T.O. Plastics, Clearwater, MN), placed into trays (450-S-15 PF; T.O. Plastics) to allow further shoot growth on the rooted cuttings [evaluated as shoot dry weight (SDW)]. Stem epinasty (an upward bending of stem at the base) was observed on the transplants in Exp. 2 that grew from cuttings treated with solutions containing 50% alcohol with 100 and 200 ppm IBA (12.5 and 100% of plants, respectively) (Table 4). It has been reported epinasty can occur as a result of an increase in endogenous

ethylene when exogenous auxin is applied (Taiz and Zeiger, 2010). These results were similar to those of Reid et al. (1981) with epinasty of poinsettia. Simple effects were assessed for stem epinasty due to a significant interaction between alcohol and IBA, with results suggesting that using 25% or 50% alcohol and 200 ppm IBA with the immersion method may increase ethylene production, causing an epinastic response. Also, general observation indicated reduced root development following transplanting on rooted cuttings that had been treated with solutions containing 25 and 50% alcohol (regardless of IBA rate). These responses may warrant additional research. Results indicate that solutions containing up to 50% alcohol can be used safely with either basal quick-dip or total immersion methods of application for stem cuttings of *I.* 'Coral'. Treatment with IBA + NAA may also promote development of larger root systems compared with nontreated cuttings.

Table 4. Stem (SB) and leaf burn (LB) (%), mortality (M) (%), root (RDW) or shoot dry weight (SDW) (g) and stem epinasty (E) (%), of *Impatiens* 'Coral' observed using a basal quick-dip with selected rates of alcohol and IBA (Exp. 1) or IBA and NAA (Exp. 3) or using total immersion with selected rates of alcohol and IBA (Exp. 2).

Experiment 1					Experiment 2					Experiment 3			
SB%	LB%	M%	SDWg	E%	SB%	LB%	M%	SDWg	E%	SB%	LB%	M%	RDWg
Significance of treatment factors (P values)					Significance of treatment factors (P values)					Significance of treatment factors (P values)			
-	-	0.3692	0.5939	0	-	-	0.2396	0.0351	<.0001	-	-	0.9868	<.0001
-	-	0.3692	0.4632	0	-	-	0.8147	0.9359	<.0001	-	-	0.839	0.0057
-	-	0.4079	0.0344	0	-	-	0.0873	0.8013	<.0001	-	-	0.7823	0.2016
Treatment means grouped by alcohol rate					Treatment means grouped by alcohol rate					Treatment means grouped by alcohol rate			
0	0	0.0	1.569a[1]	0	0	0	0.0b	1.462	0.0a	0	0	0	0.191
0	0	0.0	1.611a	0	0	0	0.0b	1.518	0.0a	0	0	9.1	0.224
0	0	0.0	1.767a	0	0	0	6.1a	1.547	0.0a	0	0	6.1	0.226
0	0	0.0	1.726a	0	0	0	0.0a	1.52	0.0a	0	0	12.1	0.208
0	0	3.0	1.639a	0	0	0	0.0a	1.574	0.0a	0	0	9.1	0.22
0	0	0.0	1.843a	0	0	0	0.0a	1.574	0.0a	0	0	15.2	0.22
0	0	0.0	2.006a	0	0	0	6.1a	1.837	0.0c	0	0	18.2	0.244
0	0	0.0	1.688b	0	0	0	3.0ab	1.653	12.5b	0	0	6.1	0.272
0	0	0.0	1.508b	0	0	0	0.0b	1.721	100.0a	0	0	12.1	0.243

[1]When the interaction term in the model is significant ($p \leq 0.20$), simple effects means followed by the same letter are not significantly different using the Shaffer-Simulated adjustment for multiple comparisons (α=0.10); otherwise, the treatment means are presented without letter groupings for informational purposes. When the interaction term in the model is not significant ($p > 0.20$), main effects means for rates within each treatment factor followed by the same letter are not significantly different using the Shaffer-Simulated method for multiple comparisons (α=0.10).

Pelargonium 'Mary Helen'

No stem burn or leaf burn was observed on any of the cuttings in Exps. 1 and 3, regardless of alcohol or IBA rate. In Exp. 2, darkening of leaf and stem tissue occurred immediately following the total immersion in solutions containing 25 and 50% alcohol (regardless of IBA rate), indicating rapid damage of tissues by alcohol. There was stem burn and leaf burn present on cuttings in Exp. 2 using solutions containing 25 and 50% alcohol, with 100% stem burn occurring in the latter case, but no stem or leaf burn occurred using solutions with 0% alcohol. Although data analysis indicated a significance effect by IBA rate and interactions between alcohol and IBA rate in causing stem and leaf burn, there was no consistent pattern; therefore, IBA rate likely had little or no effect on tissue burn (as was clearly the case with percentage of cuttings with leaf burn) (Table 5). In Exp. 1, there was no consistent pattern of RDW observed, suggesting that cuttings of *P. × hortorum* 'Mary Helen' do not require treatment with an IBA solution to root successfully. In Exp. 2, RDW of surviving cuttings generally tended to be greater with increasing rate of IBA; whereas, in Exp. 3, the greatest RDW occurred with solutions containing 50% alcohol, regardless of IBA + NAA rate (Table 5). Mortality in Exp. 1 occurred with all treatments, being different among rates of IBA, but similar among rates of alcohol. Cuttings treated with 2000 ppm IBA had

greater mortality compared to cuttings treated with 0 ppm IBA, but similar mortality to cuttings treated with 1000 ppm IBA. In Exp. 2, the greatest mortality occurred using solutions containing 25 or 50% alcohol (regardless of IBA rate). These results are consistent with Kroin (2011) who reported no tissue damage using foliar applied K-salt formulation of IBA - while addition of alcohol caused a decline in rooting percentage. In Exp. 3, cutting mortality was greatest when using 25 and 50% alcohol with 1000 ppm IBA + 500 ppm NAA indicating higher rates of auxin (and not alcohol) may affect cutting mortality. However, mortality was limited when using no alcohol with 1000 ppm IBA + 500 ppm NAA. When using 0% alcohol, mortality was greatest with 500 ppm IBA + 250 ppm NAA compared to 1000 ppm IBA + NAA and no IBA. Likewise, when using 50% alcohol no mortality occurred using 500 ppm IBA + 250 ppm NAA compared to 1000 ppm IBA + 500 ppm NAA and no IBA + NAA. These results indicate cutting mortality was affected by other factors, as noted by Hartmann et al. (2011).

Table 5. Stem (SB) and leaf burn (LB) (%), mortality (M) (%), and root dry weight (RDW) (g) of *Pelargonium* 'Mary Helen' observed using a basal quick-dip with selected rates of alcohol and IBA (Exp. 1) or IBA and NAA (Exp. 3) or using total immersion with selected rates of alcohol and IBA (Exp. 2).

Experiment 1				Experiment 2				Experiment 3			
SB%	LB%	M%	RDWg	SB%	LB%	M%	RDWg	SB%	LB%	M%	RDWg
Significance of treatment factors (P values)				Significance of treatment factors (P values)				Significance of treatment factors (P values)			
-	-	0.8837	0.9573	<.0001	<.0001	<.0001	<.0001	-	-	0.9996	<.0001
-	-	0.0087	0.0002	0.0091	0.623	1	0.0001	-	-	0.9994	0.0064
-	-	0.606	0.0003	0.0008	0.7503	0.1666	0.004	-	-	0.0112	0.0019
Treatment means grouped by alcohol rate				Treatment means grouped by alcohol rate				Treatment means grouped by alcohol rate			
0	0	9.1	0.171a[1]	0.0a	0.0	6.1a	0.162b	0	0	0.0b	0.150a
0	0	0	0.143b	0.0a	0.0	6.1a	0.166b	0	0	21.2a	0.203b
0	0	21.2	0.186a	0.0a	0.0	12.1a	0.192a	0	0	6.1b	0.177b
0	0	6.1	0.177a	87.9a	100.0	87.9a	0.038b	0	0	3.0b	0.202a
0	0	6.1	0.130b	90.9a	97.0	90.9a	0.170a	0	0	6.1b	0.174b
0	0	15.2	0.185a	63.6b	97.0	63.6b	0.132a	0	0	42.4a	0.212a
0	0	6.1	0.126b	100.0a	100.0	100.0a	-	0	0	9.1ab	0.205b
0	0	6.1	0.177a	100.0a	100.0	100.0a	-	0	0	0.0b	0.265a
0	0	12.1	0.192a	100.0a	100.0	100.0a	-	0	0	18.2a	0.247a

[1]When the interaction term in the model is significant ($p \leq 0.20$), simple effects means followed by the same letter are not significantly different using the Shaffer-Simulated adjustment for multiple comparisons (α=0.10); otherwise, the treatment means are presented without letter groupings for informational purposes. When the interaction term in the model is not significant ($p > 0.20$), main effects means for rates within each treatment factor followed by the same letter are not significantly different using the Shaffer-Simulated method for multiple comparisons (α=0.10).

Results indicate that solutions containing alcohol can cause significant stem burn when applied to stem cuttings of *P.* × *hortorum* 'Mary Helen' using the total immersion method; however, solutions containing up to 50% alcohol can be used safely when applied using the basal quick-dip method. Also, treatments of IBA + NAA appears to promote greater root development.

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IPPS European exchange 2016©

L. Kenealy[a]

Hoffman Nursery, 5520 Bahama Road, Rougemont, North Carolina 27572, USA.

Charting a career path is not always easy, but sometimes we are fortunate enough to have experiences to show us the way. In 2016, I served as the delegate from the Southern Region -IPPS for *the Early-Career Propagator Exchange Program* with the European Region. The SR provides support to attend the annual meeting in Europe and to visit nurseries and gardens in the region. The experience was one of the richest of my life. I expanded not only my professional knowledge, but also my IPPS family. The 2016 meeting was in England, and my hosts and guides treated me with thoughtfulness and generosity. At every nursery, greenhouse, and garden—they introduced me to new plants, techniques, and technologies that will benefit me throughout my career.

Edwina Biddle, owner of Godfrey and Sons Nursery, picked me up from the airport in London. We started my European tour at her nursery, where her staff cares for a broad range of perennials in a quaint and inviting retail space. After a picturesque British lunch, we toured their expansive propagation house. They produce almost all of their own material, and for the first time I witnessed nematodes being used as a biological control. Edwina then took me to meet Tim Lawrence-Owen, who was President of IPPS European Region at the time. The drive to Tim's took us to the southern edge of England and the coastal environment around Chichester.

Tim and his wife Annette were very generous hosts. They took me to several of the many nurseries the area holds. The Isle of Wight, a large island off the coast, creates a microclimate on the mainland near Chichister, which enables a warmer milder climate. That increase makes a difference—driving around the small towns in the area, we passed one nursery after another.

Our stops took us to the Tristram Nursery Group, a partnership of three nurseries that includes Walberton Nursery, where Tim Lawrence-Owen works, and Fleurie Nursery, where Lance Russel works. Lance Russel is my Euopean-IPPS Exchange Program counterpart, who will visit the US for the Southern Region meeting later that same month. All the nurseries we visited in the Chichester area were smart and well-maintained, but I was most struck by their resourceful use of space. Unlike many USA nurseries, operations in the UK are typically surrounded by neighborhoods or other industries. Land is limited and expensive, which has spurred ingenuity at these nurseries.

Tim and Annette also gave me the grand tour of Chichester, a breathtakingly beautiful city. We drank coffee beside a 900-year-old cathedral and strolled around a garden that's been there since 1158. We happened on a friend of Tim's who cares for the garden, and he took time to show us the site. We also visited West Dean Gardens, which illustrated England's long-standing dedication to horticulture and garden design.

After my adventures in Chichester, I took the train to Worcester, where I was met by Ben Gregory. He's the Product Development Manager at Wyevale Nurseries and the current Vice President of the IPPS European Region. Visiting the Wyevale Nurseries was a full-day event. They have three locations, each of which has its own specialty: grounds seedling transplants, containers, and trees. At each location, I was amazed at the range of products they offered and impressed with the efficiency of their processes. It's no wonder they are one of the leading producers in the country, with more than six million plants spread over 600 acres.

Next up was Bransford Nursery. They were unique for their use of automation and efficiency. They grow in new glass houses and poly tunnels, many of which use a sand ebb and flow system for irrigation. This allows them to produce very high-quality liners and container plants. Focusing on perennials, they pot and transplant most of their plant

[a]E-mail: lmkenealy@gmail.com

material using automation. Only 10% is potted by hand. From shipping to propagation, Bransford Nursery was top notch, so it was a treat to see them in action.

The next stop was Frank P. Matthews tree nursery, where they grow fruit and ornamental trees for retailers and garden centers. Because I began my career in fruit grafting, this was especially fun to see. Acres and acres of rootstock waiting to be grafted, scion stock fields, and a stunning display of espaliered apple trees at the entrance let us know we were at a world-class tree nursery. Frank P. Matthews is also where I met Sophie Meddins. She is a grower for the nursery, who would later receive the exchange program spot for 2017 and attend the Dallas meeting in the USA.

Next, we traveled northward to Shifnal to attend the IPPS European Region conference. The talks were incredible, and I scrambled to write down every word and quickly convert liters to gallons. It was eye-opening not only to learn about the unique difficulties Europeans face in this industry, but also to find issues and experiences we have in common.

Located just around the corner from our hotel, Boningale Nursery produces over a million plants a year, the majority of which are produced on site. The nursery is committed to protecting the environment through the green industry. They have worked with the University of Sheffield to develop a line of products for green roofs. The substrate includes recycled brick, which has the added benefit of conserving resources. The next stop on our tour was David Austin Roses. We visited their breeding and trials areas, retail space, and stunningly beautiful gardens. What none of us saw coming was David Austin—inviting us into his private garden! That was an experience I will never forget.

As the conference came to an end, we began exchanging contact information and making plans to see one another again. In the mix was John Ravenscroft, a grafting legend who is the European authority on *Magnolia* and *Rhododendron*. He invited several of us to visit his home and farm, Cherry Blossom Arboretum. This is exactly the kind of once-in-a-lifetime opportunity IPPS can bring. A small group of us spent hours following him around his vast collection of Magnolia, Oak, and Whitebeam. His dedication and life's work were visible at every step. I am grateful for the time and attention he gave us.

After the conference adventures, we toured the garden at Hidcote, which offered incredible vistas and lush cottage gardens. The last stop was Kew, where they showed us the production facility and some of the rarest specimens I am ever likely to see. For someone who loves history and plants as I do, Kew was the ideal place to end my journey.

I could write volumes about what I learned on this trip. But most importantly, the experience reaffirmed this is the perfect industry for me. Spending time with new colleagues and being immersed in the field was incredibly rewarding. I feel the same way every time I attend an IPPS meeting in the States. My IPPS family encourages and inspires me to be my best and to continually learn and try new things. I am grateful to everyone involved in planning this trip and to those who hosted and spent time with me. I will never forget you. You have created an IPPS lifer!

Back to the future: insights learned over many years—relevant then, now, and for the future©

C.E. Whitcomb[a]

Lacebark Inc., 2104 N. Cottonwood Road, Stillwater, Oklahoma 74075, USA.

1) Roots come first. Watch any seed germinate, from anywhere on the planet and it always sends down a root before producing a shoot. As the root system goes, so goes the plant (Harris et al., 1967; Hathaway and Whitcomb, 1977; Kramer and Kozlowski, 1960; Waisel et al., 2002; Whitcomb, 1981, 1988a, b, 2001).
2) Plants run on energy, just like everything else! Focus on energy production improves growth, health and all other aspects (Cobb and Mills, 1988; Gordon and Larson, 1968, 1970; Larson and Gordon, 1969; Whitcomb, 1988a, b).
3) Energy produced is not uniformly distributed. The priority of distribution: flowers, fruits, leaves, stems and, finally roots. Any reduction in energy affects roots first (Cobb and Mills, 1988; Gordon and Larson, 1968, 1970; Larson and Gordon, 1969; Whitcomb, 1988a, b).
4) Energy produced in plant tops, mostly stays there. Energy produced by mid-section leaves, mostly goes to flowers, fruits and new growth. Most energy going to the root system is produced in leaves on lower branches. Increase in root branching, increases nutrient and water absorption and energy production (Gordon and Larson, 1968, 1970; Reich et al., 1980; Whitcomb and Euchner, 1979; Whitcomb, 1988a, b).
5) If in doubt, ask the plant! Try 3 to 7 treatments, use uniform liners, replicate 8 to 10 times and watch. In nearly all cases, plants will tell you their preference. If no clear answer, change treatments or rates and try again. A computer is not needed to do valid research (Whitcomb et al., 1969, 1975; Whitcomb, 1988a, b).
6) Your first loss is your best loss! If you purchase 500 liners, only pot up the good ones. You will be saving money by tossing the marginal ones. If in doubt, throw it out! At any stage, culling marginal plants is the wise thing to do (Hathaway and Whitcomb, 1977, 1984; Watson and Himelick, 1982; Whitcomb, 1981, 1988a, b).
7) When your pH meter breaks, save your money—do not replace it! Any pH reflects only proportion of acids vs. bases and tells you nothing about "what acids" or "what bases"; pH is a common scapegoat (Lucas and Davis, 1961; Skimina, 1987; Whitcomb, 1985, 1988a, b; Young, 1988).
8) I often see the "optimum" pH, but plants show problems. On the other hand, if total nutrition is near optimum, pH will be in the "optimum" range (Lucas and Davis, 1961; Whitcomb et al., 1978; Whitcomb, 1988a, b; Yeager et al., 1983).
9) More is not better: especially as it relates to micronutrients. It is NOT how much available iron, but how much iron relative to manganese, relative to boron, relative to copper, etc. All six micronutrients have an associated inner-dependency (Hathaway and Whitcomb, 1984; Whitcomb et al., 1977, 1981; Whitcomb, 1979, 1988a, b).
10) If you have what appears to be micronutrient deficiencies or toxicities go back to item 5 and compare plant growth using your current micronutrient source vs. my original Micromax®. For example, there are four major sources of iron sulfate, but two work poorly, one fair and one very well. The one that works best also costs more. The same is true for the other micronutrient elements. Cheap is—well, cheap (Whitcomb et al., 1977, 1981; Whitcomb, 1979, 1988a, b).
11) When I did a factorial study with the six micronutrient elements (729 treatments), all four test species grew best with the same combination. Forget specialty fertilizers and specialty mixes: get your growth medium, nutrition and drainage right - and you can grow anything in one simple mix (Whitcomb, 1988a, b).
12) Just because a plant is native to a location, does not mean that is where it grows best.

[a]E-mail: carl@lacebarkinc.com

Ecologically it may be optimal or suboptimal for that environment. Two striking examples; *Pinus radiata* which is native to California, grows far better in Southern Australia and New Zealand. Likewise, *Melaleuca leucadendra,* native to Australia, grows far better in South Florida (Kramer and Kozlowski, 1960; Studer et al., 1978; Waisel et al., 2002; Whitcomb, 1988a, b).

13) Work with the plant. Minimize dictating to the plant. Always add Micromax® at 3/4 lb. and 18-6-12 Osmocote (the original 8 to 9 month release, single coating) at 6 lb./cu. yd to the propagation mix for seeds or cuttings. Do not make the plant wait until you decide to provide nutrition (Appleton and Whitcomb, 1983; Carney and Whitcomb, 1983; Tukey and Tukey, 1959; Tukey, 1962; Whitcomb, 1979, 1988a, b).
14) Chemistry of irrigation water is the most commonly overlooked factor affecting plant nutrition. Most common problems: excess sodium, high bicarbonates and high calcium. Calcium is the bully in container growth media. Avoid excess calcium (Daughtry, 1988; Good and Tukey, 1966; Rader et al., 1943; Skimina, 1987; Tukey and Tukey, 1959; Tukey, 1962; Whitcomb et al., 1977; Whitcomb, 1985, 1988a, b; Young, 1988).
15) Drainable pore space and Darcy's Law (summarized): water will move from a coarse texture to a fine texture readily. Water will not move from a fine texture to a coarse texture until near saturation. Any mix in a container is fine textured relative to the drain holes. Percent drainable pore space should be about 20% (Davis and Whitcomb, 1975; Threadgill, 1983; Whitcomb, 1972, 1988a, b; White and Mastalerz, 1966).
16) Pots with vertical slots are just pots that loose water faster. Sidewall openings provide no benefits unless roots are guided into the openings for air-pruning (Whitcomb, 1972, 1988a, b; Whitcomb and Williams, 1983).
17) The 4 in. (10 cm) rule. When actively growing root tips are killed by dehydration (air-pruning) or root tip trapping, increased branching occurs along the root axis from about 4 in. back. Place a plant started in an 18 cell RootMaker® tray which is about 4 in. square into a container 10 to 12 in. in diameter, such as a RootMaker® 3- or 5-gal container. Roots grow out, are air-pruned at the sidewall and branch profusely back to the face of the original ball. The resulting fibrous root system exploits the full volume of the container for maximum absorption of water and nutrients (Dickinson and Whitcomb, 1982; Tinus, 1978; Whitcomb, 1988a, b).
18) Killing root tips with toxic levels of copper or zinc or … creates more complications than benefits. Let that one die! (Whitcomb, 1988a, b).
19) Any more than 30% shade and you are using shade as a crutch. Light drives the energy production system. (See #4) (Jacobs, 1954; Knox and Hamilton, 1982; Neal, 1969; Neel and Harris, 1971; Telewski and Pruyn, 1998; Whitcomb, 1988a, b).

Know what you know. Know what you do not know. Do not get the two mixed up!

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What's new in the biology of cutting propagation©

F.T. Davies, Jr.[a]

Department of Horticultural Sciences, Texas A&M University, College Station, Texas 77843-2133, USA.

DEVELOPMENTAL ASPECTS OF ADVENTITIOUS ROOT FORMATION

The formation of adventitious roots is critical for successfully propagating cuttings. Cuttings with preformed adventitious roots, common to willow (*Salix*) or vines such as English ivy or creeping fig (*Ficus pumila*)—are easy to root (Figure 1). De novo adventitious roots are formed "anew" by creating a new meristematic area which is stimulated by removing a shoot or leaf-bud cutting from the stock plant (Figure 1). Wound-induced de novo adventitious roots are easy to form in herbaceous plants, such as chrysanthemum—and can be extremely difficult in woody species, such as oaks (*Quercus*)—particularly when cuttings are taken from physiologically mature stock plants (Davies et al., 2018).

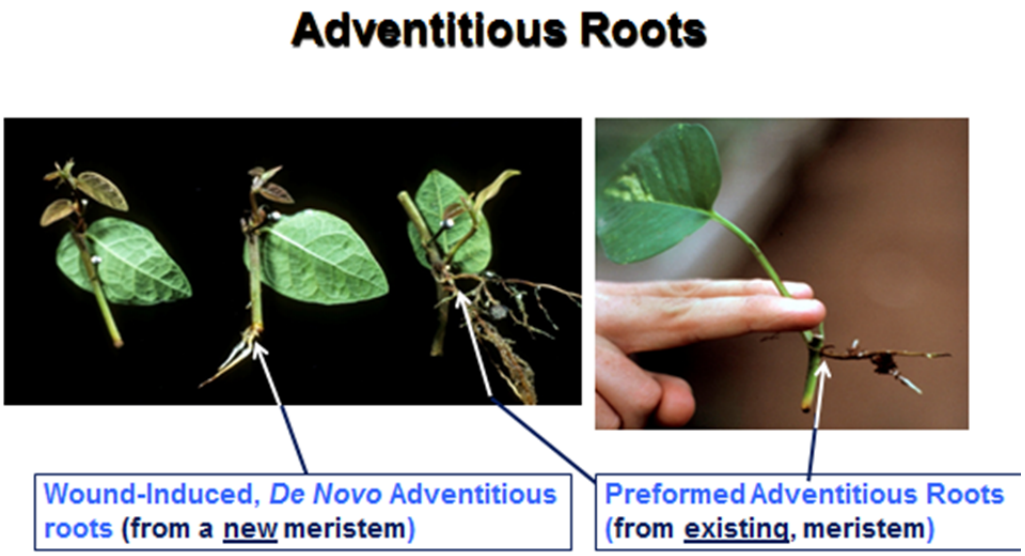

Figure 1. Preformed adventitious roots on *Ficus pumila* and philodendron and de novo adventitious roots that are formed from a new meristem after cuttings have been taken.

De novo adventitious root formation is composed of four stages: 1) dedifferentiation of parenchyma cells in the phloem ray area, 2) formation of root initials, 3) formation of a fully developed meristematic area—the root primordia, and 4) elongation of the root primordial through the cortex and periderm (Davies et al., 2018).

What separates out an easy vs. difficult to root species is the ability to complete the first two stages: dedifferentiation and root initial formation (early organization of the root primordia). If a cutting can complete these first two steps, it will successfully root—provided the proper environmental conditions are maintained.

While we have gotten to be pretty good at manipulating stock plants, using auxins and controlling environmental conditions to maximize commercial rooting of cuttings—there are still many woody plant species that are too difficult to root in acceptable numbers. It would be great if we could manipulate a single gene to enhance rooting, but adventitious root formation of cuttings is a complex process involving many genes.

Genes are important because they are expressed through the production of proteins, some of which are enzymes which help drive chemical reactions. Genes can be upregulated

[a]E-mail: f-davies@tamu.edu

(turned on) or down regulated (turned off). During adventitious root development in lodgepole pine (*Pinus contorta*) hypocotyls cuttings—there are some 220 genes are differentially expressed (Figure 2) (Brinker et al., 2004). In rooting easy-to-root petunia cuttings—there are some 1,354 genes that were induced (upregulated) and some 607 proteins identified during various stages of rooting (Ahkami et al., 2014). Why is this relevant? Well, differences between easy- and difficult-to-root species are because of gene expression. Hence, a mature, difficult-to-root plant species has certain genes that are being turned off or on, whereas the juvenile, more easy-to-root form of the same species differs in its gene expression, even though the genome (gene composition) is the same between the two. Bottom line: we still have a long way to go in understanding and utilizing the molecular biology of rooting.

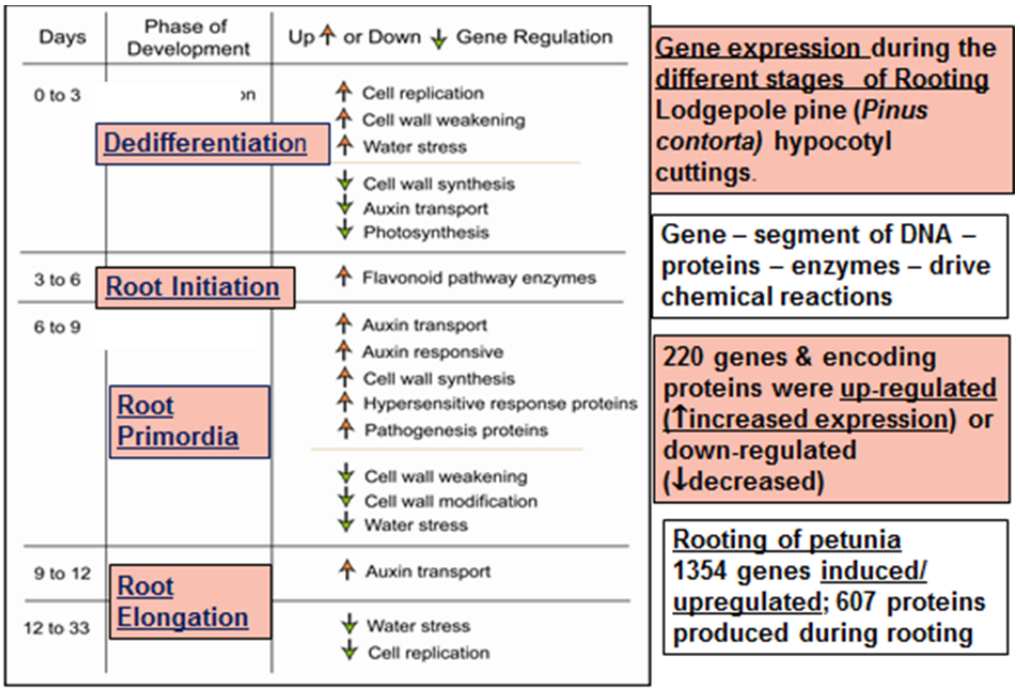

Figure 2. Microarray analysis of gene expression during the synchronized development of different stages of adventitious root formation of *Pinus contorta* hypocotyl cuttings. Transcript levels of 220 genes and their encoding proteins were up-regulated (increased expression) or down-regulated (decreased expression) (Brinker et al., 2004).

AUXINS, PHYTOHORMONES, CROSS-TALK AND ROOTING

For commercial rooting of cuttings: the auxins - IBA and NAA or in combination - are applied. However there are other phytohormones involved in the rooting process. And they communicate with each other—through phytohormone interactions and cross talk during the four stages of rooting. There is signaling (cross-talk) among hormones that impacts gene and protein expression. While auxin is considered the "master regulator" of rooting—higher endogenous levels stimulate the early events of rooting (Stage I), while lower auxin is desirable for root initial formation through the elongation of roots (Stages II, III and IV) (Figure 3).

Phytohormones such as cytokinins and ethylene, which inhibit the early events of rooting, enhance rooting during later events (Figure 3). There is cross-talk with a high auxin/low cytokinin ratio favoring the early events of adventitious root formation, while a low auxin/high cytokinin ratio favors elongation of roots and adventitious bud formation (of leaf cuttings). However, in commercial practice—only auxins are used to stimulate rooting.

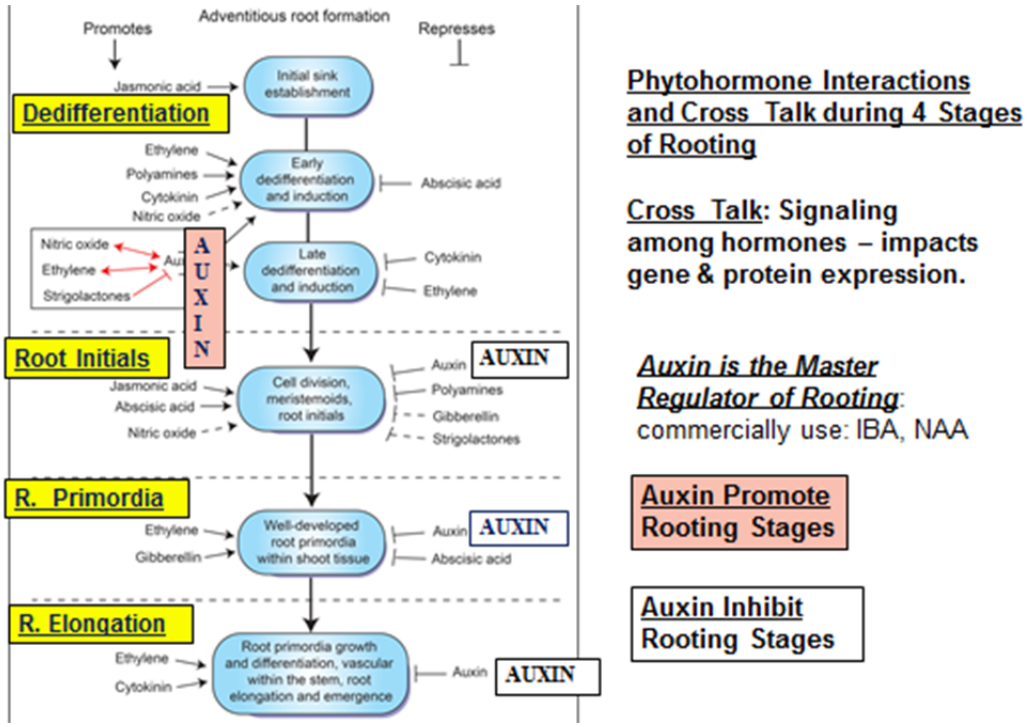

Figure 3. Phytohormone interactions and cross-talk during the four stages of rooting. There is signaling among hormones that impacts gene and protein expression. While auxin is considered the "master regulator" of rooting - higher endogenous levels stimulate the early events of rooting, while reduced auxin is desirable for root initial formation through the elongation of roots (da Costa et al., 2013; Steffens and Rasmussen, 2016).

AUXINS AND THEIR APPLICATION

To enhance rooting of stem cuttings, auxins are typically applied as 1-5 second quick-dips, which entails inserting the cutting base into the auxin solution. Auxins are also applied as spray applications to foliage or as talc powder applications to the base of the cutting, and sometimes combinations of a liquid quick-dip followed by a powder application are used with more difficult-to-root species (Davies et al., 2018).

Spray applications of auxins can be applied at the end of the day with the mist system turned off, or early morning prior to turning on the mist system. This avoids worker contact with auxin, since just the protected applicator applies the auxin as spray. Some commercial nurseries use auxin spray applications of Hortus Water soluble Salts from 500 to 1,500 ppm (Drahn, 2007). It is best to apply aqueous auxin sprays within the first 48 hours of sticking the cuttings (Davies et al., 2018).

In a study of difficult-to-root, mature *F. pumila*—applying spray applications of auxin (IBA) within the first 9 days enhanced rooting, but delaying to 15 days after sticking cuttings – greatly reduced rooting response (Figure 4). The optimum window to apply auxin was lost—in part because of the loss of cell receptivity/sensitivity to respond to auxin (Davies et al., 2018).

Auxins can speed-up rooting of easy-to-root species, but are not required (Figure 5). They are essential in propagating moderately, easy-to-root plants such as *Camellia*—but have little effect on recalcitrant species such as pawpaw (*Asimina*). Easy-to-root plants that have all the essential endogenous substances (root morphogens) plus auxin needed for rooting. Auxin is needed to enhance rooting of moderately easy-to-root plants in which the naturally occurring root morphogen(s) are present in ample amounts—but endogenous auxin is limited. Difficult-to-root (recalcitrant)—plants lack a rooting morphogen(s) and/or lack the cell sensitivity to respond to the morphogen(s), even though natural auxin may or

may not be present in abundance. Hence, external application of auxin gives little or no rooting enhancement (Figure 5).

Figure 4. The effect of applying auxin as a foliar spray application to mature, difficult-to-root *Ficus pumila* leaf-bud cuttings. Delaying auxin (IBA) application to 15 days after sticking cuttings dramatically reduced rooting (Davies et al., 2018).

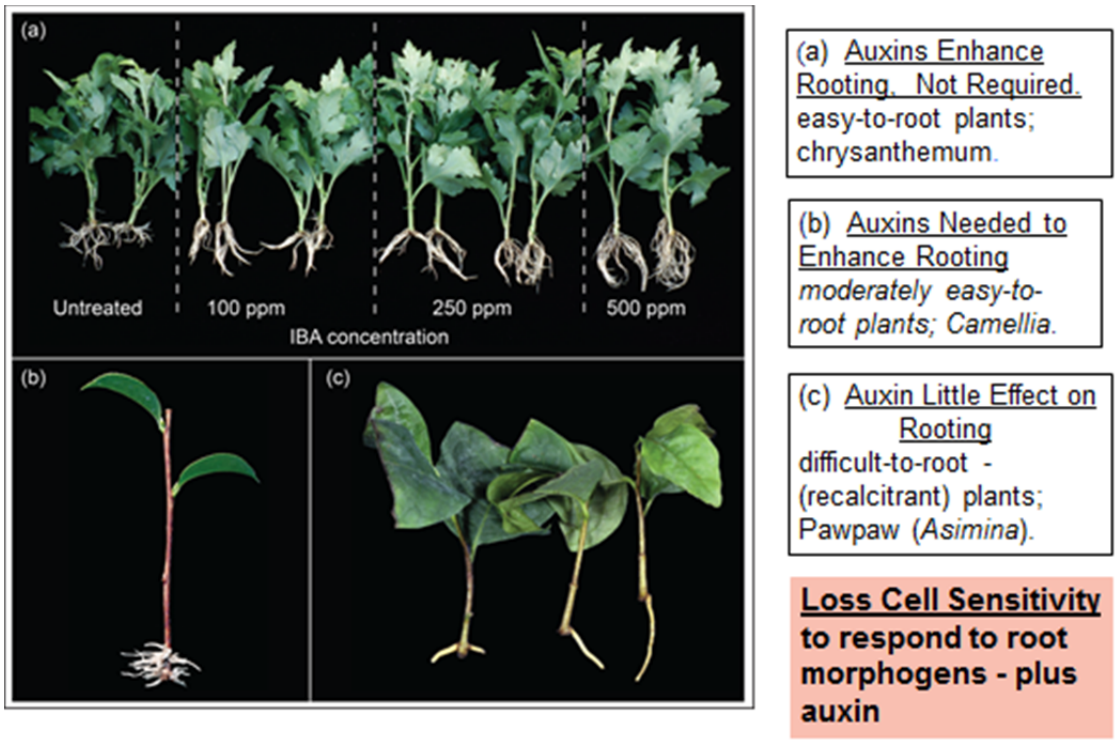

Figure 5. Auxins can (a) speed-up rooting of easy-to-root species, but are not required; (b) are needed to enhance rooting of moderately, easy-to-root species; or (c) have little effect on rooting difficult-to-root species.

Wilson (1994) proposed that a rooting morphogen can be assumed to induce roots in woody stem cuttings. The interaction between a rooting morphogen(s) of vascular origin and potential sites for root initiation is likely to be dynamic and variable. Rooting of difficult-to-root species is complicated. Potential rooting sites are not equally sensitive to the rooting

morphogen, since each cell has a unique lineage, ontogeny, and position (i.e., the competency of cells varies, which affects their ability to respond to the morphogen and root). Generally, cuttings that do not root are considered deficient in rooting promoters, including hormones.

CHRONOLOGICAL VS. PHYSIOLOGICAL AGE AND MANIPULATION OF STOCK PLANTS

Juvenile-mature gradients occur in seedling trees from the base of the tree to the top. The juvenile root-shoot junction, which is "physiologically juvenile" has a high rooting potential—even though chronologically it may be decades old (Figure 6).

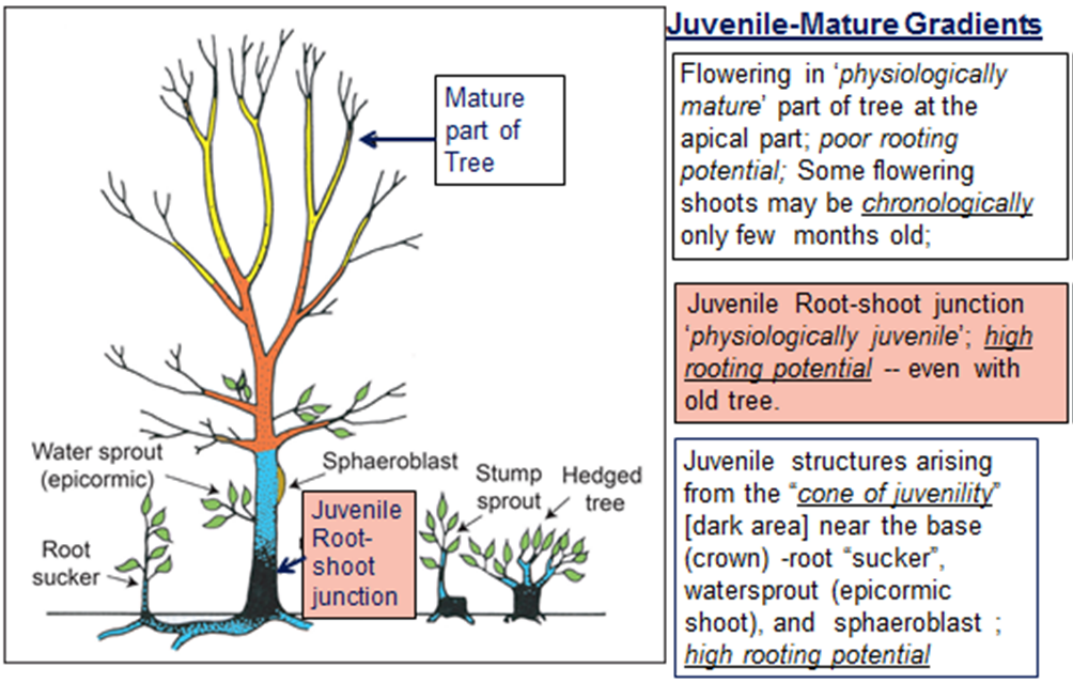

Figure 6. Juvenile-mature gradients occur in seedling trees from the base of the tree to the top. The juvenile root-shoot junction, which is "physiologically juvenile" with high rooting potential—even though chronologically it may be decades old. Flowering occurs in the "physiologically mature" part of tree at the apical part, even though some of the flowering shoots may be chronologically only several months old; shoots taken from this region generally have low rooting potential. Juvenile structures arising from the "cone of juvenility" (dark area) near the base (crown) of the tree include: adventitious root "sucker," watersprout (epicormic shoot), and sphaeroblast. Stump sprout from severe pruning, and shoots from heavily pruned or hedged bush. Rooting potential is highest from these structures close to the cone of juvenility (Davies et al., 2018).

Flowering occurs in the "physiologically mature" part of tree at the apical part, even though some of the flowering shoots may be chronologically only several months old; shoots taken from this region generally have low rooting potential. Juvenile structures arising from the "cone of juvenility" (dark area) near the base (crown) of the tree include: adventitious root "suckers," watersprouts (epicormic shoots), and sphaeroblasts. Stump sprouts result from severe pruning, and shoots from heavily pruned or hedged bushes (Figure 6). Rooting potential is highest from these structures closest to the cone of juvenility.

MANIPULATING STOCK PLANTS TO ENHANCE ROOTING

Stock plants can be manipulated to enhance rooting of woody plant species. One

technique is to force softwood cuttings (epicormic shoots) from woody stem segments to propagate hardwood species (Figure 7). Using river birch, silver maple, and stem segments of other woody species—epicormic shoots were forced under intermittent mist, later harvested as softwood cuttings—and rooted under mist (Preece and Read, 2007).

Figure 7. Forcing softwood cuttings from woody stem segments to propagate hardwood species. (a) River birch shoot forcing under intermittent mist, (b) shoot forcing of white ash and silver maple, and (c) epicormic shoots from forced silver maple—will later be harvested as softwood cutting and rooted under mist (Preece and Read, 2007).

LONG CUTTINGS

The majority of cuttings are typically 5-20 cm (2-8 in.) long. However, long cuttings of 50-152 cm (20-60 in.) are used to propagate ornamental and fruit crops with enhanced rooting success (Spethmann, 2007). Successful rooting with long, semi-hardwood cuttings has been done with rose (*Rosa canina* 'Pfänder') rootstock, elm (*Ulmus* 'Regal'), sycamore maple (*Acer pseudoplatanus*), pear (*Pyrus communis* 'Williams Christ'), *Tilia cordata* (linden), and English oak (*Quercus robur*) (Figure 8). Part of the advantage of long cuttings may be that pruning management of the stock plants—enhances rejuvenation and rooting (Spethmann, 2007). Long cuttings are also propagated using fog systems, rather than intermittent mist systems.

ENVIRONMENTAL CONTROLS TO ENHANCE ROOTING

Besides the selection and manipulation of stock plants optimizing environmental conditions can enhance propagation success and transplanting of rooted liner plants. Plants can sense changes in light and temperature, which are often referred to as "Environmental Cues". As an example, moderately high temperature (and long-day conditions) can stimulate auxin production and decrease cytokinin production, whereas cooler temperatures (less than 20°C/68°F) (and short-day conditions) reduce auxin and increase cytokinin production (Davies et al., 2018). For rooting of stem cuttings—it would be optimal to expose cuttings to moderately high temperature to stimulate auxin, whereas cooler temperatures are ideal for leaf cuttings to stimulate cytokinins and subsequent adventitious bud formation.

Figure 8. (a) A majority of cuttings are 5-20 cm (2-8 in.) long. However, long cuttings of 50-152 cm (20-60 in.) are used to propagate ornamental and fruit crops; (b) long, rooted semi-hardwood cuttings of rose (*Rosa* 'Pfaenders' rootstock for standard roses) in a greenhouse propagation bed; (c) 9-month-old rooted liners of elm (*Ulmus* 'Regal'), sycamore maple (*Acer pseudoplatanus*), pear (*Pyrus* 'Williams Christ'), (Linden) *Tilia cordata*, and English oak (*Quercus robur*) propagated from long cuttings. Part of the advantage of long cuttings may be the pruning management of the stock plants enhances rejuvenation and rooting (Spethmann, 2007).

Often overlooked are the secondary causes of poor rooting. Many leafy woody (and herbaceous) cuttings have major limitations affecting their survival (i.e., they are quite susceptible to drought and temperature stress prior to developing roots)—and require good management to avoid mortality. In rooting of poinsettia cuttings, a temperature of 27°C (80°F) was optimal, whereas 32°C (90°F) depressed rooting (Wilkerson et al., 2005) (Figure 9). Auxin requirements are lower during the later stages of root elongation. Hence, to reduce potential desiccation stress and maximize rooting—it would be best to maintain cuttings at 27°C (80°F).

During the initial week or two of cutting propagation, it is not necessary to maintain high light conditions under mist. In a study with poinsettia, relative water content, xylem water potential, net photosynthesis and stomatal conductance were initially low with unrooted cuttings (Svenson et al., 1995). Only when cuttings started to form root primordia and adventitious roots first became visible did stomatal conductance and net photosynthesis start to increase (Figure 10). The take home message is that prior to visible roots—keep light levels low to reduce vapor pressure deficit (VPD)—drought stress. When roots start to form, increase the light so plants can take advantage of higher photosynthetic rates to improve root development and production of rooted liners.

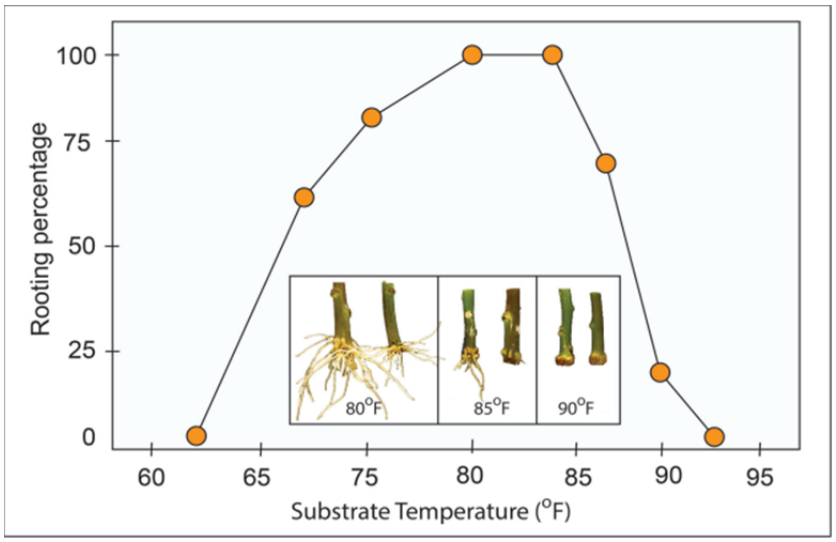

Figure 9. Effect of temperature on rooting poinsettia cuttings at 27, 29, and 32°C (80, 85, and 90°F). A temperature of 27°C was optimal. Root induction and initiation temperature is higher than that during the later stages of root elongation (Wilkerson et al., 2005).

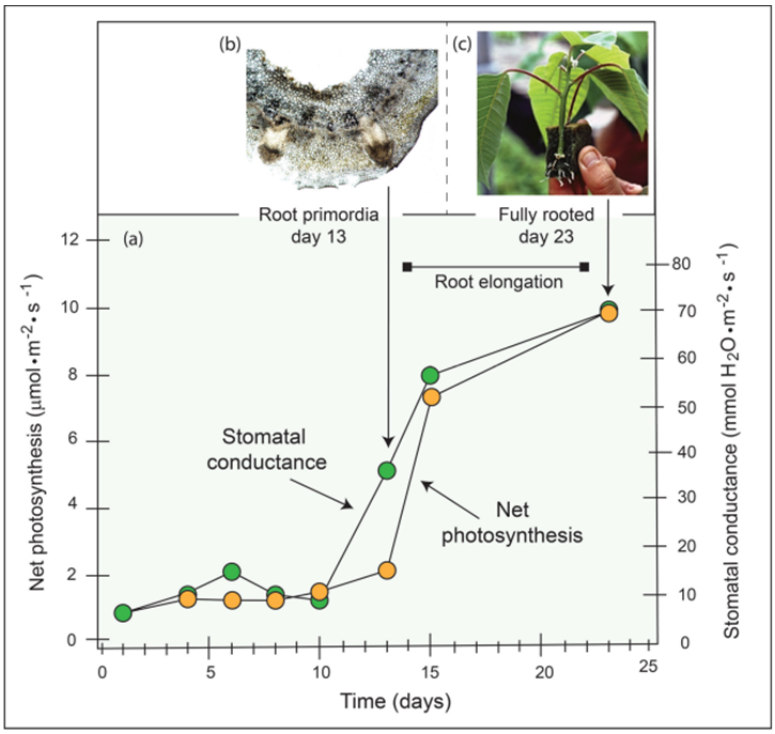

Figure 10. (a) Influence of adventitious root formation on gas exchange of poinsettia (*Euphorbia pulcherrima* 'Lilo') cuttings; (b) root primordia were microscopically observed at day 13, when photosynthesis began to increase; (c) maximum photosynthesis was at 100% rooting (Svenson et al., 1995).

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Flying dangerous: drones and the nursery industry©

J. Robbins[1,a] and J.M. Maja[2]

[1]Horticulture Department, University of Arkansas CES, 2301 South University, Little Rock, Arkansas 72204, USA; [2]Agricultural Sciences Department, Clemson University, Edisto REC, 64 Research Road, Blackville, South Carolina 29817, USA.

INTRODUCTION

Small unmanned aircraft systems (sUAS), or drones, are an emerging technology that is envisioned to be used in a variety of agricultural applications, including the nursery industry. There are lots of issues related to sUAS use that need to be addressed including types of aircraft, sensors, BIG data, flight regulations, liability, privacy, and applications. Until recently, the greatest challenge to the wide-scale adoption of this technology has been regulatory issues. However, the issuance of permanent flight regulations for commercial use in 2016 has provided clarity for users.

AIRCRAFT

Growing interest in sUAS is reflected in the rapid increase in the number and types of aircraft available. To illustrate the explosion in the number of aircraft options, on December 21, 2015 a website (http://drones.specout.com/) that compares drones listed 271 models. On April 17, 2017, the number had increased to 1,410 (420% increase over 16 months). Increasing focus by manufacturers on this emerging technology has led to tremendous advancements in aircraft systems and a reduction in cost. Of the two types of platforms, rotary and fixed-wing, it is most likely that rotary aircraft will be the predominant type used in the nursery industry due to the smaller crop areas and a greater diversity of crops. One of the most exciting advancements in the past three years has been the refinement of autonomous flight software which enhances flight performance and makes flying safer and easier. Currently, the biggest limitations of aircraft are the payload capacity and flying time (i.e., battery life).

SENSORS

Realistically the types of sensors that will be used on sUAS are no different than what has already been used with ground-equipment or manned aircraft. However, the size and weight are reduced to make sensors compatible with these smaller aircraft. Likely the most common sensors that will be used in the nursery industry will be a traditional camera (RGB), multispectral, and thermal. Currently, due to their low cost, a modified RGB camera that can yield near-infrared (NIR) images, is the sensor with the most attention. Data from a modified camera or multispectral sensor can be correlated to useful biophysical crop parameters such as leaf area index, nitrogen content, and crop water status. Currently, one of the most popular applications is to use a low-cost NIR camera to generate a normalized difference vegetation index (NDVI). The concern for the nursery industry is the current lack of research-based information to correlate these outputs to useful information. Unlike crop monocultures that are associated with traditional row crops (e.g., rice, corn, soybeans, wheat) or turfgrass - the nursery industry produces an extremely diverse number of crops that will make developing recommendations more challenging.

BIG DATA

A part of the learning curve in using sUAS to collect aerial imagery is the huge datasets that are typically associated with this activity. To minimize the financial risks, nursery users will need to understand the different types of hardware and software required to process useful imagery. Nurseries will need to explore to what degree they will process imagery in-house or whether they would be better off to use an outside vendor.

[a]E-mail: jrobbins@uaex.edu

FLIGHT REGULATIONS

The issuance of permanent flight regulations by the FAA on August 29, 2016, was a major advancement for commercial users in the US. The clarity provided by having these permanent rules will allow for more predictable growth of this technology. Nursery producers must recognize that the FAA considers their use of a sUAS as COMMERCIAL even when the aircraft is being used on their business property. Although the permanent regulations require Remote Pilot Certification to fly sUAS commercially, the requirements are vastly reduced from the previous system using waivers. Registration of aircraft has also gotten much easier with a simple online system.

LIABILITY

Commercial use of sUAS is in its infancy, so the industry is still working through issues related to liability. Each nursery business must explore with their insurance carrier the potential coverage under their current liability coverage. Many insurers now require additional specific coverage for sUAS uses.

APPLICATIONS

The reason most often cited for using sUAS is affordable access to very high-resolution images on a fairly 'as needed' basis. Five uses are envisioned within the nursery industry. The uses are:

1) Crop monitoring for nutrients, water, pests, or general health
2) Chemical or nutrient applications
3) Asset tracking or management
4) Crop inventory (count, size, quality) and crop insurance
5) Marketing and sales

CROP MONITORING

Long term, crop monitoring will become very routine and important in the nursery industry. However, as stated earlier, achieving this outcome will be more challenging for the nursery industry due to production related issues (e.g., non-continuous canopy; large diversity of crops). Initially, nursery growers should find value in simply using an RGB image to assess general production issues quickly (e.g., missed irrigation; localized pest problem).

CHEMICAL OR NUTRIENT APPLICATIONS

Considering that average acreage for specialty/horticulture crop production is smaller than acreage for traditional row crop agriculture, it is likely that chemical and nutrient applications will play a more critical role in sectors such as the nursery industry. Applying low volume pesticides to small blocks of nursery crops would be a more sustainable and environmentally sound approach than current methods. Regulatory clarity will be required before this application can be used on a routine and widespread basis.

ASSET TRACKING OR MANAGEMENT

Although little has been said publicly about this application, the use of sUAS is envisaged for 3-D mapping to estimate materials such as the size of bark piles, for monitoring glazing, structures, and systems in greenhouses, monitoring perimeter fence integrity, and monitoring irrigation systems.

CROP INVENTORY AND CROP INSURANCE

Currently, a collection of plant inventory data is time-consuming, often inaccurate, and costly. Combining a sUAS with image processing software may prove beneficial to horticultural producers in obtaining inventory and yield data in a more efficient and cost-effective manner. It is also envisioned that growers may use an inventory system that combines RFID with a sUAS. Recent hurricanes in the US emphasize the need for a quick and effective aerial-based system to validate structures and crops pre- and post-catastrophic events.

MARKETING AND SALES

Although rarely cited as an application for agricultural users, using sUAS for marketing a business or to sell the crop, will likely be a 'low hanging fruit' application since the cost to enter is so affordable. The ability to obtain and process high-quality videos of production fields and facilities from a low altitude will provide customers with a unique perspective of the nursery business.

Over the next 5 years, we anticipate that most medium or large nurseries will own their UAS to collect marketing imagery and monitor general plant health and that smaller growers will use commercial services to provide the same services but may own a small unit for to produce marketing and sales videos/images.

Lifelong learners: guilt by association©

J.P. Wilhite[a]

Wilhite Landscape and Lawn Care, Ltd., 13186 State Hwy. 64 West, Tyler Texas 75704, USA.

Once the reality of graduation sets in and we realize that we must spread our wings and go out into the "Real" world—not the one of a college student—but that of a wage earner and responsible adult—we often get the misimpression that we know something—after all we did graduate!

Perhaps we should look at a diploma as a license to learn and not the end of a process. A good university and professor will inspire and give us the basic knowledge to perform in our field without embarrassing ourselves or the institution—too badly. Often times we believe that we have "finished" - completed the task and graduated.

Once we are among peers and hopefully begin using our education—we should quickly realize that there are many ways of doing things. Some better and some not, some smarter and some not. But if we are observant—we appreciate what we learned at a good university was a great base with which to explore and move forward without making too many silly mistakes.

In horticulture we should have a basic understanding about plant physiology, how and why plants grow, what is a good soil or soil mix, how much water a plant requires and why it burns when over fertilized. We should recognize how much actual nitrogen is in a formulation and understand the potential for burning, based on the nitrogen formulation and concentration.

What we may initially lack is the knowledge of what makes a particular technique better than another or how to successfully grow 9,000 cell cultures through the first 6 months of life. This is where our boots on the ground, continuing education comes into play; continued because our degree was simply a foundation and license to learn. But there is so much more to learn after we graduated—that we did not realize—we have yet to arrive. This continuing education will take the form of reading trade magazines and going to educational programs at the IPPS, Texas Nursery and Landscape Association (TNLA) and other associations. It is critical that one's educational process include associating with others that have been successful in the business. Often a peer or mentor can cut so quickly to the chase that you will think you have been "sprayed with IBA". I hope everyone got an opportunity to take advantage of the tours that are offered with this conference. Furthermore I hope you took advantage of the once in a lifetime opportunity to ask questions on technique or why something is done one way or another. No one person or company has all the answers—but most of the time they figure out what works well for them in their unique situation.

Take advantage of the opportunity to serve your profession by serving on the associations' committees or Board of Directors. In so doing you will be offered the opportunity to meet and associate with some of the most experienced and innovative folks in this industry. Learn from them, share with them—because you never know when you might want to reach out and ask for their help. Your stable of associates may well be your most valuable resource!

[a]E-mail: jwilhite@wilhitelandscape.com

Beyond kungpao chicken: the plants of eastern China©

D. Peng[1], J. Li[2], and M. Gu[3,a]

[1]College of Landscape Architecture and Horticulture, Fujian Agriculture and Forestry University, Fuzhou, Fujian Province 350002, People's Republic of China; [2]Research Institute of Subtropical Forestry, Chinese Academy of Forestry, Fuyang, Zhejiang Province 311400, People's Republic of China; [3]Department of Horticultural Sciences, Texas A&M AgriLife Extension Service, College Station, Texas 77843, USA.

INTRODUCTION

Sichuan, where the famous Chinese dish, Kungpao chicken, originates, is a popular destination for plant explorers worldwide. However, as diverse as the Chinese cuisine, eastern China has its own unique plant germplasm. From the north to the south, Eastern China includes six provinces (Shangdong, Jiangsu, Anhui, Zhejiang, Jiangxi, and Fujian) and one direct-controlled municipality (Shanghai). In this region, the percentage of mountainous areas of each province increases from the north to the south, which presents a huge source of plant diversity.

Although the hardiness zone map indicates Zone 7-10 for the region, my personal experience of living in China for over 20 years would agree more with Zone 6-9 for the region.

In the June of 2017, I visited horticulture entities with a nurserywoman from Houston, Texas and a nurseryman from Chapel Hill, North Carolina. Our trip stops included Fuzhou (Zone 10), according to the map of 'Hardiness Zones in China' and Wuyishan (Zone 9) in Fujian Province, Ningbo (Zone 9) and Hangzhou (Zone 9) in Zhejiang Province, Nanjing (Zone 8) in Jiangsu Province and Shanghai (Zone 9). Many native plant materials have been adapted, and the current horticulture industry is developing at a rapid speed.

FUJIAN PROVINCE

Fujian Agriculture and Forestry University (FAFU)

On the FAFU campus, there is a "Map of China Garden", where the map of China and each province are featured and plants native from each province are planted. There are many plants that are unique and interesting. *Acer cordatum* with lots of red samaras in June is a small tree native in east and south China. *Lagerstroemia subcostata* has large (~20 cm long) pyramidal panicles of white flowers attracting abundant bees. About 30-50 cm long, pendulous strings of winged fruits hang from branches of *Pterocarya stenoptera*, putting on quite a show. One of the genera that Dr. Donghui Peng works on is *Melastoma*. During the tour of campus, he pointed out *M. dodecandrum*, a low growing procumbent shrub with lavender to purple flowers. Other genera that he incorporates into his breeding program include *Osbeckia*, *Barthea*, *Oxyspora*, and *Bredia*.

Native orchids are another strong research focus at FAFU. During a tour of the local longan and loquat germplasm station, we found a huge diversity of loquats. The shape ranges from oblate, spheroid, high spheroid to obovate and pyriform. The fruit skin colors range from greenish yellow to red. Fall leaf colors include yellow, yellow orange, red and maroon. Some have leaf shapes and texture similar to *Quercus oblongifolia* or *Q. emoryi*. *Syzygium buxifolium* used in the landscape at the germplasm station could be a good alternative for yaupon holly or boxwood in warm climate and is very pruning tolerant.

Fuzhou Botanical Garden

There are many unique and special plants in Fuzhou Botanical Garden. *Chukrasia tabularis* (Indian mahogany) has green shiny leaves and fragrant red flowers and is the subtropical relative of Chinaberry (*Melia azedarach*). A nickname for the city of Fuzhou is 'Ficus City' and there is a 1,000-year-old *Ficus concinna* in the garden. Pinnately compound leaves of *Heteropanax fragrans* concentrate on the upper part of the trunk and form a

[a]E-mail: mgu@tamu.edu

parasol-shape canopy. *Lysidice rhodostegia* has beautiful orchid-like purplish red flowers arranged on large (about 40 cm long) panicles in the summer. This could be an alternative for crapemyrtles as a small summer-flowering tree.

Wuyishan (Wuyi Mountain) area

Wuyishan is known for its Wuyi rock tea (because of its growing environment with rocky soil) and bamboo rafting on the 9-bend River. It is located in the northwest corner of Fujian Province. Agritourism in this area focuses on tea production, processing and appreciation. The two biggest local companies are Wuyixing (focus on tea cultivars and cultivation) and Xiangjiang Mingyuan (focus on tea processing). The best tea is thought to be made from tea plants cultivated in the mountain areas with mineral-rich rocky soils and very high relative humidity. Small tea plantations (1-3 ha) are made by clearing out native vegetation. The tea gardens are kept small so that tea plants are grown in environment conditions as natural as possible. Once established, the only input on the tea plants is annual application of organic fertilizer (often animal manure compost). This tea commands a very high premium price due to the environmentally-conscious practices. Tea plant cutting propagation is found in the rice nursery field. Each cutting, spaced just enough so that the leaves do not overlap, contains one leaf and two nodes. They are propagated under shade (>50%) cloth, supported by bamboo hoops over the cuttings. Many of the plant materials in the rock tea cultivation area are still not used in nursery trade. There are many plants along the roadside that we could not recognize, and our local guide was strictly a tea person, who could not offer much help.

ZHEJIANG PROVINCE

Henghe Yangmei Extension Station

Cixi, Ningbo is known for its yangmei (*Morella rubra* syn. *Myrica rubra*) production, and other names include waxberry or red bayberry. The fruit contains a single seed and its color ranges from crimson to dark purple. The local station has over 20 cultivars, but the most commonly cultivated is 'Biqi' with relatively big fruits and small seeds. Yangmei plants are dioecious and male trees are needed to set fruits. Although not ideal, pollens from waxmyrtle (*Morella cerifera*), native in the USA, could help set fruit on female yangmei plants. Yangmei has a relatively long juvenile stage, about 15-20 years, and cultural practices such as girdling do not shorten it. Grafting is a very common practice in local nurseries. Yangmei production in the Township of Henghe, as in many other yangmei production areas, is in the hilly area - where it is not suitable for agronomic or vegetable crops. Maintenance of the trees is minimal, as the monsoon climate brings plenty of rainfall (>1,200 mm annual precipitation) during the growing season. Weeds may be controlled once per year, and majority of labor is spent on manual harvesting. Yangmei has very short postharvest shelf life, which is comparable to raspberry. Hence, consumption is mainly limited to local markets within the province. However, yangmei is produced from as far north as Jiangsu Province to as far south as Guizhou Province in Southwest China. The species would be a good candidate as a small round evergreen landscape tree.

Hongyue Horticulture Corp. (HHC)

HHC, established in 2000, is a relatively young company, with 20 garden centers in the Yangtze River Delta and an annual sale of $440 M in 2016. The Yangtze River Delta is one of the most developed and wealthy areas in China, and there is a high percentage of population with large amount of discretionary spending. In provincial capital cities like Nanjing (Jiangsu) and Hangzhou (Zhejiang), it is common that condos are sold around 35,000 RMB m^{-2} (~$490 ft^{-2}). For a small condo of 150 m^2 (1,600 ft^2), the sales price is about $784,000—and the green space available for each condo may be the balcony of about 4 m^2 (42 ft^2). Many products in the HHC garden centers are demanding premium prices. For instance, a 5-gal privet (*Ligustrum* 'Lollypop') (a single stem with canopy pruned in a ball shape) costs around $120. HHC imports finish container plants (mainly 3-5 gallons) from European and

American companies to be sold directly to consumers. There are also many mature plants imported from Japan and Europe. For example, old olive trees with a trunk diameter around 60 cm (24 in.) are sold hundreds hundreds of thousand dollars. Most of these mature trees are sold to newly established subdivisions to give it an "established" landscape appearance. In addition to the garden centers, HHC also owns container manufacturing facility, an online app store, and 51 subsidiaries. It aims to become the No.1 domestic garden center brand and horticulture supplier in China.

Xiaoshan Nursery Market (XNM)

Xiaoshan is located in the south part of Hangzhou. Arranged in a strip mall format of around 600 stores, XNM was established in 1994. It is an open-air shopping area for wholesale nursery crops and landscape supplies. Many stores feature huge (trunk diameter 20-50 cm) containerized specimens of podocarpus, loropetalum, and *Syzygium buxifolium*. XNM is probably the largest of its kind in China, providing a market platform for the local nurseries. During the 3-day, 2016 Xiaoshan Nursery EXPO held at XNM, contracts of an estimate of RMB 660 M ($99.5 M) were signed and new registered cultivars were auctioned off for RMB 39M ($5.9 M). A new *Camellia azalea* cultivar from Zonglv Landscape (fast growing, cold and heat tolerant, and long flowering time which peaks in summer and fall—and reblooms in winter and spring) was sold for RMB 29 M ($4.4 M). This set a new record in new registered cultivar auction. New, registered cultivar auctions are a unique phenomenon in China—where intellectual property protection may seem to be a problem.

Senhe

Senhe is known for its efforts in bringing new plant materials, especially plants with variegated foliage, to the landscape market. With 17 nurseries (a total of over 1,300 ha of open field and 30 ha of greenhouse) and over 300 variegated plant cultivars, Senhe is one of the top 10 nurseries in China. The garden at Senhe headquarters offers a peek of their numerous plant materials.

JIANGSU PROVINCE

Nanjing Botanic Garden

During my literature search to manage crapemyrtle bark scale, I encountered a golden leaf crapemyrtle (*Lagerstroemia indica*) cultivar, 'Jinhuang'. While in Nanjing, we visited the breeders of 'Jinhuang', Li Ya and Wang Peng, at the Nanjing Botanic Garden. 'Jinhuang' is a mutation found on cultivar 'Fenjing' in 2002. Mature leaves are golden yellow and the young growth is purplish red. Foliage color may be 'bleached' to whitish color under the hot and strong light conditions in July and August - but soon change to golden yellow in cooler September. The original plant is only about 1.5 m in height, after 15 years of growth. The leaf color may be a factor in the relatively weak growth of this cultivar. Just as in the US, crapemyrtle is a very popular landscape plant in China. A very unique way of growing crapemyrtles in China is to weave them in the shape of a flower vase, or Chinese-style pergola.

Fangzhilin Agriculture

Fangzhilin specializes in sweet olive (*Osmanthus fragrans*). Originally the owner intended to produce sweet olive flowers for various food additives. The Chinese have a long tradition of using sweet olive flowers in desserts for their fragrance. Dust issues caused by a local cement factory forced the owner to focus on liner production, rather than selling food-grade flowers. Fangzhiling has probably the largest sweet olive cultivar collection in the region, especially the variegated selections. The owner is interested in exporting bare-root liners to customers worldwide. One interesting feather about sweet olive in China is that they are grown as trees, rather than shrubs in the US. The largest sweet olive tree we saw during this trip has a canopy diameter about 10 m.

The two weeks we spent during the trip went quickly. Before long, we returned to

Shanghai and flew back to the USA. This trip not only opened our eyes to unique plant materials in Eastern China, but also the ornamental horticulture industry and market in the region. Understanding the rapid development of the economy and the ornamental horticulture sector may help connect the world and USA producers to China.

The history of the Texas Superstar Program©

G. Grant[a]

Texas A&M AgriLife Extension Service, Smith County, 1517 West Front Street, Suite 116, Tyler, Texas 75702, USA.

Texas Superstar® (http://texassuperstar.com/) is a marketing assistance program that involves the promotion of outstanding plants that have proven performance in most regions of Texas. From the beginning, this program has been a partnership of the Texas A&M University Agriculture Program (AgriLife Extension and Research) and the Texas nursery industry. Individuals with long-time involvement in the program include: Brent Pemberton, Mike Arnold, Cynthia McKenney, David Rodriguez, and Larry Stein.

Only the most reliable and best-looking plants are included. The criteria for selecting a Texas Superstar® plant include: (1) must be attractive and useful to the gardening public; (2) must be unique and offer desirable and ornamental characteristics (i.e., the ability to perform in the heat of Texas summers or pest resistance) not usually available in commonly sold plants; (3) must consistently perform well for most Texas consumers regardless of their gardening expertise and growing locations; (4) must be as pest resistant as possible (deer proof is an added bonus); (5) must be able to be propagate and mass-produce in sufficient numbers to meet consumer demand; and (6) preferably is so attractive in the sales container that it "sells itself" to consumers—who have never heard of the attributes of the plant.

Conservatively, Texas Superstar® marketing promotions are estimated via informal surveys of producers to have increased sales at the major wholesaler level by $15 million. This does not include value-added components or smaller wholesaler production.

Texas is a climatic microcosm of much of the United States. The state spans four USDA hardiness zones, has 15 unique land resource areas and eight major soil orders. The annual precipitation rate ranges from 203 mm (8 in.) $year^{-1}$ in the far west to 1422 mm (56 in.) $year^{-1}$ in the far east. The trial sites for the program are in College Station, Lubbock, Overton, and San Antonio. These sites represent major differences in ecological zones near the majority of the population centers in the state. The Texas Superstar® Executive Board makes all decisions concerning plants selected for trialing or designated for promotion—which are based on trial site performance. All the members of the executive board are actively involved in acquiring new and improved plant materials for the program.

The Texas Superstar® program grew out of regional marketing promotions coordinated by Dr. Jerry Parsons in the San Antonio region in the 1980s. From the beginning, these promotions of plants with proven performance were coordinated with industry to insure an adequate retail supply at the time of the promotion. In 1989, the first statewide marketing promotion was accomplished featuring the Texas bluebonnet. By the mid-1990s, the acronym CEMAP (Coordinated Education and Marketing Assistance Program) was used for the program. In 1997, the term Texas Superstar® was coined by the Executive Board. All promotions were retroactively designated Texas Superstar® plants. Texas Superstar® was trademarked at the time. Later, the trademark was registered, and the rights were assigned to the Texas Agricultural Experiment Station (now Texas AgriLife Research). In 1998, Texas Superstar® tags were first used; $0.05 per tag sold was designated for the program. Horticultural Marketing and Printing (Mesquite, TX) helped develop the brand by donating artwork and the patent search. Wal-Mart (Bentonville, Arkansas) purchased the first tags. The tag revenue is used to support all aspects of the program, as approved by the Executive Board.

By the mid-2000s, changes began to challenge the viability of the program. Tag sales were declining, and some key personnel left the program because of other pursuits, retirement, or health considerations. However, recent changes and additions to the Executive Board have helped the program remain viable and to begin a renewal of industry partnerships and a campaign to increase consumer awareness in the program. In 2009, the

[a]E-mail: greg.grant@ag.tamu.edu

Texas Department of Agriculture greatly increased activity in partnership with the Go Texan Program. The Texas Superstar® brochure originally created in 1999 with the Texas Nursery and Landscape Association is updated every two years since its inception.

In 2010, ads were placed online and in the regional magazine *Texas Monthly*, and stake and hang tags were made available on request to growers and retailers. In 2011, point-of-purchase materials were made available to retailers in addition to stakes and hang tags. Television and radio ads are aired statewide in English and Spanish.

Needless to say, there is continual work to be done to raise consumer awareness of the program—but the brand is well accepted by those who are aware of it. The Texas Superstar® program started with partnerships and the future of the program is dependent on the continuing growth and strength of these partnerships.

The Bailey Nursery approach to sourcing, evaluating, and introducing new plants©

N. Hamill[a]

Bailey Nurseries Inc., 1325 Bailey Rd. St. Paul, Minnesota 55119, USA.

Bailey Nurseries (https://www.baileynurseries.com/) currently owns three consumer brands: Endless Summer® hydrangeas, First Editions® shrubs and trees, and Easy Elegance® roses. Successful brand management involves a number of components including brand strategy, positioning, revenue goals, market intelligence, product development, trialing, intellectual property protection, "go to" market strategy, licensing, production, pricing, sales and product life cycle management.

This talk focuses on Bailey Nurseries approach to product development. In today's competitive brand market place—new products are essential to keeping a brand fresh and to maintaining attention with licensees as well as retail buyers.

We use a breeding and plant finding matrix to guide our product development team. This matrix consists of 50 genera with specific breeding goals (Figure 1). These breeding goals are guided by market intelligence gathered by Bailey staff as we meet with growers, retailers, merchants, landscapers, consumers and others in the US, Canada and Europe.

Figure 1. Bailey Innovations breeders determine best practices for hand pollination in *Hydrangea macrophylla*.

Bailey Nurseries purchased Plant Introductions, Inc. (PII) (http://www.plantintroductions.com), which is a plant breeding company founded by Dr. Michael Dirr, Mark Griffith (Griffith Propagation) and Jeff Beasley (Transplant Nursery, Watkinsville, Georgia). We have renamed that company Bailey Innovations, which is managed by David Roberts (Figure 2). David and two other full time breeders use the breeding matrix to guide and prioritize their work. While *Hydrangea macrophylla* is the number one priority—many other important crops including *Distylium*, *Lagerstroemia*, and *Vitex* receive a great deal of attention. We also work with other breeders around the world to source genetics.

[a]E-mail: natalia.hamill@baileynursery.com

Figure 2. The Bailey Innovations breeding team in Athens, Georgia is led by David Roberts.

Using *Hydrangea macrophylla* as an example of our approach to new plants, the breeding matrix includes several categories. Examples include an improved Endless Summer®, purple leaf selections, compact selections, double flower selections, picotee selections, etc.

Once a cultivar with potential is selected, we put it through multiple trials in multiple locations—including Georgia, Minnesota, Illinois and Oregon (Figure 3). Cold hardiness trials are conducted in Minnesota (USDA Zone 4). Cutback trials occur at our facilities in Georgia, Minnesota, Illinois and Oregon to prove remontancy. We also do bluing studies and trials for bud and bloom crop potential in Minnesota and Oregon.

Figure 3. Potential new introductions are put through a rigorous production and field trialing process before being introduced to the First Editions® brand.

If a potential cultivar performs well—we then show it to many of our licensed growers in the US, Canada and Europe to get their input. If the feedback is positive, we send samples to them for trial and evaluation.

Because Endless Summer® is such an important brand for Bailey Nurseries, the brand management and product development teams hold a meeting with our production, propagation, sales and marketing managers as well as ownership to make the final decision in introducing new cultivars.

Pre-emerge herbicides and mulches for weed control in container-grown tree seedlings©

A.L. Witcher[a]

Otis L. Floyd Nursery Research Center, Tennessee State University, McMinnville, Tennessee 37110, USA.

INTRODUCTION

Seed propagation and seedling production in containers is a commonly used method for producing woody plant material for a range of applications including nursery stock liners and reforestation programs (Davis et al., 2008). Compared with bare root seedlings, container grown seedlings offer advantages such as an extended transplant season and increased transplant success (Fare, 2013). Some large-seeded species can be direct sown (ex. oak and hickory) into liner flats/containers while small-seeded species (ex. dogwood and yellow poplar) may need to be transplanted from plug trays. Weed control is a significant issue in containerized woody crop seedlings since plants may remain in the container for up to a year. Manually removing weeds is a time consuming and costly process due to the amount of labor required (Case et al., 2005). Additionally, agricultural labor has become difficult to maintain so nursery producers have fewer personnel to perform labor intensive tasks such as hand weeding (Rutan, 2016).

Weeding small seedlings/liners can also be a delicate process since the weed and crop roots intertwine and removing large weeds may damage crops. Pre-emergent herbicides are commonly used for weed control in container grown nursery stock, yet most products are not labeled for use in small containers [<10 cm (4 in.)] or in seedling production (Neal, 2016). Many pre-emergent herbicide labels recommend that herbicides be applied to plants after thorough irrigation and settling of substrate around the new transplants. Herbicide manufacturers are likely hesitant to approve products for use on small woody crop seedlings since they may be more susceptible to herbicide damage due to less developed root systems and/or the presence of tender foliage compared with larger plants or well established plants. Very little information is available regarding pre-emergent herbicide safety in container grown seedlings. Identifying safe and effective weed control options for woody crop seedling/liner production would benefit a large segment of ornamental crop production. The objective of this study was to evaluate the effects of mulch and pre-emergent herbicide applications on seedling growth.

MATERIALS AND METHODS

In May 2016, oak seeds [*Quercus acutissima* (sawtooth oak) and *Q. phellos* (willow oak)] were direct seeded into 8.9 cm (3.5 in.) containers filled with a 5 pine bark:1 peatmoss (by volume) substrate amended with controlled release fertilizer (Florikan 14-14-14; 4 lb yd^{-3}), dolomitic lime (4 lb yd^{-3}), and Micromax (0.75 lb yd^{-3}). In June 2016, seeds of *Cornus kousa* (dogwood), *Ginkgo biloba* (ginkgo), and *Magnolia virginiana* (sweetbay magnolia) were germinated in plug trays (128 cell) and transplanted to 8.9 cm containers. At 2 days after seeding (oaks) or 21 days after transplanting (other species) - mulches or pre-emergent herbicides were applied to containers and non-treated containers were used as controls (Table 1).

There were 9 replications per treatment per plant species, except for dogwood (7 replications) and gingko (6 replications). Mulches were applied to a depth of 0.8 cm (0.33 in.) and herbicides were applied using the labeled low rate. Spray-applied formulations were applied using a CO_2 sprayer calibrated to deliver 30 gallons $acre^{-1}$ at 30 psi using an 8003 flat fan nozzle (TeeJet Technologies, Glendale Heights, IL). Granular formulations were applied using a hand-shaker. The shoot height and stem diameter were recorded in August (oaks) and October (other species). Shoots were harvested and roots were washed to acquire shoot and root dry weight. Each plant species was treated as a separate experiment. All data were

[a]E-mail: awitcher@tnstate.edu

analyzed with linear models using the GLIMMIX procedure of SAS (Version 9.3; SAS Institute, Inc., Cary, North Carolina). Differences between treatment means were determined using the Shaffer-Simulated method (P<0.05).

Table 1. Shoot height of tree seedlings treated with a mulch or pre-emergent herbicide.

Treatment	Formulation	Shoot height (cm)				
		Sawtooth oak	Willow oak	Dogwood	Gingko	Sweetbay magnolia
Control	NA	35.9 ab[1]	36.2 a	15.6 ab	20.2 ab	21.4 a
Perlite	Mulch[2]	40.2 ab	33.4 a	17.1 a	20.9 ab	21.2 a
Pine Pellets	Mulch	35.2 ab	36.2 a	15.6 ab	23.5 a	19.2 a
Cedar Shavings	Mulch	36.3 ab	36.2 a	12.5 ab	22.1 ab	23.4 a
Trifluralin	Spray[3]	39.3 ab	32.9 a	9.4 ab	21.3 ab	21.4 a
Trifluralin	Granular	38.1 ab	32.1 a	11.1 ab	19.4 ab	22.7 a
Pendimethalin	Spray	38.4 ab	39.8 a	11.4 ab	21.7 ab	21.3 a
Pendimethalin	Granular	32.4 b	38.8 a	13.6 ab	22.3 ab	25.6 a
Isoxaben	Spray	42.3 a	38.9 a	6.8 b	20.8 ab	20.5 a
Trifluralin + Isoxaben	Granular	39.1 ab	34.7 a	13.8 ab	17.6 b	22.9 a
Prodiamine	Spray	39.6 ab	37.3 a	10.3 ab	19.4 ab	22.2 a

[1]Means followed by different letters within columns indicate significant difference at P<0.05 using the Shaffer-Simulated method.

[2]Mulches were applied to a depth of 0.8 cm (0.33 in.).

[3]Herbicides were applied using the labeled low rate (30 gal acre^{-1} application volume at 30 psi for liquid herbicide solutions).

RESULTS AND DISCUSSION

Overall, shoot height was statistically similar between seedlings in the control and seedlings in the remaining treatments for each species yet differences in shoot height among treatments varied within each species (Table 1). In particular, dogwood seedlings treated with isoxaben were significantly shorter compared with seedlings grown in perlite. Dogwood seedlings were stunted (yet not statistically) by all herbicide treatments compared with seedlings in the control, perlite, and pine pellets treatments. No significant differences in shoot height were observed among treatments for willow oak and sweetbay magnolia. Stem diameter was similar among all treatments for sawtooth oak, gingko, and sweetbay magnolia (Table 2). Dogwood stem diameter was significantly reduced for trifluralin (spray), isoxaben, and prodiamine compared with the control.

Shoot dry weight was similar among all treatments for sawtooth oak, gingko, and sweetbay magnolia, while shoot dry weight in the control was similar compared with all other treatments for willow oak (Table 3). With dogwood, shoot dry weight was greater in the control and perlite treatments compared with trifluralin (spray), isoxaben, and prodiamine. No differences occurred for root dry weight in sawtooth oak, willow oak, or sweetbay magnolia (Table 4). Although root dry weight varied within dogwood and gingko, the control treatments were statistically similar to all remaining treatments.

Overall, the herbicides and application rate evaluated in the study are safe to use on sawtooth and willow oak, gingko, and sweetbay magnolia. The labeled low herbicide application rate was used for this study, thus additional evaluations should be conducted using higher rates. Certain classes of herbicides may be more injurious to plants at potting or with developing roots. For example, herbicides in the dinitroaniline group (ex. trifluralin, prodiamine, and pendimethalin) can inhibit root development and reduce plant growth (Altland, 2003). Although not statistically significant, the reduced shoot and root dry weight observed for dogwood seedlings treated with trifluralin (spray) and prodiamine may have been a result of herbicide damage. Mulch applications did not significantly affect shoot growth, thus mulches should be considered as non-chemical options for weed control in seedling production.

Table 2. Stem diameter of tree seedlings treated with a mulch or pre-emergent herbicide.

Treatment	Formulation	Stem diameter (mm)				
		Sawtooth oak	Willow oak	Dogwood	Gingko	Sweetbay magnolia
Control	NA	3.04 a[1]	3.54 a	3.44 a	4.12 a	4.16 a
Perlite	Mulch[2]	2.94 a	3.34 a	3.35 a	4.45 a	4.30 a
Pine pellets	Mulch	2.89 a	3.29 a	2.94 ab	4.70 a	3.78 a
Cedar shavings	Mulch	2.97 a	3.31 a	2.43 ab	4.48 a	4.83 a
Trifluralin	Spray[3]	3.27 a	2.48 b	2.15 b	4.40 a	4.09 a
Trifluralin	Granular	2.84 a	3.01 ab	2.78 ab	4.00 a	4.54 a
Pendimethalin	Spray	3.10 a	3.35 a	2.53 ab	4.31 a	4.36 a
Pendimethalin	Granular	2.90 a	3.47 a	3.04 ab	4.75 a	4.92 a
Isoxaben	Spray	3.25 a	3.52 a	1.83 b	4.00 a	4.16 a
Trifluralin + isoxaben	Granular	3.18 a	3.14 ab	3.03 ab	3.71 a	4.67 a
Prodiamine	Spray	3.32 a	3.33 a	2.27 b	4.31 a	4.42 a

[1]Means followed by different letters within columns indicate significant difference at P<0.05 using the Shaffer-Simulated method.

[2]Mulches were applied to a depth of 0.8 cm (0.33 inch).

[3]Herbicides were applied using the labeled low rate (30 gal acre^{-1} application volume at 30 psi for liquid herbicide solutions).

Table 3. Shoot dry weight (g) of tree seedlings treated with a mulch or pre-emergent herbicide.

Treatment	Formulation	Shoot dry weight (g)				
		Sawtooth oak	Willow oak	Dogwood	Gingko	Sweetbay magnolia
Control	NA	4.67 a[1]	3.89 ab	2.23 a	1.47 a	2.23 a
Perlite	Mulch[2]	4.69 a	4.17 ab	2.46 a	1.99 a	2.05 a
Pine Pellets	Mulch	4.12 a	3.75 ab	1.52 ab	2.17 a	1.66 a
Cedar Shavings	Mulch	4.34 a	3.75 ab	1.33 ab	2.18 a	2.80 a
Trifluralin	Spray[3]	5.55 a	2.27 b	0.82 b	1.79 a	2.02 a
Trifluralin	Granular	4.95 a	3.03 ab	1.16 ab	1.32 a	2.32 a
Pendimethalin	Spray	5.47 a	3.86 ab	1.32 ab	1.89 a	2.21 a
Pendimethalin	Granular	3.94 a	4.18 a	1.70 ab	2.32 a	2.75 a
Isoxaben	Spray	5.63 a	4.38 a	0.32 b	1.27 a	2.04 a
Trifluralin + Isoxaben	Granular	4.56 a	3.65 ab	1.69 ab	0.98 a	2.50 a
Prodiamine	Spray	6.19 a	3.84 ab	0.71 b	1.68 a	2.16 a

[1]Means followed by different letters within columns indicate significant difference at P<0.05 using the Shaffer-Simulated method.

[2]Mulches were applied to a depth of 0.8 cm (0.33 inch).

[3]Herbicides were applied using the labeled low rate (30 gal acre^{-1} application volume at 30 psi for liquid herbicide solutions).

Although none of the products used in this study were labeled for use in container grown seedling or liner production, the results are promising and further evaluations on additional herbicide active ingredients and plant species should be considered. Many pre-emergent herbicides are not labeled for containers less than 10 cm (4 in.) wide, yet in this study only dogwood exhibited significant herbicide injury. Future studies will evaluate increased herbicide application rates and include additional plant species. The studies will also evaluate the effectiveness of various mulches and pre-emergent herbicides for controlling various weed species in small containers.

Table 4. Root dry weight (g) of tree seedlings treated with a mulch or pre-emergent herbicide.

Treatment	Formulation	Root dry weight (g)				
		Sawtooth oak	Willow oak	Dogwood	Gingko	Sweetbay magnolia
Control	NA	6.25 a[1]	4.51 a	1.22 ab	2.00 ab	2.22 a
Perlite	Mulch[2]	6.37 a	4.35 a	1.93 a	2.67 ab	2.28 a
Pine Pellets	Mulch	5.27 a	3.69 a	1.08 ab	3.09 a	1.67 a
Cedar shavings	Mulch	5.71 a	3.81 a	0.70 b	2.69 ab	2.95 a
Trifluralin	Spray[3]	6.43 a	2.68 a	0.51 b	2.20 ab	2.04 a
Trifluralin	Granular	6.39 a	4.05 a	0.72 b	1.62 ab	2.50 a
Pendimethalin	Spray	5.91 a	4.73 a	0.91 b	2.52 ab	2.46 a
Pendimethalin	Granular	5.33 a	4.35 a	1.00 b	2.28 ab	2.76 a
Isoxaben	Spray	5.38 a	4.64 a	0.30 b	1.78 ab	2.25 a
Trifluralin + isoxaben	Granular	6.38 a	3.98 a	1.03 ab	1.32 b	2.58 a
Prodiamine	Spray	7.44 a	4.40 a	0.42 b	1.70 ab	2.29 a

[1]Means followed by different letters within columns indicate significant difference at P<0.05 using the Shaffer-Simulated method.

[2]Mulches were applied to a depth of 0.8 cm (0.33 inch).

[3]Herbicides were applied using the labeled low rate (30 gal acre^{-1} application volume at 30 psi for liquid herbicide solutions).

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Effects of chicken manure compost and high percentage of biochar on container-grown basil (*Ocimum basilicum*)©

L. Huang[1,a], P. Yu[1] and M. Gu[2,b]

[1]Department of Horticultural Sciences, Texas A&M University, College Station, Texas 77843, USA; [2]Department of Horticultural Sciences, Texas A&M AgriLife Extension Service, College Station, TX 77843, USA.

INTRODUCTION

Biochar (BC) refers to the carbon-rich material derived from biomass (Lehmann, 2007). Research has shown that BC can be a potential alternative to commonly used substrates (Dumroese et al., 2011; Gu et al., 2013; Headlee et al., 2014; Housley et al., 2015; Vaughn et al., 2013), which is renewable and faster to generate (Yu et al., 2012)—compared to peat moss. Biochar could increase water and nutrient holding capacity, ameliorate acidity and provide a suitable environment for microbial activity (Dumroese et al., 2011; Vaughn et al., 2013; Zhang et al., 2014) and could increase plant growth under certain conditions (Headlee et al., 2014; Méndez et al., 2017; Nieto et al., 2016; Tian et al., 2012; Zhang et al., 2014). The effects of BC on container substrates depend on many factors such as its feedstock sources, production conditions, percentage of BC incorporation, other substrate components, plant type and fertility. There is no universal standard for BC incorporation for all plants. Therefore, it would be of interest to examine the characteristics of specific BC, amendment options based on its characteristics and their effects on different container-grown plants.

Composting is defined as the biological aerobic transformation of an organic byproduct into a different organic product that can be added to the soil without detrimental effects on plant growth (Baca et al., 1992). Previous research has shown that the growth indexes (GI), shoot dry weight (DW) and total dry weight (TDW) of basil and tomato and root DW of basil grown in mixes with vermicompost (VC—5, 10, 15 or 20%; by vol. and BC—20, 40, 60 or 80%; by vol.) were similar to or higher than those in 100% commercial substrates at 9 weeks after transplanting (WAT). Chicken manure compost (MC) has relatively similar fine texture to VC, but is cheaper and more readily available than VC. Chicken manure, which was produced from chicken waste resulting from the intensive poultry industries all over the world (Li et al., 2017), is a wildly used material in horticulture. Although chicken manure without being properly treated may contain some degradable nutrients and cause unpleasant environmental problems—such as odor and greenhouse gas emissions (Wu et al., 2016)—treated chicken manure can be a good compost component due to its rich nutrients, which are readily available to plants. With proper treatment, MC may contain 8.9% nitrogen, 8.2% phosphorus and potassium, and 86.6% organic matter (Chen et al., 2017).

Based on previous positive results from using mixes of BC and VC as container substrate for basil growth—the goal of this experiment was to test the feasibility of mixes of MC (5%, by vol.), a cheaper and more readily available alternative to VC, and high percentages of BC (50, 70 or 90%, by vol.) as replacements for commercial peat-based container substrates.

MATERIALS AND METHODS

Plant material and container substrate treatments

Basil plants (*Ocimum basilicum*) seeds (Johnny's Selected Seeds, Winslow, Maine) were sown in commercial propagation mix (propagation mix; Sun Gro Inc, Agawam,

[a]E-mail: huanglan92@tamu.edu
[b]E-mail: mgu@tamu.edu

Massachusetts) in 288-cell plug trays (cell depth: 2.5 cm; cell top length and width: 2 cm; volume: 6 mL) on March 19, 2017, in a natural lighted glasshouse at Texas A&M University, College Station, Texas. Substrates were formulated by mixing 5% MC (by vol.; Composted Chicken manure; Back to Nature, Inc., Slaton, Texas) with 50, 70 or 90% BC (by vol.; Proton Power, Inc., Lenoir City, Tennessee). And the remaining volumes were made up with a commercial substrate (Professional growing mix; Sun Gro Inc, Agawam, Massachusetts)—used as the control. The BC used in this experiment was the byproduct of fast pyrolysis of mixed hardwood. The pH of the BC is 10.2 and it had 4.6 mmhos cm^{-1} soluble salts. The physical properties and particle size distribution are shown in Table 1. Uniform basil seedlings were transplanted into the experimental substrates in 6-in. azalea pots (depth: 10.8 cm; top diameter: 15.5 cm; bottom diameter: 11.3 cm) on April 4, 2017. Each pot contained one basil seedling. Basil plants were irrigated with 200 mg L^{-1} N (20N-4.3P-16.6K) Peters Professional (Everris NA Inc, Dublin, Ohio) nutrient solutions.

Table 1. Physical properties and particle size distribution of the mixed hardwood biochar.

Total porosity	Container capacity	Air space	Bulk density	Particle size distribution		
	(% vol)		(g cm^{-3})	Large (<6.3 mm, >2 mm)	Medium (<2 mm, >0.5 mm)	Fine (<=0.5 mm)
84.7	60.3	24.4	0.15	2.6%	32.9%	64.5%

Measurements

The electrical conductivity (EC) and pH of container substrate leachates were measured weekly using handheld pH-EC meter (Hanna Instruments, Inc., Woonsocket, Rhode Island) according to the pour-through extraction method (LeBude and Bilderback, 2009). Growth index was determined by measuring plant height and two perpendicular widths at 0, 2 and 3 WAT using the formula: GI=Height/2+(Width1+Width2)/4. Fresh weight (FW) and DW of basil harvest were measured three times at 5, 9 and 15 WAT, respectively. Basil plants were harvested approximately 1 cm above the first node from the base of the plant at 5 WAT to measure the first FW and DW. Basil plants were again harvested approximately 1 cm above the first node on the two lateral branches of the plants to measure the second FW and DW at 9 WAT. The third FW and DW were determined by cutting the whole aboveground part of the basil plants from the substrates surface at 15 WAT. Dry weight was measured after being oven-dried at 80°C until constant weight. The total fresh weight (TFW) and TDW were determined by adding these three FWs and DWs, respectively.

Experimental design and statistical analysis

The experiment was set up in a completely randomized block design with the type of substrate being the main factor and there were five replications. Data were analyzed with one-way analysis of variance (ANOVA) using JMP Statistical Software (version Pro 12.2.0; SAS Institute, Cary, North Carolina) and means were separated using Dunnett's test when treatments were significant at $P<0.05$.

RESULTS AND DISCUSSION

Substrates pH and electrical conductivity

The pH of the substrates leachate was significantly different for all four measurements. Leachates pH of BC and MC mixes were significantly higher than the control commercial media (Figure 1). As biochar percentage increased, pH of the substrate leachate increased, as reflected in a significant linear or quadratic regression correlation of pH and BC percentage (Figure 2).

In the beginning of the study, EC of the BC and MC mixes leachates were similar to that of the control commercial media (Figure 3). However, EC of the BC and MC mixes leachates were higher than the control at 1 WAT, similar to the control at 2 WAT and lower at 3 WAT,

respectively. This result was not consistent with the results of Fan et al. (2015) who described that EC increased with increased BC rate. Tian et al. (2012) also found that adding 50% (by vol.) biochar made from green waste to peat moss media significantly increased EC. The different properties of the BC used in this research may have caused the difference in EC levels.

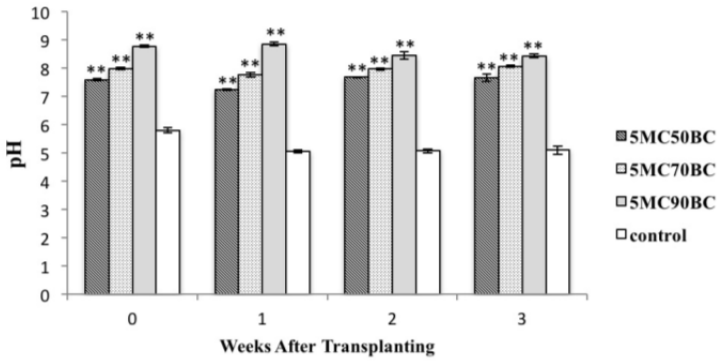

Figure 1. Substrate pH (mean ± standard error) in leachates of containers with 5% (by vol.) chicken manure compost (MC)—mixed with 50, 70 or 90% (by vol.) biochar (BC). The control was a peat-based, commercial media. The asterisks indicated significant difference from the control using Dunnett's tests [P<0.01(**)].

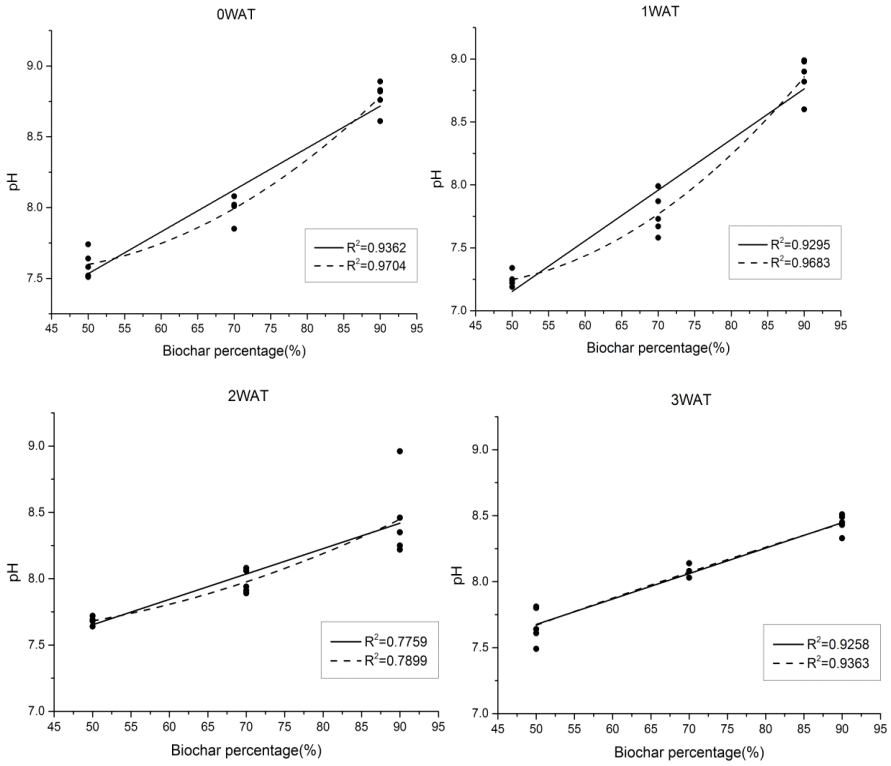

Figure 2. Linear (solid line) and quadratic (dashed line) regression correlation of the biochar percentages and the substrate pH in leachates of containers with 5% (by vol.) chicken manure compost (MC) mixed with 50, 70 or 90% (by vol.) biochar at 0, 1, 2 and 3 weeks after transplanting (WAT).

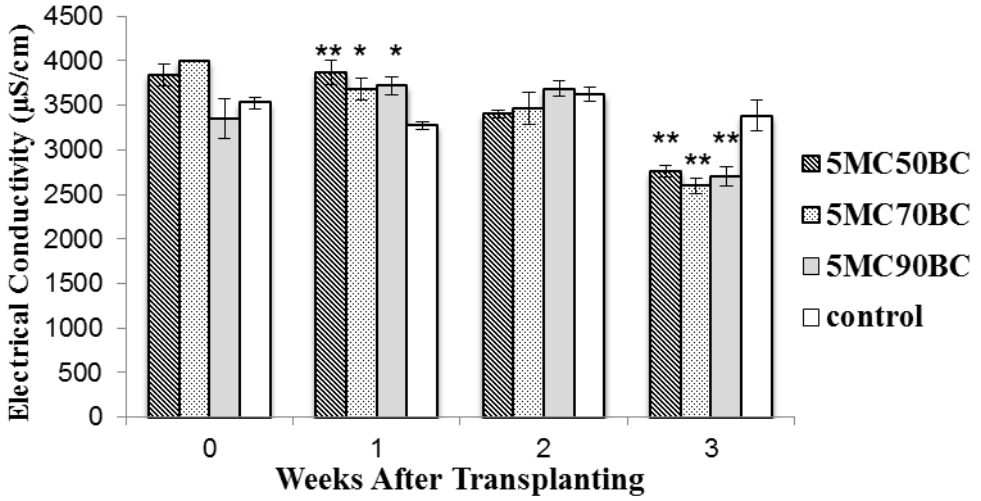

Figure 3. Substrate electrical conductivity (EC) (mean ± standard error) in leachates of containers with 5% (by vol.) chicken manure compost (MC) mixed with 50, 70 or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media. The asterisks indicated significant difference from the control using Dunnett's tests [P<0.05(*) or P<0.01(**)].

Plant growth and development

Growth indexes of the basil plants grown in substrates with 5% MC mixed with 50, 70 or 90% BC were all similar to those grown in the control commercial media at 2 and 3 WAT (Figure 4). There were no significant differences between the TFW and TDW of three basil cuttings grown in BC and MC mixes and the control (Figure 5). Yu et al. (2012) reported that when substituting Sunshine #1 Mix with 60 or 80% pinewood BC (by vol.), the DW of basil plants grown in mixes with BC was similar to or higher than the control.

From this preliminary experiment, chicken manure compost (5%, by vol.) may be a good potential amendment candidate for incorporating high volume biochar (50, 70 or 90%, by vol.) in commercial substrates to grow basil (*Ocimum basilicum*). More species need to be tested for future use.

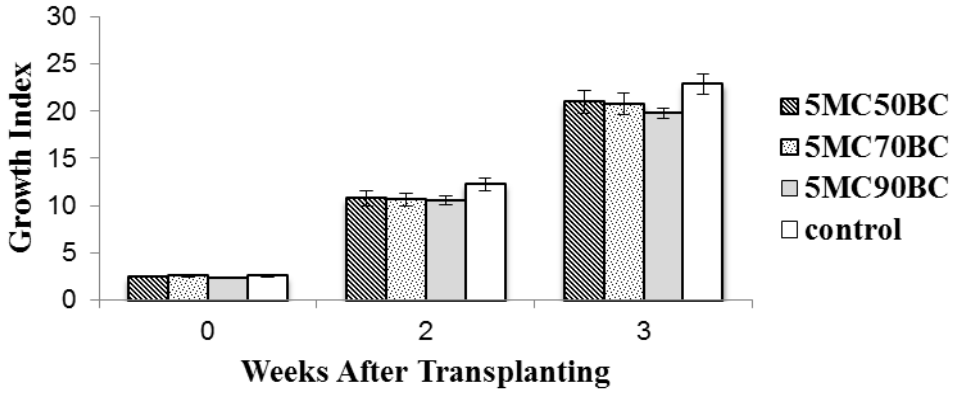

Figure 4. Growth index of basil (*Ocimum basilicum*) (mean ± standard error) at 0, 2, 3 weeks after transplanting when grown in mixes with 5% (by vol.) chicken manure compost (MC) and 50, 70 or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media.

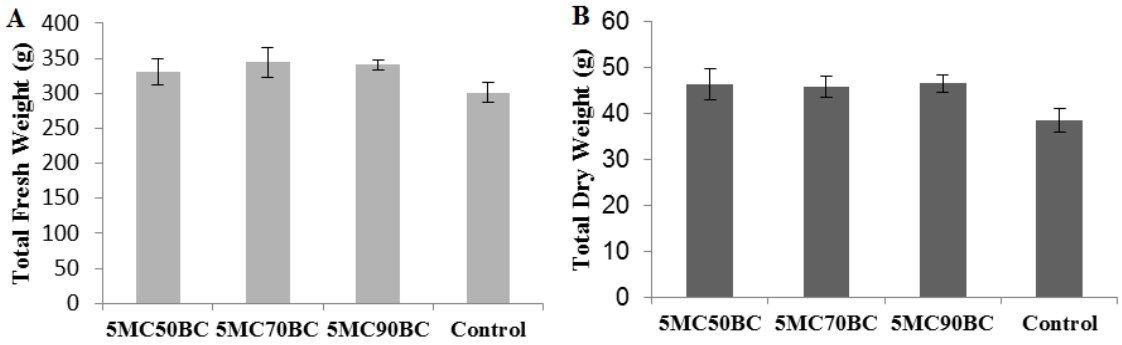

Figure 5. Total fresh weight (A) and total dry weight (B) of basil (*Ocimum basilicum*) (mean± standard error) grown in mixes with 5% (by vol.) chicken manure compost (MC) and 50, 70 or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media.

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Propagation and out planting of *Chrysopsis* species endemic to the Florida Panhandle©

G.E. Campbell-Martínez[1], N. Hooton[1], M. Thetford[1,a], D. Miller[1] and S.B. Wilson[2]

[1]West Florida Research and Education Center, University of Florida/IFAS, 5988 Hwy 90, Bldg. 4900, Milton, Florida 32583, USA; [2]Environmental Horticulture Department, University of Florida/IFAS, PO Box 110670, Gainesville, Florida 32611, USA.

INTRODUCTION

Goldenasters (*Chrysopsis*), members of the *Asteraceae*, range from eastern to central North American native annuals to short lived perennial plants- with many endemics found throughout the southern United States. Two *Chrysopsis* native to the Florida panhandle include *Chrysopsis godfreyi* which is present in two forms (f. *godfreyi* and f. *viridis*) and *C. gossypina* ssp. *cruiseana* which occur in secondary beach dunes and scrub plant communities (FNAI, 2000a, b). Both species are considered endangered in Florida and are restricted to the western Panhandle of Florida, with *C. godfreyi* occurring also in one coastal county in Alabama (FNAI, 2000a, b; Keener et al., 2017).

These three *Chrysopsis* taxa may be differentiated based on foliar vegetative characteristics. Basal foliage of *C. godfreyi* f. *godfreyi* has leaves with a wooly pubescence and a silvery appearance while foliage of *C. godfreyi* f. *viridis* has green leaves with pubescence composed of glandular trichomes, resulting in a sticky leaf surface. For both forms of *C. godfreyi*, the bracts of the inflorescences express the same trichome characteristics as leaves from the basal rosette. *C. gossypina* subsp. *cruiseana* has green leaves with moderate pubescence and a moderate silver appearance for fall and winter basal leaves with the quantity of trichomes diminishing as the inflorescences extend; bracts of the inflorescences are glabrous.

These endemic species are important in coastal restoration projects as a food source for subspecies of the endangered beach mouse (*Peromyscus polionotus*) and as a pollinator sustainer. Additionally, these species have potential as an ornamental for low-input landscapes for their adaptability to dry, infertile soils, interesting foliage, growth form, numerous yellow fall flowers and use in pollinator gardens.

While *Chrysopsis* species described here have restoration and ornamental potential, little published information is available on their propagation or planting in low input landscapes or restoration sites. Reproduction from seed was studied by Hooton (2011) to characterize seed production and germination requirements for these *Chrysopsis* from native populations in Escambia County, Florida. From mature flowers collected in a native setting, a range of 6,000 to 8,000 seeds was recorded per plant. Smith et al. (2014) produced landscape quality transplants from seed in a variety of production substrates. Here we describe sexual and asexual propagation information and planting results for these plants within a restoration context.

ASEXUAL PROPAGATION

We have successfully propagated all three *Chrysopsis*, described herein, utilizing terminal stem cuttings collected from seed-grown stock plants as well as terminal stem cuttings collected from wild populations. The following protocol was successfully implemented to produce research grade plants. Non-flowering terminal stem cuttings containing several visible nodes were removed and direct-stuck without supplemental auxins in a well-draining substrate (Fafard 4P or Fafard 3B). Propagation flats with 72 cells flat^{-1} were used with high rooting success. Cuttings rooted readily under intermittent mist resulting in rootballs that remained intact within 7 days of sticking (Figure 1). Rooted liners may be transplanted within 2 weeks and in our experience filled a 4-in. pot in 8 to 10 weeks. It is important to only collect vegetative cuttings and avoid cutting collection once plants

[a]E-mail: thetford@ufl.edu

begin floral initiation. Floral initiation occurs in response to changes in photoperiod in the fall. Cuttings from plants that have initiated floral development will also root readily but will have little or no potential to develop new vegetative buds.

Figure 1. *Chrysopsis gossypina* subsp. *cruiseana* stem cutting 1 week after sticking in Fafard 3B using a 72-cell flat and overhead mist.

SEXUAL PROPAGATION

These three *Chrysopsis* taxa may also be grown from seed. To determine germination potential, seeds were collected in December 2009 from two coastal sites (Pensacola Beach and Perdido Key) within the western panhandle of Florida. Wild collected seed were separated from the seedheads and surface sterilized. Seed were soaked in a Physan 20™ solution (1.0 mL Physan 20 per 500 mL of deionized water) for 5 min, placed on the surface of a peat based media and lightly covered with vermiculite. Four replicates of 50 seeds (n=200) were used for each species. Seed trays were maintained inside a greenhouse in south Florida (Ft. Pierce) and trays were watered from below with seep irrigation. Germination (emergence) was recorded every other day for 8 weeks.

Cumulative germination did not differ between the three *Chrysopsis* 8 weeks after sowing and was between 30-50% (Figure 2). However, cumulative germination differed between all three *Chrysopsis* 6 weeks after sowing, *C. godfreyi* f. *viridis* had the highest (27±3%) followed by *C. gossypina* subsp. *cruiseana* (22±2%) with *C. godfreyi* f. *godfreyi* having the lowest (18±0.8%) cumulative germination at 6 weeks.

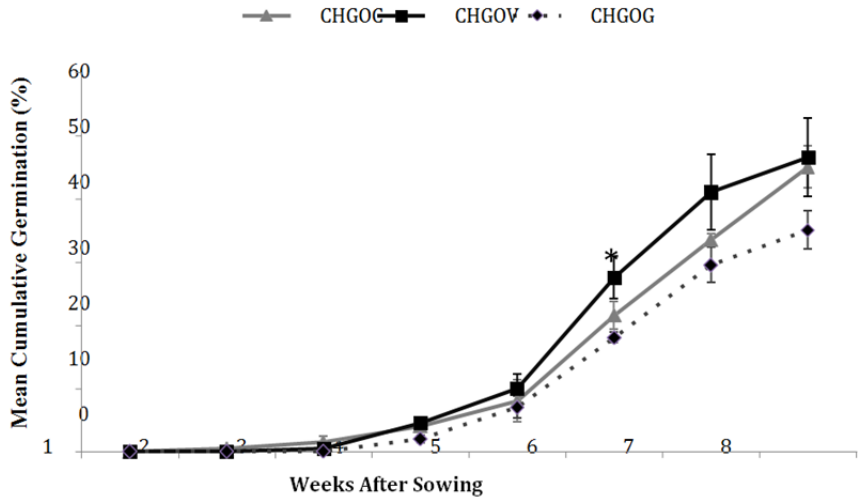

Figure 2. Mean cumulative germination (%) of *Chrysopsis godfreyi* f. *godfreyi* (CHGOG), *Chrysopsisgodfreyi* f. *viridis* (CHGOV), and *Chrysopsis gossypina* subsp. *cruiseana* (CHGOC) over 8 weeks in a greenhouse in Fort Pierce, Florida from September to November 2010. Error bars represent ±1 standard error of the mean, *n*=200. * = week where cumulative germination between the three taxa was statistically different.

OUT PLANTING

Beach planting of *Chrysopsis* for coastal restoration was evaluated with transplants produced from terminal stem cuttings of *C. gossypina* subsp. *cruiseana* as described above. Plants for the restoration evaluation were grown in 4-in. pots containing a 2:1 ratio of pine bark:Fafard® 3B substrate starting mid-October 2016. Plants with rootballs that held the substrate together when removed from pots were planted midslope on secondary beach dunes in the western panhandle of Florida in January 2017. Two spatially separated beach dune systems were used with 6 replicate blocks at each site. Each block contained a total of 20 plants with 10 plants receiving 1/2 teaspoon of Osmocote® (18-6-12) and the other 10 receiving no fertilizer at the time of planting. Survival, plant height and plant width (2 perpendicular widths) were recorded (inches) 8 months after beach planting and a plant index computed [(mean of two widths + height)/2].

Survival was near 100% and did not differ between planting sites or fertilizer treatments 8 months after planting (Figure 3). Growth index for plants receiving fertilizer indicates the application of Osmocote at the time of planting increased overall plant size by 37% compared to plants receiving no fertilizer at the time of planting.

DISCUSSION

Utilization of western panhandle Florida endemic *Chrysopsis* in restoration and as a low-input ornamental is currently limited. What is needed are available stock plants and published data on their propagation and out planting. The asexual and sexual propagation methods for the *Chrysopsis* described here are easily accomplished without complicated procedures and protocols - and can be standardized across all three taxa. Seeds should be selected and sown without pre-treatment in winter, fall, or spring, and exposed to light for germination. Plants propagated asexually from small 1-in. apical stem cuttings can result in a marketable product within 8 to 10 weeks. While individual clones may be desirable for ornamental plantings, care must be taken to collect cuttings from the broadest possible population of individual plants when producing transplants for restoration projects utilizing asexual propagation techniques in order to ensure genetic diversity and resilience. Since these plants are mostly on protected lands, the status of the plants may require permits for collection. It is advisable to seek all appropriate permits prior to wild collection of seeds or

cuttings.

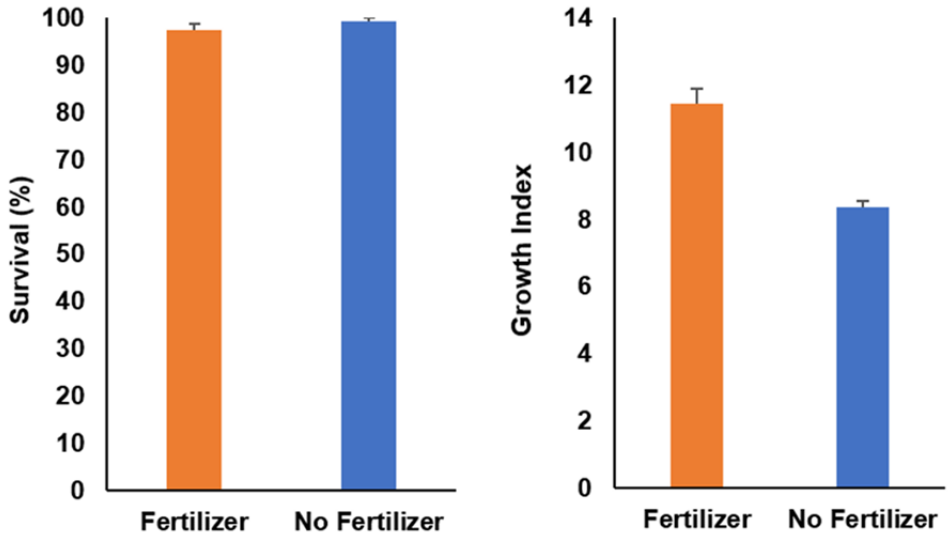

Figure 3. Survival (%) and Growth Index computed [(mean of two widths + height)/2] for *Chrysopsis gossypina* subsp. *cruiseana* 8 months after beach planting of plants grown in 4-inch pots. Error bars represent ± 1 standard error of the mean.

Based on our present work, supplemental fertilization at out planting provides no benefit to transplant survival. However, supplemental fertilization did increase overall plant size, plant vigor and increased aesthetic appeal when nursery-grown plants were planted in a restoration context within a beach dune area. Continued monitoring and assessment is needed to determine if supplemental fertilization will affect flowering characteristics, seed production, or subsequent seed germination characteristics or if there will be differences in the ability of these plants to overwinter and become perennial.

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Indoor plant toxicity concerns some consumers©

S.A. Keene[a], T.N. Kalk, D.G. Clark, T.A. Colquhoun and H.R. Moskowitz

University of Florida, 1525 Fifield Hall, Gainesville, Florida 32603, USA.

Abstract

The addition of plants to an indoor environment provides many benefits; however, some of the most popular plant species purchased for interior use possess harmful qualities. Using conjoint analysis, this study assayed consumers' preferences for toxic attributes in indoor plants. Consumers demonstrated the highest interest in plants that were non-toxic to humans and pets, whereas consumers demonstrated the lowest interest in plants that were extremely toxic to humans and pets. Cluster analysis revealed two distinct segments of consumers characterized by their divergent responses to toxicity attributes.

INTRODUCTION

The addition of plants to an indoor environment whether to a home, school, or office brings real benefits. Some plant species remove major contaminants of indoor air (Kim et al., 2010). The presence of plants in an office setting has been associated with decreased tension and anxiety (Chang and Chen, 2005). In a classroom setting, students reported the presence of plants improved air quality, increased pleasantness, and improved performance (Khan et al., 2005).

Despite the advantages indoor plants bestow and their popularity in American households and businesses, many of these plants possess toxic features. These plants vary in their degree of toxicity, the species they affect, and their routes of exposure. For example, a number of *Spathiphyllum* and *Philodendron* species contain oxalate crystals which can cause contact dermatitis or, upon ingestion, irritation of mucous membranes in people and animals (Franceschi and Nakata, 2005). The Annual Report of the American Association of Poison Control Centers' National Poison Data System (AAPCC-NPDS) ranks plants in the top 25 substance categories that are most frequently involved in human exposure cases that result in serious outcomes (moderate, severe, or death) (Mowry et al., 2015, 2016). The 2014 and 2015 AAPCC-NPDS provide lists of the top 25 plants most frequently responsible for human exposures. These lists include a number of popular houseplants, including peace lily (*Spathiphyllum*), *Philodendron*, calla lily (*Zantedeschia aethiopica*), pothos (*Epipremnum aureum*), and poinsettia (*Euphorbia pulcherrima*) (Mowry et al., 2015, 2016).

Given the harmful nature of certain plants grown for indoor use, we wanted to investigate whether toxic characteristics affect consumer preference for indoor plants. Two studies investigated the effect of plant toxicity on consumer interest. Solano (2012) included toxicity as a binary attribute (toxic or not toxic) in choice-based conjoint analysis surveys, along with a number of other houseplant features. While toxicity overall had a negative effect on consumer willingness to pay (WTP), WTP increased when toxicity was presented with other attributes such as the ability to remove indoor air pollutants. Rihn et al. (2015) surveyed 91 individuals from central Florida on barriers to purchasing indoor foliage plants. Given the option to "check all that apply", 17% of participants indicated toxicity to pets was a barrier to purchase, while 3% indicated toxicity to kids was a barrier. Though the two studies provide useful baseline information about consumer preference for indoor plants with toxic qualities, their evaluation and scope are limited. New insights into consumer preference can be gained by investigating preference for a range of toxicities (mild to extreme), as well as for toxicity that affects only humans or only pets. Additionally, the small size and localized nature of the study sample in Rihn et al. (2015) constrains the generalization of their results to a wider population. Assaying toxicity preferences in a

[a]E-mail: keene284@ufl.edu

larger, non-localized sample would generate consumer preference data more representative of the broader population and could yield novel results. A detailed evaluation of toxicity attributes would lead to a more thorough understanding of consumers' preferences for them, which could improve how growers and retailers market plants with these features.

The objective of this study was to investigate toxicity attributes in-depth and gain greater insight into their effect on consumer interest. Specifically, we utilized modified conjoint analysis to assess consumers' preferences for indoor plants with a range of toxic attributes.

MATERIALS AND METHODS

To evaluate consumers' interest in houseplants with toxic attributes, modified conjoint analysis was implemented using IdeaMap® (Mind Genomics Advisors, Inc., Saratoga Springs, New York), a software tool which allows for the rapid assay of consumer interest in products composed of various combinations of distinct attributes (Gofman and Moskowitz, 2007). Consumers indicate their interest in each combination of attributes using a 9-point scale. Regression analysis relates the independent variables (the product features) to the dependent variable (consumer interest). The effect of a single independent variable is isolated from a group of independent variables presented together. We chose five categories for toxic houseplants and their purchasing environment and generated seven concise descriptions, or elements, for each category (Figure 1). We also composed a welcome screen, one rating question, 14 demographic questions, and a "thank you" screen. The University of Florida Institutional Review Board (IRB) approved this study as exempt (IRB201600642).

Study participants were recruited from across the US by a contracted company, Panel Direct Online (Focus Forward, LLC, New York, New York). We screened for participants that purchased a houseplant in the past five years. Following the welcome screen, the participant was presented with 50 randomized element combinations, or "concepts". Each concept contained between three and four elements and each element appeared the same number of times (Moskowitz et al., 2006). The participant rated each concept on a 9-point Likert-style scale, with 1 indicating the lowest interest and 9 indicating the highest. After rating all 50 concepts, the participant answered 14 demographic questions. A total of 321 individuals completed this study.

The data were transformed and analyzed in the same manner as characterized extensively in previous work (Gofman and Moskowitz, 2007; Moskowitz et al., 2006; Dewar et al., 2016; Moskowitz, 2012). Regression modeling, executed by the software tool, connected the participant's rating to the presence or absence of every element in the concepts (Gofman and Moskowitz, 2007; Moskowitz et al., 2006). The independent variables (the elements) were related to the dependent variables (the ratings) and each element was given a numerical value. This value was calculated using the following equation, which was generated for each respondent: Rating = k0 + k1 (element A1) + k2 (element A2) +…+ k35 (element E7); k0 denotes the additive or baseline constant, and k1 to k35 denote the coefficients that describe the interest values (InVs) of elements 1 to 35, respectively. The additive constant provides a baseline level of interest that the participant has in houseplants alone without the input of the other elements. The InV of each feature reveals the conditional probability of that element driving consumer interest, and is compared to the additive constant to determine the incremental or detrimental effect of that element on consumer liking (Dewar et al., 2016). An InV of ≥3 suggests that consumer interest is favorably increased by that product feature. InVs between -2 and 2 indicate the element is neutral and does not influence consumer interest. A feature that receives an InV of ≤-3 indicates a negative impact on consumer interest, and should be avoided by retailers. Additionally, k-cluster analysis, executed by the software tool, was used to find segments of consumers within the study population that were similar in their preferences.

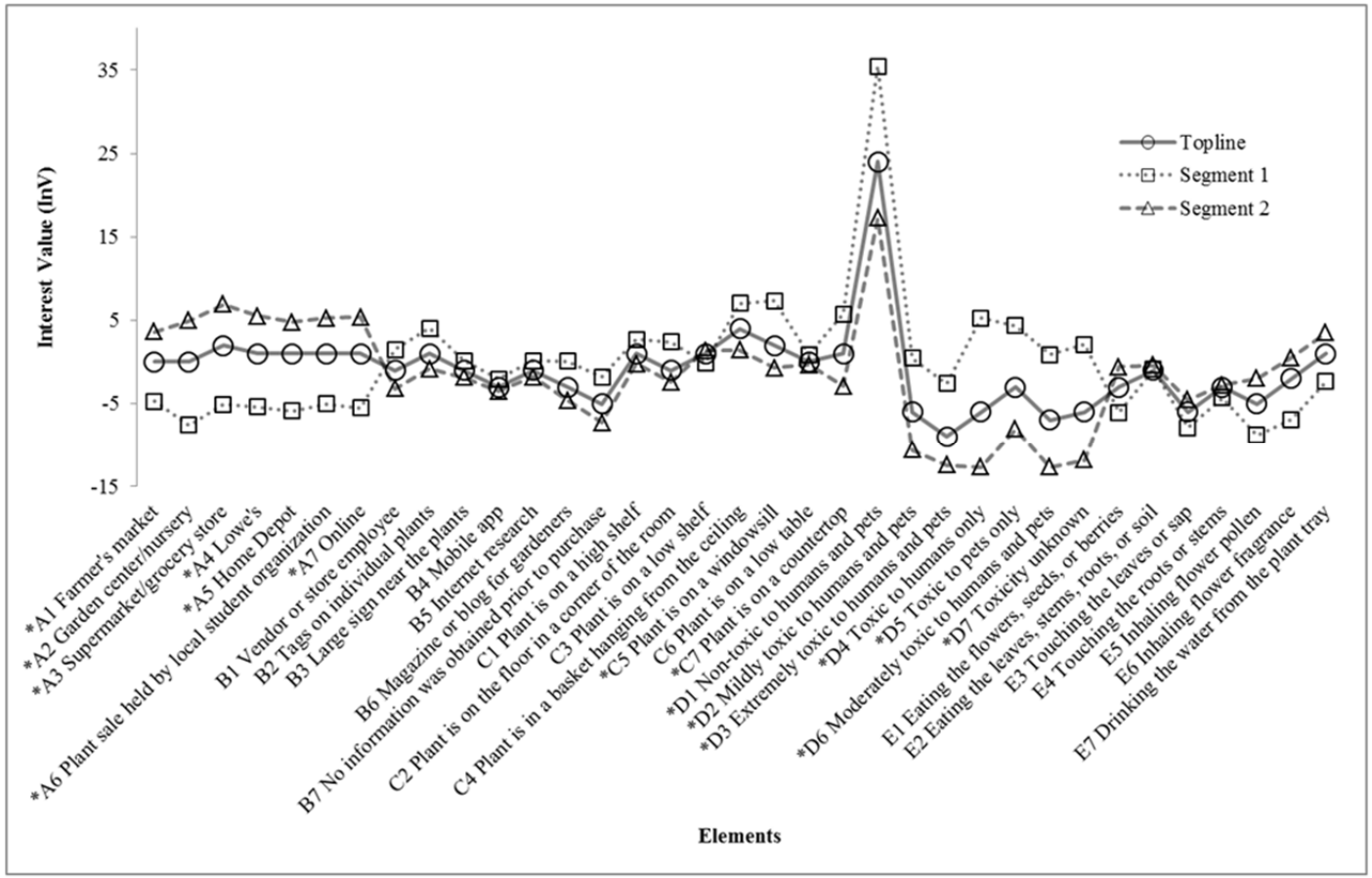

Figure 1. Interest values (InVs) of elements A1 – E7 are provided for the total study and for each segment. The InVs are relative to the baseline constant of each group: 36 for the total study population, 34 for Segment 1, and 37 for Segment 2. An asterisk (*) preceding an element along the x-axis indicates a significant difference (P<0.05), identified with a Student's t test, between the InVs of the two segments for that element.

RESULTS

Plants that were "non-toxic to humans and pets" received the highest InV (Figure 1). Many of the elements pertaining to purchase location and the location of the plant in the home were broadly neutral. Fourteen elements received an InV of -3 or lower, indicating a negative effect on consumer interest. The majority of these elements pertained to the degree of toxicity and the route of exposure.

Two segments of consumers were identified as a result of k-cluster analysis (Figure 1). The two segments had similar levels of interest in houseplants with constants of 34 and 37 for the first and second segments, respectively. Segment 1 was characterized by positive interest in several plant locations in the home, plants that were toxic to either only humans or pets, and tags on individual plants. The other elements from the toxicity category were either neutral or only slightly negative. Toxic attributes strongly and negatively affected consumer interest in Segment 2.

DISCUSSION

The purpose of evaluating a range of toxicity attributes was to determine whether consumer preference changed depending on the level of toxicity or specificity. From a topline perspective, consumers most preferred plants that are non-toxic to humans and pets, while every other attribute describing toxicity, including mild, had a negative effect on consumer interest. These results show that, for the study population as a whole, toxicity level or specificity did not alter consumer preference. These results support the findings of Solano that toxicity overall negatively impacted consumer willingness to pay (Solano, 2012). The strong negative response to various toxic attributes contrasts somewhat with the findings of Rihn et al. (2015) that toxicity was considered only a minor barrier to purchasing indoor plants by a small portion of their study population. While our results indicate toxic attributes negatively affect overall consumer interest, ultimately those attributes might not prevent someone from purchasing a plant. Indeed, while not the largest, the market is sizeable for foliage and flowering plants sold for indoor or patio use. The 2014 Census of Horticultural Specialties lists the combined yearly value of all sales of potted foliage and flowering plants for indoor or patio use at $1,806,163,000 (USDA, 2015). The census includes poinsettia, daffodil (*Narcissus*), philodendron, pothos (*Epipremnum*), and peace lily (*Spathiphyllum*) in their list of the top selling plants for indoor or patio use (USDA, 2015). Incidentally, all of the aforementioned plants appear on the AAPCC-NPDS list of plants most frequently responsible for human exposure cases with serious outcomes (Mowry et al., 2015, 2016).

The relatively strong sales of these plants could indicate multiple things. Perhaps some consumers are aware of the toxic attributes possessed by these plants, but do not consider that toxicity a barrier to purchase. The results from the cluster analysis support this idea. Cluster analysis identified two distinct market segments most prominently characterized by their divergent response to toxicity attributes. Simply put, one group of consumers strongly dislikes toxicity while the other group of consumers is not too concerned about it. Another explanation for the strong sales could be that some consumers are unaware of the toxic attributes these plants possess. Retailers are not required to provide such information. If toxicity information is not provided at the point of purchase, then it falls upon the consumer to do their own research, which they may or may not do.

While the results of this study indicate that consumers prefer plants that are non-toxic to humans and pets, advertising a plant as non-toxic could be risky. If an individual buys a plant marketed as "non-toxic" but then has an unexpected, serious allergic reaction to it, the seller of that plant could be liable. On the other hand, labeling a plant as toxic could adversely affect sales. Moreover, if retailers started labeling toxic plants, where would the labeling begin and end? Without an industry-wide standard for what should be labeled toxic, deciding whether to label or how is at the discretion of the retailer. Ultimately, if retailers of indoor plants are aware of the segmented nature of consumer preference for toxicity attributes, they can determine how best to apply that information in how they market plants

to their consumers.

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Influence of herbicide application volume on weed control in non-irrigated nursery production areas©

C. Conner, C. Marble[a] and A. Chandler

University of Florida/IFAS Mid-Florida Research and Education Center, 2725 S. Binion Rd., Apopka, Florida 32703, USA.

Abstract

Preemergence (PRE) herbicides require activation with rainfall or irrigation within 1-3 weeks after application in order to perform effectively. During dry weather periods, erratic weed control may result if herbicides are not properly activated. In this study flumioxazin (SureGuard® suspension concentrate) and indaziflam (Marengo®), two PRE herbicides utilized in bareground areas of nurseries and as directed applications in larger containers (often not irrigated with overhead sprinklers), were examined at different application volumes to determine if increasing herbicide application volume could increase weed control in the absence of activation irrigation. Flumioxazin was applied at 8 and 12 fl. oz. acre^{-1} while Marengo was applied at 7.5 and 15 fl. oz. acre^{-1} to 1.3-L containers filled with a pinebark:peat substrate using application volumes of 5, 10, 20, 40, 60, 80, or 100 gal acre^{-1} (gpa) for control of common nursery weed species. The most consistent control was achieved with the high rate of Marengo across all application volumes (91 to 100% control) while SureGuard provided the most consistent results across all application volumes at both rates, with percent control ranging from 61 to 84% control. It is recommended that growers use application volumes at least as high as or higher than suggested on herbicide product labels and still attempt to time applications when some rainfall is expected in the coming days if possible.

INTRODUCTION

Florida and many other areas experience unusual weather patterns and may experience prolonged periods of dry weather. When applying a PRE herbicide, sufficient irrigation (typically 0.25 to 0.5 in.) is necessary in order to activate the herbicide within the soil. Otherwise, sporadic weed control may develop, as herbicide can be lost via volatility or other means. The length of time in which a herbicide must be activated varies with different herbicides, but is typically anywhere between a few days up to several weeks. Weed control in and around non-crop production areas (soil storage, roadways, aisles, etc.) is important to prevent weeds from encroaching into production areas. However, if no rainfall occurs and the area is not irrigated—growers have no way to properly activate the herbicide. Lack of rainfall is also important in large containers that are irrigated via spray-stakes or drip irrigation which may not sufficiently activate a herbicide.

When applying herbicides to non-crop areas, growers will typically apply these products using low application volumes 15 to 30 gal acre^{-1} because it is more efficient. There are no data available on the influence of application volume on efficacy of preemergence herbicides used in nursery production. The objective of this research project was to determine if PRE herbicide efficacy could be increased by increasing the herbicide application volume in times where rainfall was not expected and overhead irrigation was not available.

METHODS AND MATERIALS

Nursery pots (1.3 L) were filled with a standard pinebark:peat growing media (Fafard 52, SunGro Horticulture) and amended with Osmocote Plus 17-5-11 at a rate of 12 lbs. per cubic yard. After pots were filled, flumioxazin (SureGuard® suspension concentrate) was

[a]E-mail: marblesc@ufl.edu

applied at 8 or 12 oz. acre^{-1} and indaziflam (Marengo®) was applied at 7.5 or 15 fl. oz. acre^{-1} using a CO_2 backpack sprayer. Each herbicide and each rate was applied using an application volume of 5, 10, 20, 40, 60, 80, or 100 gpa. Once the appropriate PRE herbicide was applied, the pots were moved to a rainout shelter and received no rainfall or irrigation for a 28-day period. After 28 days, pots were moved to a quonset greenhouse and overseeded with equal amounts of eclipta (*Eclipta prostrata*) seeds and spotted spurge [*Euphorbia maculata* (syn. *Chamaesyce maculata*)] seeds. After pots were overseeded, they received 0.35 in. of overhead day^{-1} for a duration of 8 weeks. Data collected included visual percent control ratings in comparison with nontreated pots (0 to 100, 0 = 0% control; 100 = 100% control) at 2, 4, 6, and 8 weeks after seeding (WAS) and shoot dry weight data was collected at 8 WAS. Shoot fresh weight data were converted to percent control ratings using the formula [(fresh weight of non-treated – fresh weight of treated)/fresh weight non-treated]*100. Data were analyzed using the Proc GLM procedure in SAS and treatment means separated using Fisher's LSD test (p=0.05). For the sake of brevity, only fresh weight data will be discussed.

RESULTS

When examining data across both rates and across all application volumes, herbicide was not significant with indaziflam and flumioxazin providing 81 and 80% control, respectively (Table 1). Herbicide rate was significant with the rate of both products providing 89% control and the low rate providing 72% across all application volumes and both herbicides. Few differences were seen when herbicides were applied at an application volume of at least 10 gpa.

Table 1. Main effect of herbicide, rate and application volume on percent control[1] (biomass reduction) of spotted spurge and eclipta in absence of activation moisture.

Herbicide[2]	Marengo®	81 a[3]	Application[4]	5	64 b
	SureGuard®	80 a	volume	10	86 a
				20	79 a
Rate[5]	Low	72 b		40	84 a
	High	89 a		60	82 a
				80	85 a
				100	84 a

[1]Percent control was calculated by using the formula [(dry wt. of non-treated – dry weight of treated)/dry weight of non-treated]*100.

[2]Marengo® SC (indaziflam, BayerCrop Science, Research Triangle Park, NC); SureGuard® SC (flumioxazin, Nufarm Inc., Alsip, IL).

[3]Means followed by the same letter in each category are not significantly different according to Fisher's LSD (p=0.05).

[4]Application volume is shown in gallons acre^{-1}.

[5]Rates applied included 7.5 and 15 fl.oz. formulated product per acre for Marengo® and 8 and 12 fl. oz. formulated product acre^{-1} for SureGuard® for the low and high rates, respectively.

When examining individual herbicides applied at the two different rates, results varied at different application volumes and there was no clear trend in terms of higher application volume increasing control (Figure 1). Application volumes of 10 to 100 gpa provided approximately 80 to 90% weed control while only 64% control was seen when an application volume of 5 gpa was used (Table 2). The high rate of Marengo provided better control than any other treatment at application volumes of 5, 20, 40, and 80 gpa (Table 3). The low rate of Marengo was similar to both rates of SureGuard at most application volumes.

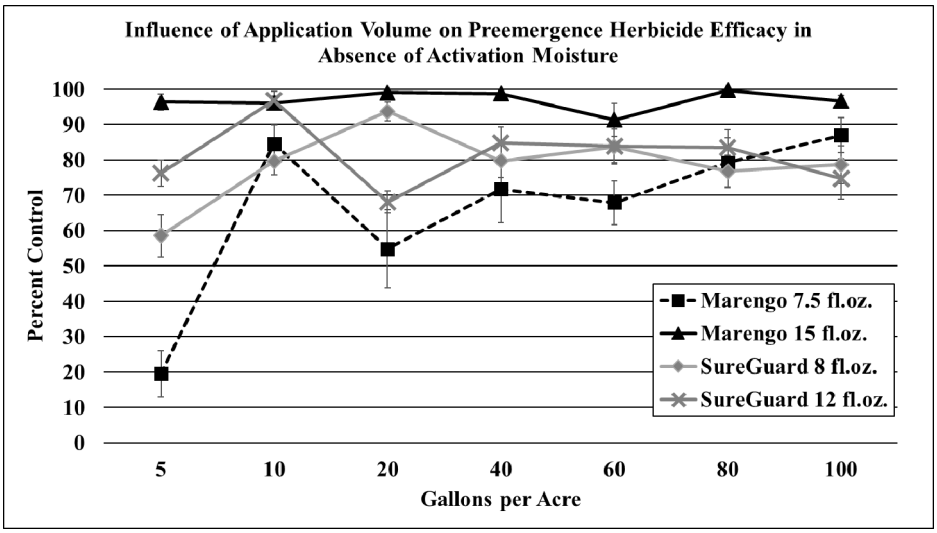

Figure 1. Influence of application volume on preemergence herbicide efficacy in absence of activation moisture.

Table 2. Impact of application volume on efficacy of two herbicides[1] applied at labeled rates without application activation moisture for control of spotted spurge and eclipta.

Application volume[1]	Ratings[2]				Shoot D.W.[3] percent control
	2 WAS[4]	4 WAS	6 WAS	8 WAS	
5	95 c[5]	77 c	64 b	60 b	64 b
10	100 a	92 a	83 a	77 a	87 a
20	97 bc	83 bc	73 ab	66 ab	79 a
40	99 ab	90 ab	79 a	71 ab	84 a
60	99 ab	89 ab	75 ab	68 ab	82 a
80	99 ab	89 ab	78 a	74 a	84 a
100	99 ab	90 ab	80 a	72 ab	84 a

[1]Data show means of SureGuard® (flumioxazin) and Marengo® (indaziflam) herbicide applied at rates of 8 and 12 fl. oz. acre^{-1} for SureGuard® and 7.5 and 15 fl. oz. for Marengo®.

[2]Ratings were taken based on a scale of 0 to 100 (0 = 0% control, 100 = 100% control) based upon percent coverage of non-treated pots.

[3]Shoot D.W. = Shoot dry weight collected at 8 weeks after seeding. Shoot dry weight data were converted to percent control ratings using the formula [(weight non-treated – weight of treated)/weight of non-treated]*100.

[4]WAS = weeks after seeding. Pots were treated and were not seeded or irrigated for 28 days after herbicides were applied.

[5]Means within a column followed by the same letter are not significantly different according to Fisher's LSD (p=0.05).

Table 3. Effects of herbicide and rate on efficacy of indaziflam (Marengo®) and flumioxazin (SureGuard®) when applied at 7 different application volumes in the absence of activation moisture for control of spotted spurge and eclipta.

		Application volume (GPA)						
		5	10	20	40	60	80	100
Herbicide	Rate (fl.oz)	Percent control[1]						
Marengo®	7.5	20 d[2]	85 ab	55 b	80 b	68 b	79 b	89 b
	15	96 a	96 a	99 a	99 a	91 a	100 a	97 a
SureGuard®	8	61 c	76 b	55 b	72 b	84 a	77 b	79 b
	12	79 b	93 a	68 b	80 b	91 a	84 b	75 b

[1]Percent control calculated using the formula [(shoot dry weight non-treated - dry weight treated)/dry weight of non-treated]*100.

[2]Means within a column followed by the same letter are not significantly different according to Fisher's LSD (p=0.05).

CONCLUSION

The high rate of Marengo generally provided the best control of eclipta and spurge across all application volumes, resulting in 91 to 100% control. However, the low rate provided variable control ranging from 20 to 87% control. SureGuard was generally consistent across both rates and across all application volumes with control ranging from 61 to 87% control. Based on results of this trial, using application volumes higher than recommended (10 and 5 gpa for Marengo and SureGuard, respectively) did not significantly improve weed control when the herbicide was not activated. Growers should continue to apply preemergence herbicides according to label instructions and use application volumes at least as high as recommended on product labels. It should be noted that this trial was conducted using a soilless substrate, and results could vary in field soils. This trial was also not conducted using an activated control, a treatment in which irrigation was applied within the time period specified on product labels. Future work will evaluate use of multiple application volumes in a variety of field soils and also utilize irrigated controls to further determine the impact of different application volumes on weed control.

Which is better for mother stock of leaf-bud cuttings of kaki (*Diospyros kaki*), root-sucker or hedge?©

T. Tetsumura[a], S. Ishimura and C. Honsho

Faculty of Agriculture, University of Miyazaki, 1-1 Gakuen Kibanadai-Nishi, Miyazaki 889-2192, Japan.

INTRODUCTON

We have demonstrated how to propagate kaki (*Diospyros kaki* Thunb.) using softwood cuttings (Tetsumura et al., 2000, 2001, 2002, 2003, 2009, 2011, 2015b, 2017; Hejazi et al., 2018). One of key success factors of softwood cutting propagation, which had been thought to be difficult (Tao and Sugiura, 1992), was the length of cuttings; the shorter the cuttings were, the higher the rooting percentages were (Tetsumura et al., 2000, 2001). We recommend using 3- to 4-cm-long single-node stem cuttings with one leaf, namely leaf-bud cuttings (Figure 1). Another factor was the cuttings collected from root-suckers (Figure 2), not from hedges (Figure 3) (Tetsumura et al., 2001, 2002, 2009, 2011, 2015b, 2017). Although micropropagation is thought to create physiologically juvenile and to provide cuttings with improved rooting (Howard, 1987; Osterc and Štampar, 2015), cuttings from the hedges derived from micropropagated plants of 'Hiratanenashi' and FDR-1 kaki showed lower rooting rates than those from root-suckers (Tetsumura et al., 2002, 2017). The idea of using root-suckers was got by the in vitro results, which showed that rooting percentages of shoots regenerated from roots of kaki cultivars were higher than those of shoots that originated from shoot tips (Tetsumura and Yukinaga, 2000). Del Tredici (1995) pointed out that root-suckers are physiologically juvenile and tend to root more readily than cuttings taken from other parts of the tree.

Figure 1. 'MKR1' leaf-bud cuttings rooting well 2 months after planting.

Figure 2. Root-suckers sprouting on roots of 'MKR1' in summer.

[a]E-mail: tetsumur@cc.miyazaki-u.ac.jp

Figure 3. A hedge of 'MKR1' in summer.

Recently, we found that the cuttings from hedge of 'MKR1', a dwarfing rootstock for kaki, rooted well, although the rooting speed was slower (Tetsumura et al., 2015b). Hence, the objective of this study was to confirm, "which is better for mother stock of leaf-bud cuttings of kaki, root-sucker or hedge?"

MATERIALS AND METHODS

Four micropropagated 'MKR1' nursery stocks were planted in the Field Science Center, Faculty of Agriculture, University of Miyazaki, in December 2008. One was cut back to a height of 40 cm each winter for establishment of a hedge to provide a mother stock for cuttings. In March 2011, the others were cut to just above ground level and then the surface soil of approximately 0.25 m^2 around the stump was removed to a depth of 20 cm (Figure 4). Roots >0.5 cm in diameter were exposed to sunlight to promote differentiation of 'MKR1' root-suckers. Rootstock a (R-a) (Tetsumura et al., 2010, 2015a) propagated by cutting was also used for this study. Two rooted cuttings were planted in March 2001. One was made for the hedge and, in May 2006 the other was cut for supplying root-suckers.

Figure 4. 'MKR1' roots for supplying root-suckers.

Root-suckers and shoots on hedges of 'MKR1' and R-a were collected on June 15, 2014 and 2015. The leaf-bud cuttings were prepared, dipped at their bases in 50% aqueous ethanol with 3000 ppm indole-3-butyric acid (IBA) for 5 s, planted singly in a plastic pot (EG-90, 300 mL, Minamide Inc., Japan) which was filled with Metro-Mix®360 (Sun Gro, Horticulture Distribution Inc., Washington DC), and then placed under a vaporized aluminum netting (80% shading) in a propagation frame covered with plastic film. The propagation frame was intermittently misted (30-s mist and 15-min stop in the daytime) using micro sprinklers (DN752A, SUN HOPE Inc., Tokyo, Japan), and was ventilated with fans when the ambient air reached 38°C. Twenty-four cuttings per cutting source were used. When the roots were visible at the bottom of the pot (Figure 5), the cutting was considered as "rooted," and then the rooted cuttings were transplanted singly to a plastic pot (EG-105, 400 mL, Minamide Inc., Japan) filled with Metro-Mix® 360. Controlled-released fertilizer (1 g pot^{-1}; Hi-control all 10, JCAM AGRI. Co., Ltd., Japan), containing 10% N, 10% P, 10% K, and 10% Ca, which releases for 100 d when the soil temperature reached 25°C, was applied upon transplanting of the rooted cuttings. Pots were placed in a propagation frame covered with 50% shade netting with the plastic film open at the sides and were watered adequately. Survival of rooted cuttings over the winter was confirmed by whether the cuttings sprouted leaves in April of the following year.

Figure 5. A root (arrow) coming out from a pot, in which a 'MKR1' cutting was planted 2 months earlier.

Two micropropagated 'Maekawajiro' nursery stocks were planted in the Field Science Center in December 2002. One was made for the hedge and, in May 2006 the other was cut for supplying root-suckers. Four Rootstock c (R-c, previous name "KD-3") (Tetsumura et al., 2003) nursery stocks propagated by cutting were planted in December 2008, and one was made for the hedge and, in March 2011 the others were cut for supplying root-suckers. On June 9, 2016, the cuttings collected from hedges and root-suckers of 'Maekawajiro', 'MKR', R-a and R-c were planted in the pots. The experiments were conducted by the same methods as those in 2014 and 2015.

RESULTS AND DISCUSSION

In 2014 and 2015, the cuttings collected from root-suckers of 'MKR1' and R-a started

rooting from one month after planting and almost all of the cuttings had rooted by the end of two months after planting (Figure 6). The final rooting percentages were 100% in the two years. Cuttings from 'MKR1' hedge also started rooting from one month after planting; however, the rooting speed was slow and the final rooting was 54%. In 2012, the rooting of cuttings from 'MKR1' hedge gradually increased and occurred even when the average daily temperature in the propagation frame decreased at 20°C, and the final rooting percentage was 92% (Tetsumura et al., 2015b). The temperature in the propagation frame may not have made the difference in the final rooting percentage, because the temperature changes in 2014 and 2015 was similar to that in 2012 (data not presented). Cuttings from R-a hedge started rooting from one and a half months after planting and the final rooting percentage was higher than that of 'MKR1', although the rooting speed was as slow as that of 'MKR1' (Figure 6).

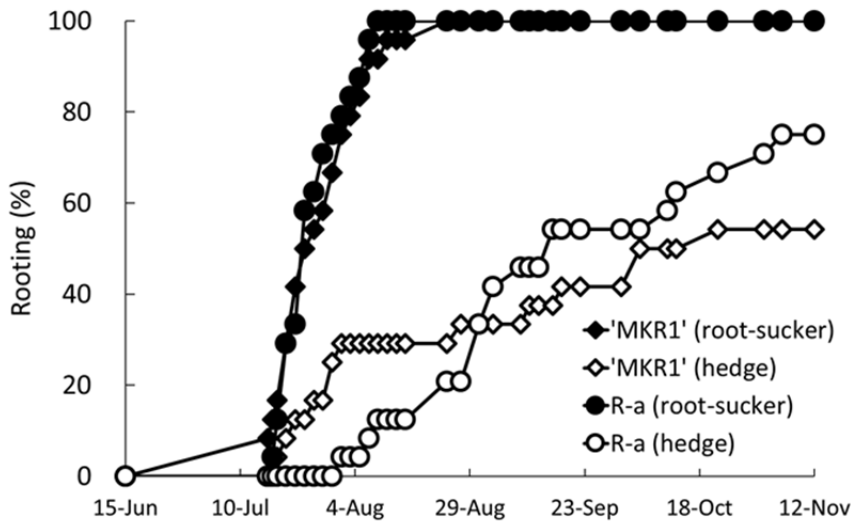

Figure 6. Rooting percentages of the cuttings collected from root-suckers and hedges of 'MKR1' and R-a in 2014 and 2015.

The overwinter survival percentage of the rooted cuttings collected from root-suckers of 'MKR1' was higher than that from hedge (Tetsumura et al., 2011, 2015b), and this tendency was also shown in this study; the survival of the rooted cuttings collected from root-suckers in the following year was 84% and that from hedges was 59%. Moreover, the same was true of R-a; the survival from root-suckers was 81% and that from hedges was 31%. The fact that almost all of the cuttings, especially from the hedges, rooting after 2 months of planting could not be overwintered (data not presented) made these differences in the survival percentages. Earlier rooting very likely contributed to a well-developed root system of the transplanted cuttings because the duration of growing season after transplanting was longer. The developed root system of the cuttings likely contributed to overwinter well (Tetsumura et al., 2011). Furthermore, the number of roots must have related to the development of the root system, and the cuttings collected from root-suckers had more roots than those from hedges (Tetsumura et al., 2011).

The cuttings collected from root-suckers of 'MKR1' planted in 2016 showed the same rooting performance as those in 2014 and 2015 (Figure 7). On the other hand, the cuttings from 'MKR1' hedge showed the same performance as those in 2012 (Tetsumura et al., 2015b); they continued rooting until early November and the final rooting percentage became 88%. However, the overwintering survival was very low (33%) so that the number of survived cuttings in the following year was almost the same for the three years. All of the rooted cuttings from root-suckers of 'MKR1' transplanted in 2016 overwintered successfully,

that is, all the cuttings planted in the mist system could be used as rootstocks.

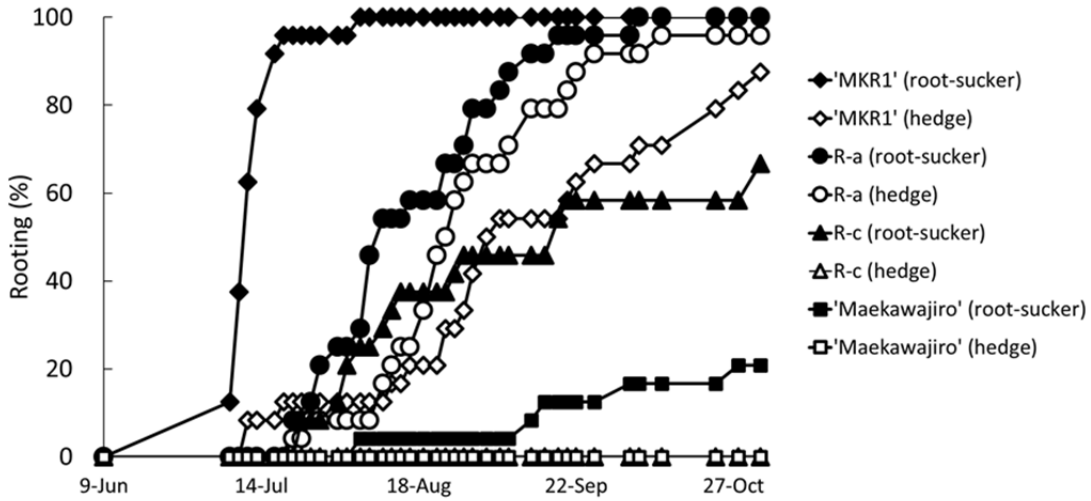

Figure 7. Rooting percentages of the cuttings collected from root-suckers and hedges of 'MKR1', R-a, R-c, and 'Maekawajiro' in 2016.

The start of rooting of the cuttings from root-suckers of R-a planted in 2016 was half a month later than that in 2014 and 2015 and the rooting speed was slower, although all of them rooted by the beginning of October (Figure 7). The start of rooting of the cuttings from R-a hedge planted in 2016 was the same as that in 2014 and 2015 and the rooting speed was also the same, but almost all of them rooted. However, the same as rooted cuttings from 'MKR1' hedges, the overwintering survival was extremely low (22%). As a result, 21% of cuttings from R-a hedges planted in 2016 survived, while 79% from R-a root-suckers did. In 2014 and 2015, 23% from R-a hedges survived.

In 2016, the cuttings from root-suckers of 'Maekawajiro' and R-c rooted to some extent (Figure 7), and in 2017, 60 and 69% of the rooted cuttings sprouted, respectively. However, the cuttings from their hedges did not root at all.

On the whole, the final rooting percentages of cuttings from 'MKR1' and R-a hedges occasionally became almost the same as those from root-suckers, but the overwintering survival rates of the rooted cuttings were always low. The cuttings from hedges derived from micropropagated plants of 'Jiro' and 'Nishimurawase' rooted as well as those from their root-suckers, but their overwintering survivals were not investigated (Tetsumura et al., 2002). Moreover, the cuttings from hedges of 'Maekawajiro' and R-c did not root. Hence, in conclusion, we recommend using root-sucker rather than hedge for mother stock of leaf-bud cuttings of kaki, because one can get many rooted cuttings from root-suckers.

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Comparison of growth, yield, and fruit quality of own-rooted and grafted 'Spirit of '76' mango trees grown in pots©

M. Fumuro[a]

Experimental Farm, Kindai University, Arida-gun, Yuasa, Wakayama 643-0004, Japan.

Abstract

To assess the practicality of using pots to grow mango cultivar 'Spirit of '76' (*Mangifera indica* L.) trees using their own roots propagated by air layering and trees grafted onto Taiwanese native-strain rootstock were planted in pots containing approximately 25 L of soil. The growth, yield, and fruit quality of the trees were monitored and measured for 7 years after planting. Trunk diameter was significantly smaller in the own-rooted compared with the grafted trees for the first 5 years, but there was no difference between the two after 6 years. The trunk diameter of the own-rooted trees was also significantly greater than the scion diameter of the grafted trees after 3 years. The total green-branch length was at least as long in the own-rooted trees as it was in the grafted trees after 3 years, and the leaf number tree^{-1} was greater in own-rooted than in grafted trees after 4 years. There were no significant differences in height between the two tree types. Fresh and dry weights were significantly greater for leaves, green branches, thick branches, above-ground parts of trees, fine roots, and whole trees, but significantly lower for the trunks of own-rooted trees compared with those of grafted trees. However, there were no significant differences in the weights of thick roots and under-ground parts of trees between the two tree types. The dry matter top/root biomass (T/R) ratio was significantly higher (47%) in own-rooted trees, but the fresh weight T/R ratio did not differ significantly between the two tree types. In addition, there were no significant differences in yield tree^{-1}, fruit numbers tree^{-1}, or fruit quality between own-rooted and grafted trees. Based on these results, it is suggested that own-rooted mango trees may be grown in pots because their growth characteristics are similar to, or perhaps even better than, those of grafted trees, and yield and fruit quality do not differ between the two.

INTRODUCTION

Because mango (*Mangifera indica* L.) trees are generally vigorous, fruit production is often stabilized by laying underground sheets to restrict root elongation (Yonemoto, 2005) or by growing trees in pots. Pot culture can produce good yields of high-quality fruits by optimizing and automating the supply of nutrients and water; the approach is gradually becoming more popular with farmers. Trees planted in pots also tend to bear fruits 40-60 cm higher on the tree compared with trees planted in the ground, depending on the height of the pot. In addition, because mango seedlings are grafted at a height of approximately 25-30 cm above the ground to improve grafting success rate, the rootstock of grafted seedlings tends to become longer, and the fruit positions even higher.

In Japan, the flower cluster and fruits are hung at the top of the crown to improve their color because fruit with good color has a higher commercial value. Often trees are covered with a fruit net before harvesting to ripen fruits on the trees; this is more practical if fruits are not located too high up. One effective method of lowering the fruit position is to utilize own-rooted trees rather than grafting.

By using own-rooted trees, it is possible to position the scaffold branch closer to the ground. In addition, by excluding vigorous rootstocks it may be possible to suppress tree vigor. Own-rooted nursery trees must be propagated by vegetative methods that include

[a]E-mail: fumuro@nara.kindai.ac.jp

using cuttings or air layering. However, propagating mango trees using cuttings is extremely difficult. Only young seedlings can be rooted (Mukherjee et al., 1967; Yamashita et al., 2006), and rooting from older seedlings or cuttings from cultivars in the adult phase is nearly impossible.

Fumuro (2011) investigated vegetative propagation by air layering 'Irwin' and 'Aikou' mangoes and discovered that own-rooted nursery trees can be propagated by spraying a 2000-ppm 1-naphthaleneacetic acid solution on the girdled part of a branch. The propagation efficiency of air layering is lower than that of cuttings, but it is an effective method for investigating the growth characteristics, yield, and fruit quality of own-rooted trees. In addition, the use of pots to culture mango trees was introduced relatively recently and little research has been done (Fumuro, et al., 2009; Fumuro, 2011; Yonemoto et al., 2007); therefore, the effect of using pots to grow mangoes on tree growth, yield, and fruit quality over a period of years has not been established.

To assess the practicality of using pots to grow 'Spirit of '76' mango (*M. indica* L.) own-rooted trees propagated by air layering and trees grafted onto Taiwanese native strain rootstock were planted in pots, and tree growth, yield, and fruit quality were monitored and measured over a 7-year period.

MATERIALS AND METHODS

Planting and culture methods

1. Production of own-rooted and grafted nursery trees.

'Spirit of '76' trees planted in a greenhouse (width: 9 m, length: 54 m) at Kindai University experimental farm (Yuasa, Wakayama Prefecture, Japan) were used. Air layer propagation was performed on August 8, 2008 according to the method described by Fumuro (2011). On October 9, 2008, rooted branches (Figure 1) were removed and planted in small pots (diameter: 13.5 cm, height: 11 cm). On June 20, 2009, the own-rooted nursery trees were transferred to 25-L pots made of a non-woven fabric (diameter: 32 cm, height: 35 cm) and filled with a mixture of mountain soil, perlite, compost, and vermiculite (volume ratio: 1:1:1:1).

Figure 1. Rooting of air-layered mango cultivar 'Spirit of '76' (October 9, 2008).

To generate the grafted nursery trees, 'Aikou' scions were grafted onto 2-year-old rootstocks (Taiwanese native strain seedlings) on June 9, 2009 and planted in 9-L polythene pots (diameter: 24 cm, height: 24 cm). On October 22, 2009, they were transferred to pots made of non-woven fabric, as described above. Both the own-rooted trees and the rootstocks of the grafted ones were 2 years old; five trees of each type were used in this study.

2. Pot spacing and cultivation management.

Pots were arranged 1.4 m apart in the greenhouse in rows 1.5 m apart. In November

2012, all pots were transferred to a smaller plastic house (width: 6 m, length: 18 m) with the same space between pots, and growth was continued. The greenhouse was heated from early December to ensure a minimum temperature of 6°C. This minimum temperature was gradually increased from mid-February, and then maintained at 18-20°C from the middle of March until late April during the flowering period. A fan was used for ventilation to ensure the internal air temperature remained below 30°C until and below 35°C after the flowering period.

Approximately 3 L of tap water was dispensed for irrigation using an automatic timer once every 2 d in December and January, once daily from February until April, twice daily in May and June, 4× daily in July and August, 2-3× daily in September and October, and once daily in November.

Approximately 40 g of slow-release fertilizer ($N:P_2O_5:K$ = 10:10:10%) was supplied to each tree in February, March, April, May, June, July, September, and November. Approximately 2 L pot^{-1} of liquid fertilizer ($N:P_2O_5:K:Mg:B:Mn$ = 2:5:4:3:5:1%) diluted 1000-fold was applied in March. Assuming 476 pots 1000 m^{-2}, the annual quantities of nitrogen, phosphoric acid, and potassium supplied were approximately 15.3 kg each.

Pruning began when harvest was almost complete and ended in late September. As part of the training method, 2-3 scaffold branches $tree^{-1}$ and an appropriate number of bearing shoots were set within a crown diameter of 1.3 to 1.4 m. In 2015, no pruning was carried out due to the dissecting survey taking place in October. Disease and pest control were performed according to conventional procedures.

3. Fruit management and harvesting.

The flowering period of the own-rooted and grafted trees was almost identical, and full bloom occurred toward the end of April. The harvesting periods were August 15 to September 25, 2011, August 12 to September 30, 2012 (Figure 2), and August 23 to September 27, 2013. The trees were covered with a bag-shaped net before harvesting, and the fruits were allowed to drop into the net. In 2014 and 2015, pollination by insects (bees) was not very successful, and the fruit yield was poor.

Figure 2. The own-rooted (left) and grafted (right) mango cultivar 'Spirit of '76' trees when fruit reached maturity in 2012.

Measurements

1. Tree growth.

The trunk diameters, leaf numbers $tree^{-1}$, and green-branch lengths $tree^{-1}$ were all measured in late December every year from 2009 until 2014, and also in October 2015 (before the dissecting survey).

The trunk diameters were measured using calipers. The measurements were made at 10 cm above the ground in grafted trees and approximately 3 cm above the ground in the own-rooted trees because the scaffold branches of the own-rooted trees were close to the ground. In the grafted trees, scion diameters were also measured 3 cm above the graft. The lengths of green branches with less than 10% lignification were measured, and the total green-branch length was calculated. Tree heights were measured in October 2015 at the time of the dissecting survey.

2. Fresh and dry weights of each organ.

The dissecting survey was performed between October 7 and 15, 2015 (Figures 3 and 4). The trees were 8 years old at the time of dissection. The different parts of the tree were categorized as follows: leaf, green branch, trunk, thick root (≥1 mm in diameter), and fine root (<1 mm in diameter). Because the scions of the grafted trees were 20-30 cm above the ground, these trunks included the stems of the rootstock seedlings. After the fresh weight of each organ sample was measured, it was dried, and the dry matter percentage was determined. The total dry weight of each organ was calculated by multiplying the dry matter percentage by the total fresh weight of each organ.

Figure 3. The own-rooted (left) and grafted (right) mango cultivar 'Spirit of '76' trees before dissection in 2015.

Figure 4. The under-ground part of own-rooted (left) and grafted (right) mango cultivar 'Spirit of '76' trees after dissection in 2015.

Forty leaves were randomly sampled from each tree, and leaf area was measured using an automatic leaf area meter (AAM-9; Hayashi Denko Co Ltd., Tokyo, Japan). The average leaf area tree^{-1} was calculated by multiplying the average leaf area and the total number of leaves tree^{-1}.

As part of the dissecting survey, tree trunks were cut using a saw at the position used to measure their diameters. The contours were copied onto paper and the area of each trunk's cross-section was measured using an automatic leaf area meter.

3. Yield and fruit quality.

After weighing, fruit quality data on 10 fruits harvested between late August and early September in 2011, 2012, and 2013 were recorded. In 2014 and 2015, no yield measurements were made due to the very small number of fruits produced in these years.

Peel color (Hunter's L-, a-, and b-values) was measured using a color-difference meter (CR-400; Konica-Minolta, Tokyo, Japan) positioned centrally on the side of each fruit. Flesh firmness was determined using a Magness-Taylor-type fruit penetrometer with an 11.3-mm-diameter plunger (FT011; Effegi, Alfonsine, Italy) by removing a piece of peel 3 cm in diameter with a sharp knife. The maximum force generated when the plunger penetrated 7 mm into the flesh through the cut surface was recorded. Measurements were performed on both sides of the fruit, and the average value was calculated. In addition, flesh was collected from a central point on both sides of the fruit. Juice from the fruit was squeezed and filtered through gauze, and total soluble solids (TSS) together with titratable acidity were determined. TSS was determined using a refractometer (PAL-1; Atago Co. Ltd., Tokyo, Japan), and the titratable acid was determined by the titration method with 0.1 N NaOH to a phenolphthalein endpoint and converted into citric acid content.

Statistical analysis

The data obtained in this study were subjected to analysis of variance (ANOVA) followed by a Tukey-Kramer's multiple range test and *t*-tests.

RESULTS

Tree growth

The trunk diameters increased with age in both types of tree (Figure 5). The diameter of own-rooted trees was significantly smaller than that of grafted trees for the first 5 years, but no significant difference was observed between the two after 6 years. The trunk diameter of the own-rooted trees was significantly greater than the scion diameter of the grafted trees after 3 years. The trunk cross-section area was approximately 50 cm^2 in both types of tree (Table 1).

Table 1. Comparison of total leaf areas per tree, trunk cross-sectional areas, and heights of own-rooted and grafted 8-year-old mango cultivar 'Spirit of '76' trees.

Propagation method	Total leaf area (m^2 $tree^{-1}$)	Trunk cross-sectional area (cm^2)	Tree height (m)
Own-rooted	8.98±1.18[1]	46.5±6.0	2.22±0.17
Grafted	7.15±1.14	56.1±9.6	2.04±0.12
Significance[2]	*	NS	NS

[1]Average ± standard deviation.

[2]NS, *; non-significance and significance at P=0.05, respectively.

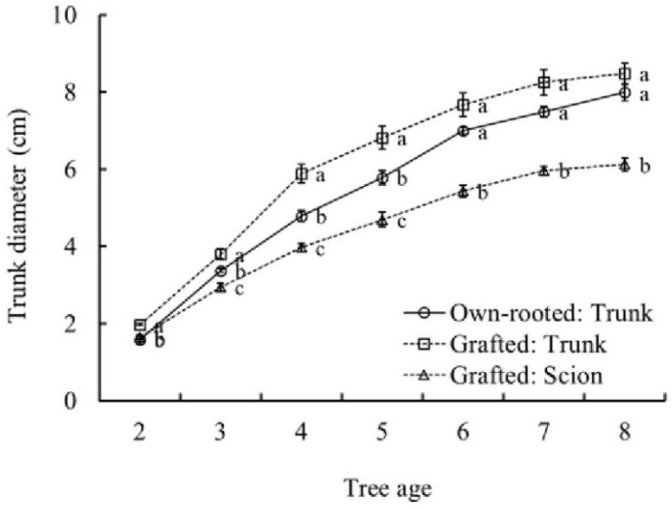

Figure 5. Annual changes in trunk diameters of own-rooted and grafted mango cultivar 'Spirit of '76' trees grown in pots. Vertical bars represent ± standard error (n=5). Values followed by the same letter indicate no significant difference (P<0.05) according to Tukey-Kramer's multiple-range test.

In 4-, 6-, and 8-year old trees, the total green-branch length in own-rooted trees was greater than that in grafted trees (Figure 6). The total green-branch length in 8-year old own-rooted trees was 21 m, approximately 45% higher than that in grafted trees.

The leaf number tree^{-1} of the own-rooted trees was greater than the number in grafted trees after 4 years (Figure 7). In 8-year old own-rooted trees, this included approximately 1750 leaves, 38% more than in grafted trees of the same age. The leaf area tree^{-1} of 8-year old own-rooted trees was significantly higher than that of grafted trees (Table 1). There was no significant difference in height between the two tree types.

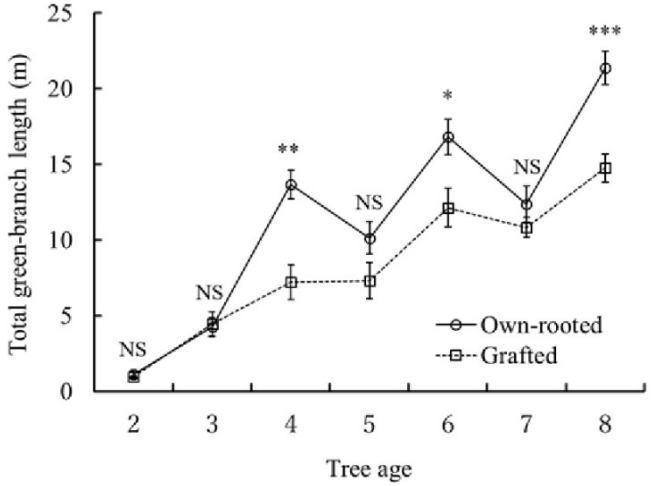

Figure 6. Annual changes in total green-branch length tree^{-1} of own-rooted and grafted mango cultivar 'Spirit of '76' trees grown in pots. Vertical bars represent ± standard error (n=5). NS, *, **, and *** indicate not significant and significant at P=0.05, 0.01, and 0.001, respectively, using t-tests.

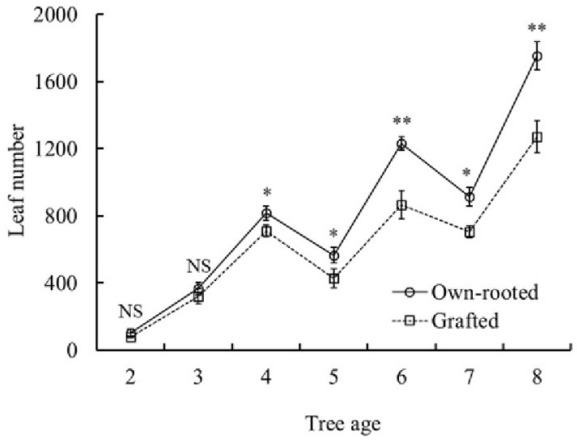

Figure 7. Annual changes in leaf number tree^{-1} of own-rooted and grafted mango cultivar 'Spirit of '76' trees grown in pots. Vertical bars represent ± standard error (n=5). NS, *, and ** indicate not significant and significant at P=0.05, and 0.01, respectively, using t-tests.

Fresh and dry weights of each organ

Fresh and dry weights were significantly greater for leaves, green branches, thick branches, above-ground parts of trees, fine roots, and whole trees, but significantly lower for the trunks of own-rooted trees compared with those of grafted trees (Table 2). However, there were no significant differences in the weights of thick roots and under-ground parts of trees between the two tree types. The fresh and dry weights of whole own-rooted trees were approximately 12 and 5 kg, respectively; this is approximately 22 and 33% greater than those of grafted trees, respectively.

The top/root weight (T/R) ratio is calculated as the weight of the above-ground part minus the leaves, divided by the weight of the under-ground part. The dry matter T/R ratio was 47% higher in own-rooted trees compared with grafted ones, but fresh weight T/R ratios did not differ significantly between the two tree types.

Yield and fruit quality

The yield tree^{-1} was approximately 1.4 kg in 4-year-old, 2.5 kg in 5-year-old, and 3.3 kg in 6-year-old trees, with no significant differences between the two tree types (Table 3). There were also no significant differences between the two types of tree in the number of fruits tree^{-1} or the average fruit weight. In addition, there were no significant differences in peel color, soluble solid contents, or organic acid contents (Table 3). In both tree types, the soluble solid contents were 19-21%, and the organic acid contents were 0.20-0.32, with only small annual variations.

DISCUSSION

The annual changes in trunk diameters, total green-branch lengths tree^{-1}, leaf numbers tree^{-1}, and the results of the dissecting survey of 8-year old trees all suggest that the growth characteristics of own-rooted 'Spirit of '76' trees are similar to, or perhaps even better than, those of grafted trees. In addition, compared with own-rooted 'Aikou' trees grown in pots containing the same soil volumes (Fumuro, 2016), both of our 'Spirit of '76' tree types were more vigorous. The Taiwanese native strain used as rootstock in this study is vigorous (Yonemoto, 2008), and the vigor of trees grafted onto Taiwanese native strain seedlings tends to be enhanced. Therefore, the vigorous growth characteristics of the grafted trees may result from the influence of the rootstock. The 'Spirit of '76' cultivar used to generate the scions is also vigorous (Ishihata, 2000), and the additional influence of the rootstock could enhance the growth of grafted trees synergistically. However, the vigorous growth of the own-rooted trees was thought to result from the growth characteristics of the scion cultivar.

Table 2. Comparison of fresh and dry weights of own-rooted and grafted 8-year-old mango cultivar 'Spirit of '76' trees.

	Propagation method	Above-ground part (kg)					Under-ground part (kg)			Whole tree (kg)	T-R ratio
		Leaf	Green branch[1]	Thick branch	Trunk	Total	Thick root[2]	Fine root[3]	Total		
Fresh weight	Own-rooted	2.72	0.89	4.84	0.44	8.90	1.93	1.32	3.25	12.15	1.90
	Grafted	1.97	0.68	2.47	1.69	6.81	2.54	0.59	3.13	9.94	1.62
	Significance	**[4]	*	***	***	*	NS	***	NS	*	NS
Dry weight	Own-rooted	1.23	0.31	2.09	0.18	3.80	0.71	0.38	1.09	4.89	2.36
	Grafted	0.90	0.23	0.81	0.62	2.56	0.95	0.16	1.11	3.67	1.61
	Significance	**	**	***	**	**	NS	***	NS	**	*

[1]Branches which ratio of lignification was less than 10%.
[2]Roots of 1 mm or more in diameter, including the root crown.
[3]Roots less than 1 mm in diameter.
[4]NS, *, **, ***; non-significance at P = 0.05, significance at P = 0.05, 0.01 or 0.001 by t-test, respectively.

Table 3. Comparison of yields and fruit qualities of own-rooted and grafted 8-year-old mango cultivar 'Spirit of '76' trees.

Tree age	Propagation method	Yield (kg tree^{-1})	Fruit number (no. tree^{-1})	Fruit weight (g)	Peel color			Flesh firmness (N cm^{-2})	Total soluble solids (%)	Organic acid (%)
					L-value	a-value	b-value			
4	Own-rooted	1.26	2.5	504	46.5	25.3	17.0	11.8	21.1	0.32
	Grafted	1.59	3.3	482	46.9	19.8	18.1	10.2	20.1	0.31
	Significance	NS[1]	NS	NS	NS	NS	NS	NS	NS	NS
5	Own-rooted	2.80	4.6	608.0	47.3	17.3	17.4	7.3	20.0	0.22
	Grafted	2.25	3.6	625.5	45.9	18.5	18.7	6.8	20.5	0.20
	Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS
6	Own-rooted	3.45	6.0	574.6	45.7	19.7	18.3	7.4	19.6	0.20
	Grafted	3.14	5.4	582.2	44.0	22.7	17.7	6.4	18.9	0.27
	Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]NS; non-significance at P=0.05 by t-test.

In this study, pollination by insects was not particularly successful, and fruit production was poor in 2014 and 2015. A strong relationship has been reported between tree growth and fruit load (Fumuro et al., 1999; Fukuda et al., 1991), and photosynthetic products may have been diverted from fruits to other organs. In a previous study, Tamashiro et al. (2003) reported that mango root growth is significantly suppressed by fruit load and that roots grow more vigorously, as does the rest of the tree, after harvesting.

In this study, the growth of the roots and the rest of the tree may have been more vigorous due to the low fruit load. Oya et al. (2015) compared 8-year-old own-rooted 'Kosui' Japanese pear trees propagated by cuttings with grafted ones; they detected no difference in growth (measured as dry matter weight) between the two. Ram (1993) reported that the growth of own-rooted mango trees propagated by air layering was slower than that of grafted trees; however, in our study, the growth of the own-rooted trees was similar to, or perhaps better than, that of grafted trees.

In the grafted trees, a relatively long main root gradually enlarged and developed into a thick root crown, whereas in the own-rooted trees, the branch rooted by air layering became the root crown, and some of the first roots to extend from this gradually developed into thick roots.

In the own-rooted trees, the root crown was short. However, some lateral roots developed, and the thick roots and root crown in the own-rooted trees did not differ significantly from those in the grafted trees. However, the fresh and dry weights of fine roots in the own-rooted trees were approximately 2.2- and 2.4-fold greater than those of grafted trees, respectively. Therefore, the own-rooted trees might be more capable of producing new roots than the Taiwanese native strain, resulting in the greater fine root weight of the own-rooted trees.

The dry weight of above-ground part in own-rooted trees was significantly greater than that in grafted trees, although the dry weight of under-ground part did not differ significantly between the two. Therefore, the dry matter T/R ratio was significantly higher in own-rooted compared with grafted trees. The T/R ratio of grafted apple trees, which was approximately 2.2, reportedly did not differ among different rootstock varieties (Fukuda and Takishita, 1993), similar to the case with the own-rooted mango trees in this study.

The yield tree^{-1} increased with tree age from 2.3 to 3.5 kg pot^{-1} until 2013, but was not particularly high overall. The yield calculated for 6-year-old trees, assuming 460 pots 1000 m^{-2}, was estimated at approximately 1.6 t in the own-rooted trees and 1.4 t in the grafted ones. When the target yield 1000 m^{-2} was set to 2.5 t, both types of tree produced approximately half the required total. Therefore, to ensure adequate yields, it is important that insect pollination is well managed. The fruit quality analyses demonstrated that soluble solid contents, organic acid contents, and flesh firmness did not differ significantly between the two tree types, and these parameters achieved the required standards for this cultivar.

Few studies have investigated the cultivation of own-rooted mango trees over many years, and their economic life has not been determined. Farmers often use 60- to 80-L pots, whereas in this study, we used 25-L pots, and the smaller soil capacity may well shorten the economic life of the trees. Over the 7-year period, both tree types studied here maintained their vigor. Nonetheless, the influence of pot soil volume on the economic life of the trees needs to be assessed over longer periods of time.

There were no significant differences in height between the two tree types. In both tree types, the tree height and fruit position were relatively tall. This is because 'Spirit of '76' is a vigorous cultivar, and it was unable to widen the tree crown by enlarging the interval between pots because of a small facility. As a result, cut back of branches could not be sufficiently conducted to achieve the required reduction in tree height, even for the own-rooted trees.

These results demonstrate that own-rooted mango tree growth characteristics are similar to, or perhaps even better than, those of grafted trees, and that yield and fruit quality do not differ between the two. The cultivation of own-rooted mango trees in pots should therefore be considered a practical and economically viable option.

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Micropropagation of ornamental aquatic plants, *Glossostigma*, *Microcarpaea* and *Limnophila* 2. Effect of $CaCl_2 \cdot 2H_2O$, KH_2PO_4, Fe-EDTA concentrations on the growth of explants©

M. Minamiyama, A. Noguchi and W. Amaki[a]

Department of Agriculture, Tokyo University of Agriculture, 1737 Funako, Atsugi, Kanagawa 246-0034, Japan.

Abstract

For each concentration of $CaCl_2 \cdot 2H_2O$ (1.5, 0.6 and 0.3 mM), KH_2PO_4 (0.63, 0.25, and 0.13 mM), and Fe-EDTA (50, 25, and 13 µM) in the tissue culture medium, the effects on the in vitro growth of three aquatic plants, *Limnophila* sp. (unidentified), *Glossostigma elatinoides* (Benth.) Hook.f., and *Microcarpaea minima* (K.D. Koenig ex Retz.) Merrill., were examined. On the result of $CaCl_2 \cdot 2H_2O$, *Limnophila* and *M. minima* showed the highest value of plant fresh weight (FW) on medium supplemented at 0.3 mM. However, leaf yellowing and abnormal growth occurred at 0.3 mM in *Limnophila*. On the other hand, leaf color of M. minima became darker at the lower concentration. In *G. elatinoides*, the highest value of FW was obtained when the concentration was 0.6 mM. In all three species, lowering the concentration of KH_2PO_4 decreased the FW of plants. There was a clear tendency for FW to increase with decreasing Fe-EDTA concentration in *Limnophila* and *M. minima*. On the other hand, FW was maximized at 25 µM of Fe-EDTA and when the concentration was lowered to 13 µM, FW remarkably decreased in *G. elatinoides*.

INTRODUCTION

In recent years in Japan, the commercial demand for tissue cultured aquatic plants has considerably increased. There are already several reports on the growth of aquatic plants by tissue culture (Rao and Ram, 1981; Huang et al., 1994; Kane et al., 1999; Zhou et al., 2006; Kanchanapoom et al., 2012; Jabir et al., 2016). We have also reported on optimized conditions of medium for three aquatic plants, *Glossostigma elatinoides* (Benth.) Hook.f., *Limnophila* sp. (unidentified), and *Microcarpaea minima* (K.D. Koenig ex Retz.) Merrill (Niki and Amaki, 2014). That is, the optimal strength of the Murashige and Skoog (1962) medium (MS medium) was half strength, and the optimal concentrations of sucrose and gellan gum were 20 and 3 g L^{-1}, respectively. The optimum pH value at the time of medium preparation was 5.0 for *G. elatinoides* and was 6.0 for *Limnophila* sp., and *M. minima*. With these medium conditions, in vitro propagation of three aquatic plants became possible, but leaf yellowing and withering occurred after 2 months culture. The cause might be expected to be an imbalance in constituents of the medium or excess and/or deficiency of specific constituents. Considering the natural environment of the three plants' habitat, there was a possibility that the ½ MS medium concentration was too high. In this report we investigated the effects of lowering $CaCl_2 \cdot 2H_2O$, KH_2PO_4, and Fe-EDTA concentrations on the growth of three aquatic plants [*G. elatinoides* (Benth.) Hook.f., *Limnophila* sp. (unidentified), and *M. minima* (K.D. Koenig ex Retz.) Merrill].

MATERIALS AND METHODS

Preparation of materials

Shoot tip explants (about 1 cm long) were prepared from in vitro mother plants, *G. elatinoides* (*Phrymaceae*), *Microcarpaea minima* (*Plantaginaceae*) and *Limnophila* sp.

[a]E-mail: amaki@nodai.ac.jp

(unidentified; *Plantaginaceae*). The explants were inoculated in the multiplying medium which was ½ strength MS constituents supplemented with 20 g L^{-1} sucrose and 3 g L^{-1} gellan gum (Wako Pure Chemical Industries, Ltd., Osaka, Japan) (pH 5.8) for maintenance and multiplication of stock plants for the following experiments.

Experiments for the optimal concentration of three constituents

With the concentration of ½ MS as the control concentration, the concentrations of respective constituents such as calcium chloride ($CaCl_2 \cdot 2H_2O$) and potassium phosphate monobasic (KH_2PO_4) (Kanto Chemical Co. Inc., Japan) and ferric monosodium ethylene-diaminetetraacetate (Fe-EDTA) (Wako Pure Chemical Industries, Ltd., Osaka, Japan) were lowered. The concentrations of $CaCl_2 \cdot 2H_2O$ were 1.5, 0.6 and 0.3 mM; KH_2PO_4 were 0.63, 0.25, and 0.13 mM; and Fe-EDTA was 50, 25, and 13 μM.

Culture conditions and measurements

Thirty mL of each medium was poured into φ 40×150 mm flat-bottomed glass test tubes and autoclaved at 120°C for 15 min before explant inoculation. One explant (shoot tip explant about 1 cm long) was inoculated in a test tube and closed with double layers of aluminum foil. All cultures were incubated under 23±1°C and 16-h light with cool white fluorescent lamps (40 μmol m^{-2} s^{-1} PPFD)/8-h dark condition. Total fresh weight of multiplied plants in each test tube was measured at 60 days after the inoculation of explants.

RESULTS AND DISCUSSION

The results for $CaCl_2 \cdot 2H_2O$ concentrations are presented in Figure 1. *Limnophila* and *M. minima* showed the largest value of fresh weight (FW) per plant on the medium supplemented at 0.3 mM. From visual observation, more roots were at the lower concentration. However, leaf yellowing and abnormal growth occurred at 0.3 mM in *Limnophila*. On the other hand, leaf color of *M. minima* became darker at the lower concentration. In *G. elatinoides*, the highest value of FW was obtained at a concentration of 0.6 mM. In the description that explains the medium components of freshwater aquatic plants (Watanabe, 2012), although the target plants are not specified, the amount of $CaCl_2 \cdot 2H_2O$ is less than 1/10 the concentration of MS in most of the media and there is a possibility that it may be even lowered. As a result of tentative judgment including plant form, the optimum concentration for each plant is 1.5 mM for *Limnophila*, 0.6 mM for *G. elatinoides* and 0.3 mM for *M. minima*.

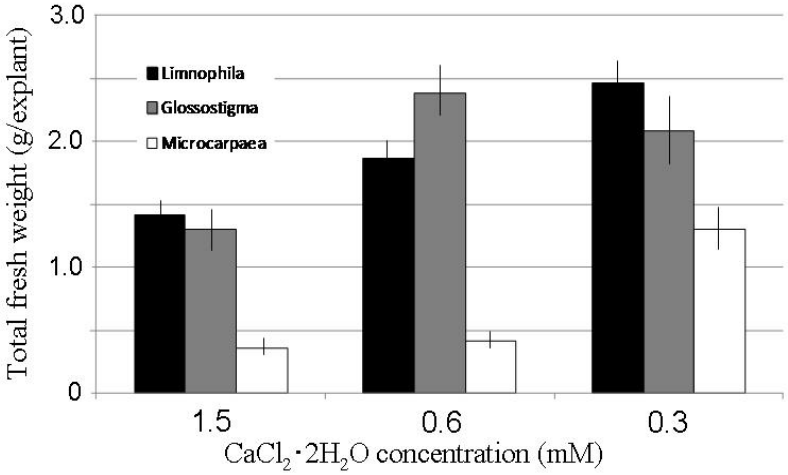

Figure 1. Effect of $CaCl_2$ concentration in the medium on the in vitro growth of plants in *Limnophila*, *Glossostigma*, and *Microcarpaea*. Vertical bars represent the value of standard errors (*n*=5).

Figure 2 shows the results of KH_2PO_4 concentration. In all three species, lowering the concentration of KH_2PO_4 decreased the fresh weight of the plants. In particular, FW of *G. elatinoides* and *M. minima* were significantly less than half for them at 0.13 mM when compared with 0.63 mM. Therefore, it was shown that lowering the concentration of KH_2PO_4 to not more than 0.63 mM of the ½ MS is not preferable for maintaining growth of all three species. It is shown that the demand for phosphate is high in some plants (George, 1993), and it seemed that it is necessary to experiment at even higher concentration of phosphate.

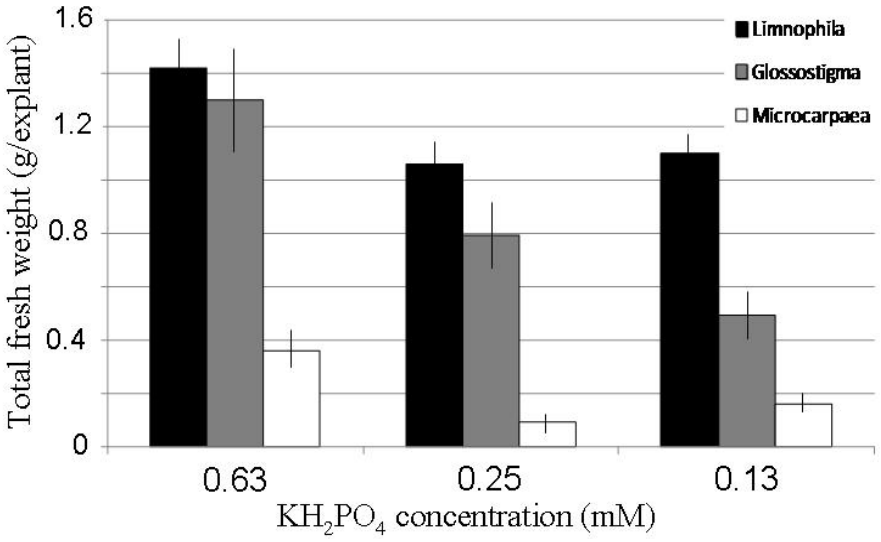

Figure 2. Effect of KH_2PO_4 concentration in the medium on the in vitro growth of plants in *Limnophila*, *Glossostigma* and *Microcarpaea*. Vertical bars represent the value of standard errors (*n*=5).

Figure 3 shows the results of Fe-EDTA concentration. In *Limnophila* and *G. elatinoides*, there was a clear tendency for FW to increase with decreasing Fe-EDTA concentration. On the other hand, FW was maximum at 25 μM, and when the concentration was lowered to 13 μM, FW remarkably decreased in *M. minima*. In considering this result, it is necessary to consider that Fe-EDTA is composed of Fe as an essential micronutrient element and EDTA as a chelating agent having a growth inhibiting effect in some case (Legrand, 1975; Dalton et al., 1983). Watanabe (2012) listed a medium suitable for cultivating many freshwater aquatic plants. The amount of Fe in the medium is 20 μM, which is consistent with the results of our experiment in *Limnophila* and *G. elatinoides*. In addition, both species may be more susceptible to EDTA toxicity. However, *M. minima* showed exactly the opposite tendency. *Microcarpaea* minima is endemic to India and Southeast Asia, and it is said to grow vigorously in paddy fields and river floodplain (Ishida et al., 2010). In *M. minima*, Fe demand is expected to be high compared with other two species. In order to confirm, it is necessary to conduct the experiment by changing the concentration of EDTA alone, which is a future research subject.

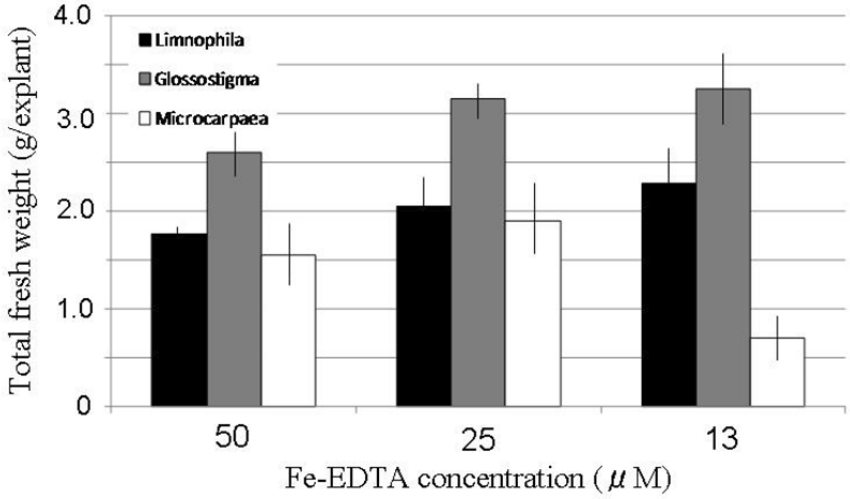

Figure 3. Effect of Fe-EDTA concentration in the medium on the in vitro growth of plants in *Limnophila*, *Glossostigma* and *Microcarpaea*. Vertical bars represent the value of standard errors (*n*=5).

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