# Container Nursery Irrigation Basics©

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## INTRODUCTION

Container nursery production is reliant on frequent irrigation to maintain appropriate substrate moisture and sustain quality plant growth. Irrigation water management is a key production consideration and critical for reducing the impact of fertilizer and pesticide runoff from nursery production (Beeson et al., 2004). The objective of this paper is to provide some basic information regarding choices for container irrigation leading to more sustainable choices in the nursery. The paper will be organized into sections on: (a) Types of irrigation systems, (b) Irrigation efficiency, and (c) Irrigation scheduling.

## TYPES OF IRRIGATION SYSTEMS

There are two basic systems used for container irrigation. These include overhead sprinkler irrigation and micro-irrigation. Selection of which system to employ depends on site topography, water source and quality, and cost.

Overhead sprinkler irrigation is the traditional, popular nursery irrigation system. It is relatively inexpensive to set up, but it can be an inefficient system in regards to water use and high operational cost of pumps. The three basic types of overhead irrigation systems include rotary, stationary, and traveling boom systems (Figs. 1 and 2).

Rotary sprinklers utilize a rotating head with nozzles that distribute a large droplet size stream of water over a large area of the crop. The two basic nozzle designs for rotating sprinklers are impact rotors and spinning heads. These can be located on stationary risers within the crop or mounted overhead on overwintering structures.

Stationary sprinklers do not rotate. Water is forced through the head or against a deflection plate to form a smaller droplet size and constant uniform coverage. Stationary sprinklers are usually placed on risers within the crop and like rotating nozzles can be configured in different patterns from 45 to 180 degrees. Stationary sprinklers can be designed to operate at lower water pressure, but can be more prone to clogging compared to rotary sprinklers.

Traveling booms are most common for use within protected cultivation such as greenhouse production, but they can be designed to function in outdoor nursery settings as long as the crop structure is not too tall. They tend to deliver water more efficiently and uniformly compared to other overhead irrigation systems.

Micro-irrigation is a low volume system that delivers water directly to the container. It is generally more water efficient compared to overhead irrigation. The three basic types of micro-irrigation utilize micro-sprayers, drip emitters, or in-line drip tubes (Fig. 3). Micro-sprayers or spray stakes deliver water in a sprinkler pattern over a specific diameter on the surface of the container. Drip emitters are placed at the end of a "spaghetti" tube and drip water into the container over a limited area. Each drip tube emanates from a main water line and like micro-sprayers more than one can be placed in each container. In-line systems do not have extension tubes or need specific drip emitters and are best used in crops on a regular spacing in rows. A punch is used to create an opening in the main poly line over each container to drip water.

Micro-irrigation systems are generally more susceptible to clogging compared to overhead irrigation systems and therefore a water filtering system is usually included to exclude particles or debris from the line. Also, because these are low pressure, low volume systems, grade changes across the nursery row can impact water delivery uniformity. Including in-line pressure equalizers will help provide uniform distribution of water over the entire emitter line.

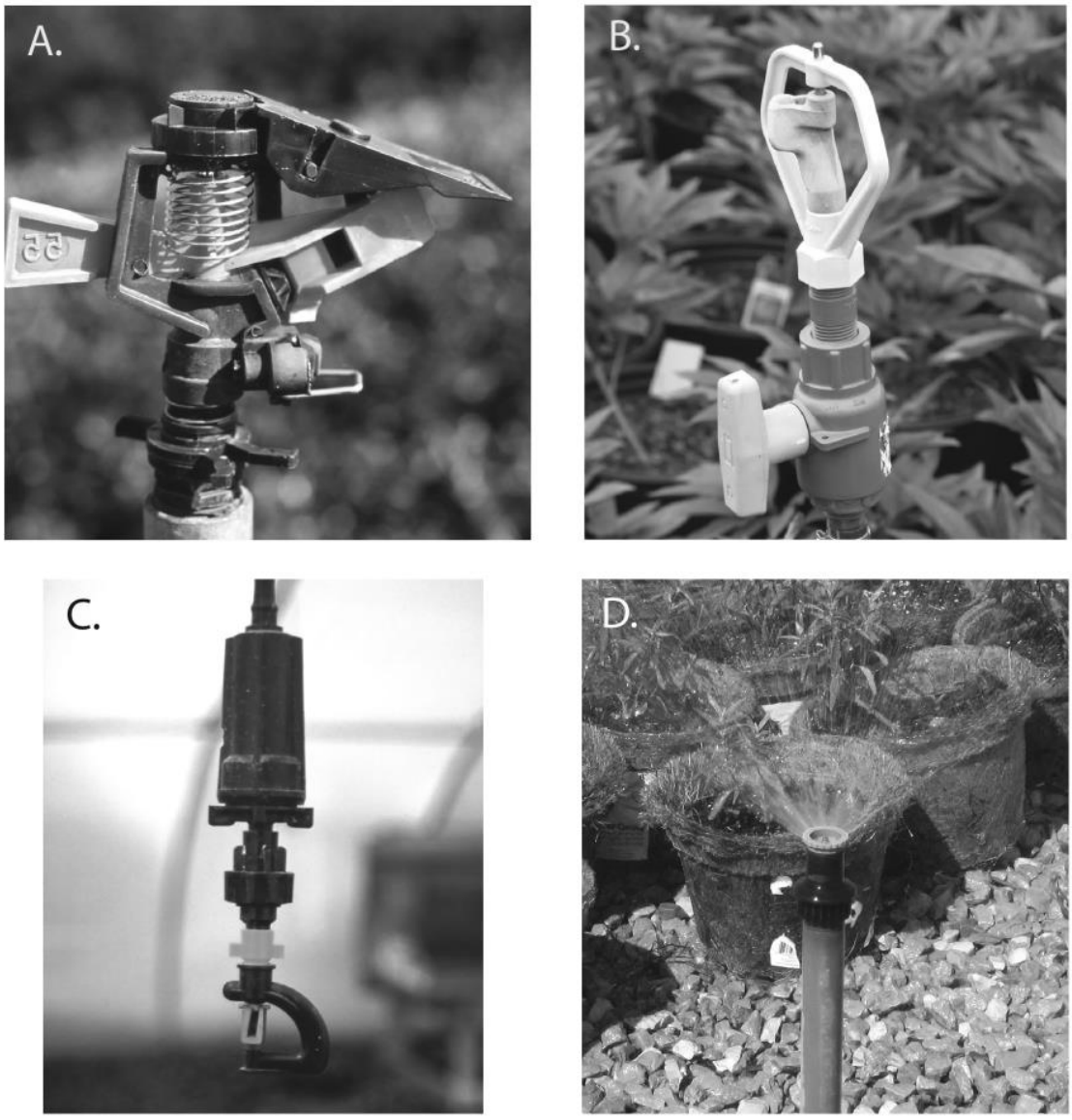


Fig. 1. (A) Sprinkler head types; (B) Rotary impact head sprinkler; (C). Rotary spinning head sprinklers; and (D) Stationary head nozzle.

Fig. 2. An outdoor nursery traveling boom system.


Fig. 3. Three basic types of micro-irrigation systems: (A) Micro-sprayers, (B) Drip emitters, and (C) In-line drip tubes.

**IRRIGATION EFFICIENCY**

Irrigation efficiency is a function of irrigation system performance and uniformity of irrigation water application. For most container nursery production, irrigation is usually delivered by overhead sprinklers. Overhead irrigation is relatively inefficient for a number of reasons including:

- High operating pump pressure.
- The large water droplet size is needed to reduce evaporation during application which can lead to water and nutrient leaching.
- Poor target water application.
- Non-uniform irrigation distribution and evaporation during application.

The amount of water reaching the container surface during overhead irrigation can be between 25 to 70% depending on container spacing (Zinati, 2005).

Overhead irrigation efficiency can be improved by: (a) grouping plants into irrigation zones based on relative water usage, (b) crop spacing, and (c) cyclic irrigation. By grouping plants into water use irrigation zones, a grower can irrigate the crop with less water waste than would occur if plants with dissimilar water use requirements were irrigated side-by-side. One of the biggest impacts on irrigation efficiency is crop spacing because the larger the spacing the greater the non-targeted water application becomes. For example, a 1-gal container spaced on 20 in. vs. 10 in. centers reduces irrigation capture by the container surface by about 60% (Table 1).

Table 1. Overhead irrigation application efficiency based on spacing of 1-gallon nursery containers.

| | Spacing on a square | | Spacing on a triangle | |
|---|---|---|---|---|
| On-center spacing (in) | Area covered (in) | Interception efficiency (%) | Area covered (in) | Interception efficiency (%) |
| 10 | 100 | 79 | 87 | 91 |
| 15 | 225 | 35 | 195 | 41 |
| 20 | 400 | 20 | 346 | 23 |

Adapted from Owen and Stoven (<http://www.climatefriendlynurseries.org/resources/irrigation_efficiency.pdf>)

A second way that overhead irrigation efficiency can be improved is by adopting a cyclic irrigation strategy. Most soilless container substrates have a low capacity for retaining water and nutrients, and supplying a large amount of irrigation at one time can result in substantial leaching. Typically cyclic irrigation systems apply water for brief intervals separated by a waiting period rather than applying water all at once. Cyclic irrigation was found to improve irrigation application efficiency by allowing time for water to gradually move through the micro-pores of the container substrate therefore reducing leaching. Along with a substantial improvement in water use, as much as a 30% reduction in nitrogen leaching was observed with cyclic irrigation compared to a single application watering regime (Lamack and Niemiera, 1993; Karam and Niemiera, 1994).

Compared to overhead irrigation, micro-irrigation is relatively efficient because it uses lower operating pump pressure, has high irrigation application uniformity, and targets water directly to the container. Greater efficiencies can be realized by applying cyclic irrigation strategies or by adopting a pot-in-pot production system. Under a pot-in-pot production system, roots experience a moderated temperature similar to the soil temperature below ground, which reduces evapotranspiration and production water use compared to above-ground containers.

## IRRIGATION SCHEDULING

Irrigation can be scheduled based on either: (a) static controllers, (b) plant-based control, or (c) substrate moisture sensors. Static controllers are the simplest and most common irrigation scheduling system. It is accomplished with timers that open a solenoid for a set time to provide a pre-set water amount. Static control is the least efficient irrigation scheduling method because it does not automatically respond to changes in the environment that impact optimal irrigation scheduling. Its efficiency can be improved by installing rain sensors to postpone irrigation events following rain. The grower may also manually alter the quantity and frequency of irrigation based on weather information.

Plant-based control relies on information provided to a crop model that schedules irrigation by monitoring environmental and/or crop physiology. Plant evapotranspiration models have been developed and are beginning to be commercialized for nursery production. These systems usually utilize weather station data and a computer determines irrigation scheduling using a mathematical model specifically designed to estimate daily

water loss (evapotranspiration) for each crop or crop group. Irrigation models are also available that rely on measuring crop transpiration. Various sap flow meters are available that fit around the main tree stem and indirectly measure transpiration. Irrigation decisions are similar whether the model is based on estimating evapotranspiration (water loss from crop and substrate) or crop transpiration. Irrigation is then applied to replace water used by the crop on the previous day or days.

Substrate moisture sensors directly monitor water loss from the substrate. There are basically two types of sensors — tensiometers and electrical resistance sensors (Fig. 4). Tensiometers measure substrate suction and control irrigation based on substrate matric potential settings. Electrical resistance sensors measure electrical resistance and relate the resistance reading to substrate moisture levels.


Fig. 4. Substrate moisture sensors (A) tensiometer, and (B) electrical resistance sensor.

Irrigation events are triggered when the sensor indicates the substrate moisture content has reached a predetermined set-point. A drawback with most sensor-based irrigation scheduling is the extensive wiring that is required to link the sensor to the controller and the controller to the solenoid. However, remote sensing has recently become available and will eventually replace hard-wired systems for acquisition and control of irrigation.

Soil moisture sensors and other environmental sensors are now becoming affordable. Therefore, utilization of these technologies is no longer restricted to research applications. Recently, commercial agricultural producers have begun adopting sensors to guide irrigation management decisions (Beeson et al., 2004; Rundel et al., 2009). These sensors have the potential to allow growers to utilize more precise irrigation practices that improve efficiency and reduce water use.

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# Monitoring Irrigation in a Production Nursery©

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**Arnelia Farms is a potted plant nursery as well as an export cut flower farm close to the town of Hopefield on the West Coast of South Africa. The nursery specialises in *Proteaceae* although the range is slowly expanding to complementary plant families. Except for two species which are propagated from seed the other cultivars currently in production are vegetatively propagated from mother stock. The mother stock is a high value section in the nursery and irrigation (fertigation) needs to be monitored very closely as these plants are sensitive to increased levels of nitrates and phosphate as well as water-logged conditions in winter and drying out during summer. Irrigation monitoring takes place by continuous logging soil moisture probes, weekly measuring of the total drainage water, and daily total irrigation water supplied, measuring the EC and checks by the nursery manager. Similar irrigation monitoring is done in the retail section (15-cm pots). Temperature is recorded by an automated weather station. The difference in EC calculated between the EC of the drainage water and EC of the irrigation water, as well as the soil moisture recorded with the probes, correlated well with mean daily and mean daily maximum temperature. Over time, analysis of data will improve the manager's ability to make decisions concerning irrigation and reduce the risk.**

## INTRODUCTION

Arnelia Farms are situated in the West Coast, close to the town of Hopefield in the Western Cape. The business consist of a 20-ha cut-flower section of which most of the produce is exported and a pot-plant nursery which produces 150,000 pots annually. The nursery also supplies rooted cuttings to protea producers on order. Arnelia Farms specialise in *Protea*, *Leucospermum*, *Leucadendron*, and *Chamelaucium*. Recently the selection has expanded to *Erica*, *Lachenalia*, and *Bougainvillea*. Arnelia Farms grow over 100 different pot-plant cultivars or species in total. Except for two species, all the plants are vegetatively propagated from our own mother stock under cover (plastic in winter and shade cloth in summer). The majority of the cultivars are sensitive to high nitrate and phosphate levels in the irrigation water and potting soil, therefore, close monitoring is necessary. The 20-cm mother stock and the 15-cm retail pot plants are closely monitored with the use of soil moisture probes, measurement of total irrigation supplied, drainage and EC, as well as the EC, pH, $NO_3$, and P of the potting soil. The focus of this paper will be the 20-cm mother stock as it is a very high value section in the nursery.

## MATERIALS AND METHODS

The mother stock consists mostly of *Proteaceae* and *Ericaceae*, as the *Chamelaucium* is harvested elsewhere. The section was divided into nine rows; each on its own valve. Each valve contains several different cultivars. The plants were potted in 80% coir and 20% peat.

The irrigation was controlled by a solar counter connected to an Aquarius irrigation controller and the countdown was set at 1500 during winter and in summer it was reduced stepwise to 800 units. The length of irrigation cycles was determined by drainage data, probe readings, and adjusted by the nursery manager.

The total volume of irrigation was recorded from Monday to Friday per valve. Each of the nine valves was divided into four sections and in each section drainage was collected from Monday to Thursday in a saucer below the pot. On Thursdays the total drainage was recorded and a daily average was calculated. The EC of the irrigation and drainage water was measured with an EC60 pocket-size conductivity/TDS/temperature meter in $mS \cdot cm^{-1}$ (Martini instruments, Milwaukee Instruments, Inc., North Carolina, USA). The difference

between the EC measured in the drainage water and irrigation water was calculated. A Davis weather station on the farm recorded air temperature.

## RESULTS AND DISCUSSION

When the difference between the EC measured in the irrigation water and drainage water (Fig. 1) increase the drainage decrease and irrigation time can be increased or the solar counter can be reduced to increase irrigation. The EC difference correlates well with mean daily air temperature (Table 1) (r = 0.75) and when warm temperatures are forecasted irrigation is increased before, rather than after the warm spell. The probe data also correlates well with mean daily (r = -0.61) and mean daily maximum air temperature (r = -0.59), respectively (Fig. 2). The probe data (Fig. 3) serves as a check and displays increasing or decreasing trends in soil moisture. The probes also record soil temperature. The soil temperature closely follows air temperature (Fig. 4), but during early spring the soil temperature is significantly higher as the tunnels are covered with plastic, which is replaced with shade cloth in November (early summer). Finally, the nursery manager checks the moisture of pots and can reference the observed information with the data collected to support irrigation changes.

Table 1. Correlation coefficients are shown for various parameters. Air temperature was recorded with a Davis weather station. The soil moisture was recorded with five continuous logging probes developed by DFM, the mean weekly drainage is drainage from 16 different pots and the EC difference was the difference between the EC measured in the drainage water and the EC measured in the irrigation water.

| | Mean soil moisture at top 10 cm (%) | Mean weekly drainage (%) | EC difference calculated weekly ($mS \cdot cm^{-1}$) |
|---|---|---|---|
| Mean daily air temperature (°C) | -0.61 | -0.56 | 0.75 |
| Mean daily maximum air temperature (°C) | -0.59 | -0.56 | 0.71 |

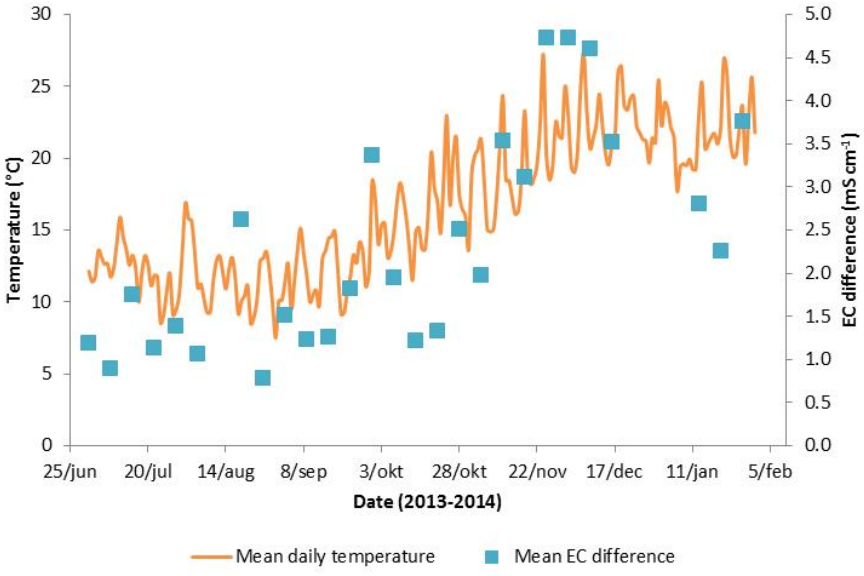


Fig. 1. Mean daily air temperature measured by a Davis weather station and mean EC difference. The EC difference was the difference between the EC measured in the drainage water and the EC measured in the irrigation water.

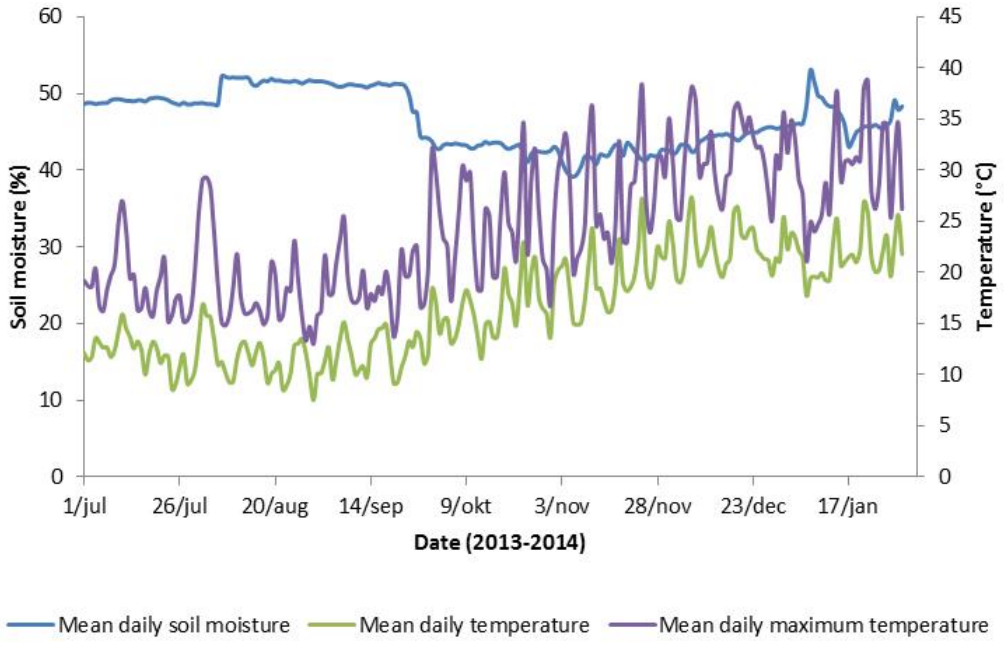


Fig. 2. Mean daily soil moisture recorded with five continuous logging soil moisture probes developed by DFM and mean daily, as well as mean daily maximum, air temperature recorded with a Davis weather station.

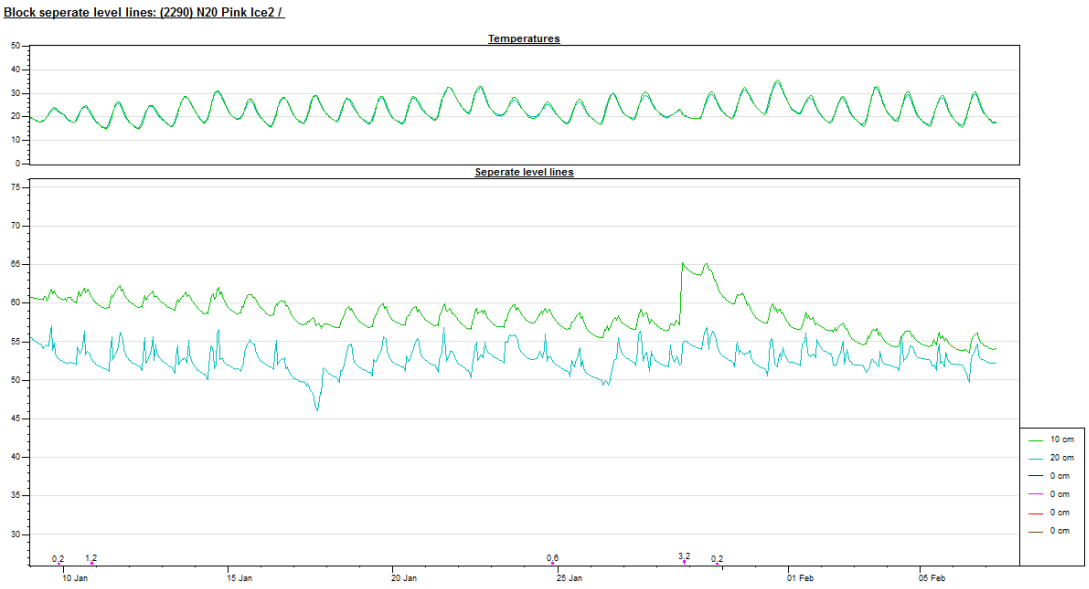


Fig. 3. A typical soil moisture graph generated by DFM Probe Utilities (bottom graph) and temperature graph (top graph). In the bottom graph, the bottom line and top line are the soil moisture levels recorded at 10 and 20 cm, respectively. The small bars on the x-axis are actual rain (mm) recorded by a Davis weather station on Arnelia Farms.

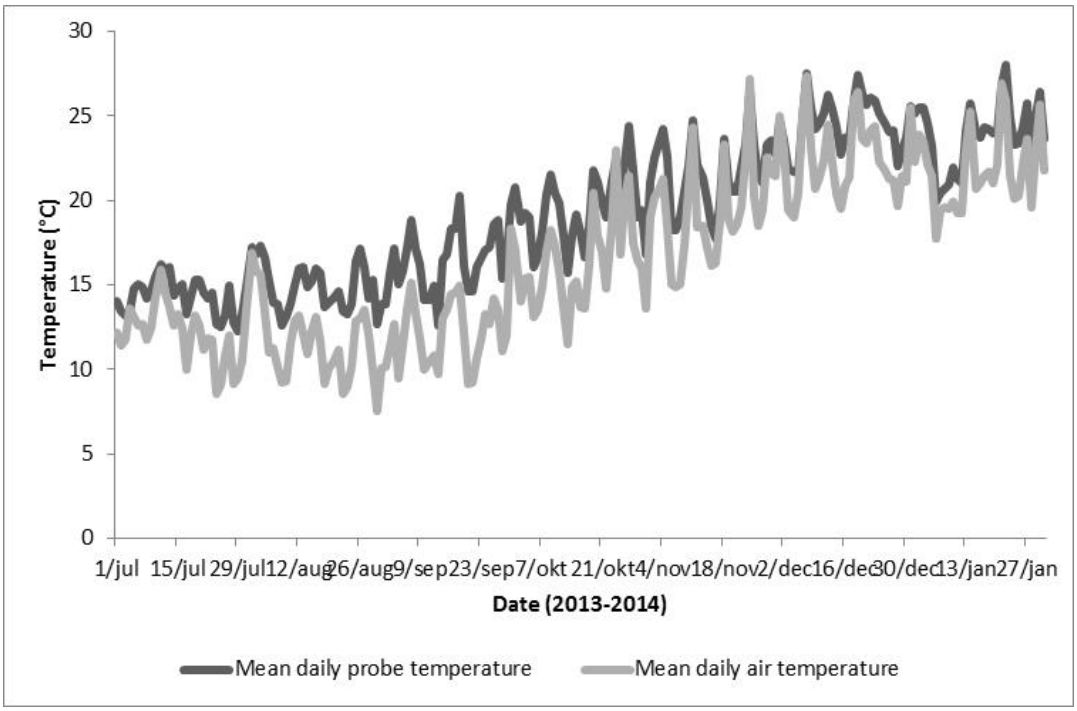


Fig. 4. Mean daily probe temperature recorded with continuous logging probes developed by DFM and mean daily air temperature recorded with a Davis weather station.

Accurate records of daily and weekly monitoring of irrigation increases irrigation efficiency and ensures maximum plant growth over time. The irrigation control points at Arnelia Farms are the solar counter which is part of the Aquarius irrigation system and the irrigation time of each valve. Preferably, one irrigation cycle of the 20-cm mother stock which includes the retail 20-cm pots that run on the same program, should not exceed 1 h. This, together with excessive drainage, limits the irrigation time of each valve. To increase the number of cycles per day the solar counter can be adjusted to count down less or more units before commencement of the next cycle. In order to make decisions on the number of irrigation cycles that need to run each day and for how long, irrigation monitoring is crucial. The main aim is to achieve 10-15% drainage on average during a week. Over time the system should be refined and changes in irrigation time or the solar counter would be anticipated more accurately during the year.

# Breeding for Sterility in Invasive Ornamental Plants©

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## INTRODUCTION

Invasive plants are introduced species that can thrive in areas beyond their natural range of dispersal (USDA-NISIC, 2014). They naturalize over large areas, displace native plants, and disrupt natural ecosystems (Ranney, 2004). In Florida, over 1.5 million acres (approximately 600,000 ha) of public conservation lands have been invaded by introduced plant species (Fig. 1), and approximately USA$7 million was spent on management and control of invasive upland plants in 2011 (FFWCC, 2011). In the USA, control costs and production losses due to weeds was estimated at US $30.6 billion per year (Cusack et al., 2009). For example, purple loosestrife (*Lythrum salicaria*), was introduced from Europe to USA in the early 1800s. Purple loosestrife is now found in all continental states except Florida (Blossey, 2002) and accounts for USA$50 million per year in control costs and forage losses. Mexican petunia, *Ruellia simplex* (previously also known as *R. brittoniana*, *R. coerulea*, *R. malacosperma*, and *R. tweediana*), was introduced to Florida from Mexico sometime before 1940 (Hupp et al., 2009) and has now naturalized throughout the state, plus six other southern USA states, Puerto Rico, the USA Virgin Islands and Hawaii (USDA-NRCS, 2014). It is considered as a Category I invasive species in Florida because it is altering native plant communities by displacing native species and changing community structures or ecological functions (FLEPPC, 2013). However, there is no evidence that it is hybridizing with native species (Freyre and Tripp, 2014). Sales of *R. simplex* 'Purple Showers' in Florida were ranked third for herbaceous perennials after pentas and lantana (Rick Brown, Riverview Flower Farms, pers. comm.), so a breeding program aiming to develop sterile, non-invasive cultivars was established at the University of Florida in 2007 (Freyre et al., 2012a). This species will be described in more detail in this paper.

Fig. 1. Invasive *Ruellia simplex* in Lake Jesup Conservation Area, Seminole county, Florida USA (photo courtesy of Adrienne Smith).

## CHARACTERISTICS OF INVASIVE PLANT SPECIES

The most successful non-native species, those capable of displacing natives, share several characteristics: (1) Effective reproductive and dispersal mechanisms; (2) Competitive ability superior than that of the native; (3) Few to no herbivores or pathogens; (4) Ability to occupy a "vacant niche"; (5) Capability of altering the site by either significantly changing resource availability or disturbance regimes or both (Gordon, 1998). *Ruellia simplex* shows many of these characteristics. Plants flower within 3 months (Wilson and Mecca, 2003), and can produce fruits from either open or self-pollination. Under low light levels, plants can produce cleistogamous flowers, which have greenish-brown, very small corollas that do not open, and form fruits from self-pollination (Khoshoo et al., 1969). Capsules contain on average 20.6 seeds per capsule. Seeds do not have a dormancy period, and have 98 to 100% germination rate under ideal conditions of 30°C day and 20°C night. Moreover, seeds are capable of germination under a wide range of temperatures and under conditions of both light and dark (Wilson et al., 2004). Explosive dehiscence of the seed capsule results in seed dispersal distances from the parent plant of 2.5 to 3 m (Witztum and Schulgasser, 1995). Seeds become mucilagenous and adhesive when wet, aiding their dispersal by animals (Ezcurra and Daniel, 2007). Seeds can even germinate under water (personal observation).

*Ruellia simplex* plants have the ability to grow in a wide range of environmental conditions, from wetlands to almost xeric. In Florida, the species has been reported in five different plant community types: pine flatwoods, prairies; hardwood (hammocks, tree islands, etc.); freshwater marshes; rivers, springs; and salt marsh (Hupp et al., 2009). In the meantime, native *R. caroliniensis* is found primarily in dry native woodlands (Gilman and Landrum, 1999). A study comparing growth and development of *R. caroliniensis* and *R. simplex* established that under wet conditions in laboratory experiments, *R. simplex* exhibited several traits that favor efficient use of resources and high growth rates. It was therefore concluded that under typical wetland conditions *R. simplex* might be expected to out-grow and out-compete native *R. caroliniensis*, especially if the supply of nutrients is limited (Wilson et al., 2004). In several areas where *R. simplex* has naturalized, its coverage was found to constitute 50% of the infested stratum, thus changing community structure by adding a new stratum, or increasing plant density in the stratum by 5-fold. It was also probably altering the hydrology within plant communities (Hupp et al., 2009).

## BREEDING METHODS TO OBTAIN STERILITY IN ORNAMENTAL PLANTS

For several years, ornamental plant breeders have been using a number of methods to develop sterile (or nearly sterile) plants that will not be invasive by seed dispersal:

### Selecting and Breeding for Double Flowers

Many plant species have forms exhibiting double flowers, which have more than the normal number of petals in the corolla. The reproductive organs (stamens and carpels) are modified into additional petals, thus conferring sterility or near sterility. Many garden plants have been selected for having double flowers, for example roses, carnations, camellias, and double columbines, petunias, and impatiens. Recently, a molecular model that accounts for the formation of double flowers was described (Lohmann et al., 2001; Lenhard et al., 2001).

### Induced Mutagenesis

Induced mutations have successfully assisted in developing improved and new cultivars among both seed- and vegetatively-propagated crops (Jain, 2006). Mutations resulting from treatment with X-ray or gamma irradiation or chemicals such as ethylmethanosulfonate (EMS) can result in sterility. However, mutations are random, resulting in the need to screen large numbers of individuals. Irradiation treatments have been successful in inducing male and/or female sterility in several ornamental crops that are clonally propagated for commercial production, including *Chrysanthemum*, *Cineraria*, and *Verbena* (Broertjes and Dejong, 1984; Huang, 1995; Saito, 2005).

**Wide Hybridization**
This involves interspecific or intergeneric crosses between distantly related individuals. Chromosome dissimilarities between the parental genomes can result in meiotic failure during gamete formation, leading to sterility. Some examples include interspecific crosses between *R. caroliniensis* × *R. simplex* (Freyre and Tripp, 2014), and ×*Chitalpa*, an intergeneric cross between *Chilopsis linearis* × *Catalpa bignonioides* (see also ×*Chitalpa tashkentensis*) (Rusanov, 1964). In some cases, breeders may need to use ovule or embryo culture in vitro to obtain hybrid plantlets that would not otherwise survive (Bridgen, 1994).

**Polyploidization and Development of Triploids**
Ploidy manipulation is an important tool in plant breeding, exemplified by the development of seedless triploid sugar beet and water melon (Stebbins, 1956). The development of triploid plants (with 3 sets of chromosomes) involves first the induction of tetraploids (with 4 sets of chromosomes) from original diploid plants (with 2 sets of chromosomes) by use of the chemicals colchicine or oryzalin, followed by cross pollination between tetraploids and diploids. Triploids typically grow and function normally, but they have an inherent reproductive barrier in that the three sets of chromosomes cannot be divided equally during meiosis (Ranney, 2004). In ornamental plants, triploids have been bred in rose-of-sharon (Egolf, 1988) and spurflower (Brits and Li, 2008) and this approach has also been utilized to breed triploid sterile selections of invasive tutsan (Olsen et al., 2006) and lantana (Czarnecki and Deng, 2008).

**BREEDING STERILE MEXICAN PETUNIA**
Polyploidization experiments were performed at the University of Florida in Gainesville in 2008 using oryzalin on the apical meristem of seedlings of *R. simplex* as described by Jones et al. (2008). Ploidy levels were determined on mature plants using flow cytometry as described by Czarnecki and Deng (2009). Treatments of three applications of 25 or 50 μM oryzalin every 12 h were most successful in inducing polyploidy. Hybridizations were performed with plants of different ploidy levels, such as $4x \times 2x$ and $2x \times 4x$, aiming to obtain sterile triploid plants. A total of 495 *Ruellia* plants were obtained in 2010 and initially evaluated in the greenhouse for growth habit, flowering, and lack of fruit formation. Fifteen *Ruellia* hybrids and five controls were selected for field trials and propagated vegetatively.

In 2011, plants were trialed in three simultaneous field experiments conducted at the North Florida Research and Education Center in Quincy, Florida, at the Plant Science Research and Education Unit in Citra, Florida; and the Indian River Research and Education Center in Ft. Pierce, Florida (northwestern, north central, and southeastern Florida, respectively). The experimental design was a randomized complete block with three blocks. Each plot consisted of three plants for each cultivar or breeding line, spaced 50-cm apart. Wild *R. simplex* ($2x$) and 'Purple Showers' ($4x$) were included as purple-flowered comparison lines, 'Chi Chi' ($2x$) as pink-flowered and 'Snow White' ($4x$) as white-flowered controls. Each plant was evaluated every 4 weeks, from May to October (24 weeks), for landscape performance, flowering and fruiting (Freyre at al., 2012a).

Three $4x$ plants with different flower colors were outstanding and better than their respective controls at all locations. The three selected breeding lines: purple-flowered R10-102, semi-dwarf pink R10-105, and white R10-108 were evaluated for female fertility by harvesting and germinating open pollinated fruits from the field, and by germinating seeds obtained from manual cross pollinations and self-pollinations in a greenhouse. Additionally, male fertility for each plant was determined by staining pollen grains with lactophenol cotton blue. It was estimated that R10-105 had 5% viable seeds per plant as compared to the invasive wild *R. simplex* and 6% as compared to female and male fertility than the existing commercial pink cultivar 'Chi Chi', and it was not approved for cultivar release by the UF/IFAS Invasive Plants Working Group. However, it was demonstrated that R10-102 and R10-108 are both female and male sterile. These

lines were released as new cultivars ‘Mayan Purple’ and ‘Mayan White’, respectively (Freyre at al., 2012b), and were commercialized in 2013 (Fig. 2).

Fig. 2. Close-up of Ruellia ‘Mayan Purple’, ‘Mayan White’ and ‘Mayan Pink’ (left to right).

Fruits were collected at the three field locations in 2011 from open pollination of pink-flowered R10-105. Seed was germinated obtaining 148 progeny, which were then trialed in the field in Citra in 2012. A total of 29 pink-flowered open pollinated progeny from R10-105 were selected for further trials based on performance and apparent low or no fruiting. These plants were propagated vegetatively and grown in a greenhouse in Gainesville. Nineteen plants were selected for 2013 field trials in Citra and in Fort Pierce, and for potted plant trials in Gainesville.

The plant R10-105-Q54 was selected as the best performing pink-flowered plant that also had low fruit count. In Citra it was observed that R10-105-Q54 produced some fruits from open pollination but they all seemed to abort prior to maturation. To confirm female fertility, 10 self-pollinations were performed in a greenhouse as well as 20 cross pollinations using either wild *R. simplex* or ‘Chi Chi’ as males. A few fruits were produced but they all aborted before maturation, with the exception of one fruit which matured and dehisced naturally. This fruit contained 14 seeds but they did not germinate. Additionally, it was determined that R10-105-Q54 had only 10% pollen staining compared to wild *R. simplex* with 69%. Since it was demonstrated that R10-105-Q54 had extremely low to null fertility, it was approved for release as a new cultivar by the UF/IFAS Cultivar Release Committee and the UF/IFAS Invasive Plants Working Group. This line will be commercialized under the name ‘Mayan Pink’ (Freyre and Wilson, 2014).

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# New Approaches to Recalcitrant Species Propagation — Never, Never, Never, Ever Give Up©

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## OVERVIEW

This presentation will cover the following:

- Background to natural area business.
- Propagation in our market and our experience and approach.
- Propagation and treatment methods.
- Success to date and some future targets species.
- Nursery financial and performance implications.
- Relevance to IPPS and this audience.

## BACKGROUND

This presentation is about the ways in which we have pursued propagation of recalcitrant and difficult species, mainly from seed and the benefits that have accrued to the business. For us, it's been about deciding that standing still is not an option and non-stop product development is the way to drive our market, motivate our staff, and enhance our broader environment business.

### Our Nursery

Natural Area operates in contracting, consulting, and supplies for the management, maintenance, and rehabilitation of natural habitat areas in Perth metro and regions with all operations integrated to provide a comprehensive in-house service. Our staff total is 43 going to 50 in peak season.

Stock is produced for in house company projects and for outside revegetation and natural landscape markets. We produce approximately 300 species mainly Perth provenance. Current volume is 650,000 units split between contract production (40%) specific production (60%). Our focus is on difficult-to-grow species and bringing new species into production. We anticipate client needs and back ourselves to promote sales to project users.

Where our plants go:

- Coastal rehabilitation
- Woodland rehabilitation
- Riverine rehabilitation
- Wetland rehabilitation

### Our Propagation Market

Western Australia (WA) has 13,500 naturally occurring plant species and less than half have ever been propagated. Perth plain species total about 2,200, 50% endemic to Southwest WA. Many exhibit high levels of seed dormancy and successful techniques for many are not well documented. Generally no more than a third of these would be available in market at any one time and many in low numbers.

Our market is full of propagation challenges and opportunities. Propagation from seed is considered highest and best for restoration and rehabilitation. Cuttings do not always perform well in dry land revegetation. Tissue is important to meet essential species return but not always cost recoverable. Vegetative propagation from cuttings is not as important to us as it is being done well by others and does not provide us with an economic point of difference but plant salvage and division figures highly for us as it connects with our on ground presence.

We started propagation 14 years ago, but after the first few years realised that there were many plants which were important to our revegetation business and the broader

market that we did not know how to grow and the market demand was not being met. It would have been easy to accept that it was all too hard and that we would stick to the sausage plants, you know the ones that many nurseries grow because they are relatively safe, this is the conventional wisdom. We took the view that our reputation and our returns would be enhanced by tackling the hard ones. This often involved unconventional approaches and a willingness to experiment and speculate.

This has been a long road, starting from a low knowledge base and we are now seeing the benefits flow from the early decision and ongoing work. Many plants, which we though impossible from seed in the early years, are now within our capability (Table 1).

I am talking about propagation difficulties due to various forms of seed dormancy, varying viability as well as seed that either cannot be isolated from the host plant, or that most commercial seed collectors will not collect because it is uneconomic for them to do so.

**SEED GERMINATION**

Experience has shown us that:

- Seed from outside collectors often performs badly.
- Seed from different locations and collected at different times can show significant variance in viability.
- Propagating specialist native species requires understanding and involvement in the on ground habitats.
- Obtaining specialist vegetative material requires rigorous pursuit of collection opportunities, e.g., land clearing applications and seed collection opportunities.

**Our Approach**

- Study all available literature and references to target species.
- Pursue botanical gardens authorities or universities for their research and practical experience. (It's often publicly funded and therefore should be available to propagators.)
- Study the plant in its natural habitat and different locations and understand the natural processes/replicate the natural processes.
- Collect and buy in seed from a wide range of locations. In any one season we would collect seed from over 200 sites in and outside Perth.
- Pursue established methods and if not successful, go radical.
- If we can't isolate seed, we take the mature inflorescence and process it.
- Genera often the guide to what will work.
- Some species require immediate sowing after collection. Viability can be lost rapidly.
- Important to maintain detailed and accurate propagation records and techniques employed, both successes and failures.
- Staff needs to be informed on protection of company ownership of intellectual property.
- We use enzymes to remove thick fleshy coats.
- We treat damp prone species seed with fungicide pre sowing.
- We use wetting agent when preparing to imbibe seeds.
- We use granulated fungicide on potting for damp prone species.
- We use hormone on root cuts to improve survival.

**Propagation Methods/Treatment Options**

**1. Isolated Seed.**

- Weathering.
- Manual scarification (small numbers).
- Hot and or cold water treatment, often repetitive.
- Concentrated acid exposure ($H_2SO_4$).
- Extended conventional sowing (Patience, don't throw out those seed trays).
- Temperature stratification, hot and/or cold.
- Variable stratification.
- Extended imbibitions (deionised or rain water with wetting agent or smoked water).

- It may be unconventional but we have had high success in some cases from soaking particular seed for anything up to 14 days.
- Physical smoke: Often for extended periods up to 1 week.
- Heat: We are surprised by the resilience of some seeds to high heat (100°C and beyond) and their response.
- Light: Some seeds require light to germinate and a carefully controlled surface sow is essential.
- Extended burial.
- Inoculants and fungi are added to selected species.
- Exposure to plant hormones, e.g., gibberellic acid, jasmonic acid, and abscisic acid.

Our experience suggests that often a combination of treatments can yield results. We don't get too carried away with the science behind all this. We are not doing research; we are trying to get an outcome, a business result and one that we can learn from.

**2. Unisolated Seed.** Some species hold seed for extended periods and isolation of seed is either very difficult or not commercial. The solution may be to depart from the desire to isolate clean seed and harvest the entire inflorescence and sow In mass. We have had outstanding success with a number of species using this method.

Key targets for future work include: *Astroloma*, *Conostephium*, *Cyperacae*, *Ericaceae*, *Liliaceae*, *Mesomelaena*, *Schoenus*, *Tetraria*, and *Tricoryne* sp.

## NURSERY BUSINESS IMPLICATION

Being a specialist propagation nursery is generating sales prices at levels of between 50 to 250% above industry tube stock (sausage plant) average price.

They represent about 10% of our production but produce over 25% of our gross sales revenue and 40% of our pre-tax bottom line. Our net profit before taxes and dividends has ranged from 27 to 33% of sales. If we did not do this and substituted more of the straight forward lines our net profit before tax would fall to well below 20% of sales.

Importantly, being a go to firm for the difficult species leads to new customers and complimentary sales of the easier plants often without downward price pressure. We are in a position also to say that if you only want the hard to grow stock then maybe we will sell them to someone else, therefore becoming a price maker and not price taker.

The enhancement of our reputation has extended to cases where we are being paid for advanced propagation services regardless of outcome, i.e., where particular and not previously grown plants are requested, we are being paid for the attempted propagation and not a per plant price outcome. We intend to press for more such arrangements in the future.

Our nursery capability enhances our revegetation reputation and provides a competitive advantage. Being able to guarantee inclusion of specialist plants in revegetation project plans and tenders can get us over the line ahead of other revegetation contractors who are not growers.

The benefits from pursuing difficult propagation also include strong staff interest in outcomes, their willingness to trial and be proactive, development of high end staff skills in botanical development, and potential to develop plants for the broader landscape market.

Table 1. Cases of species propagated from seed considered recalcitrant or often difficult.

| Family | Genus | Species |
|---|---|---|
| *Apocynaceae* | *Alyxia* | *buxifolia* |
| *Laxmanniaceae* | *Acanthocarpus* | *preissii* |
| (including *Lomandraceae*) | *Laxmannia* | *squarrosa* |
| | *Lomandra* | *maritima* |
| | *Dichopogon* | *capillipes* |
| *Amaranthaceae* | *Atriplex* | *cineria* |
| | *Atriplex* | *isatidea* |
| | *Atriplex* | *hypoleuca* |
| *Cyperaceae* | *Machaerina* | *articulata* |
| | *Machaerina* | *juncea* |
| | *Machaerina* | *preissii* |
| | *Chorizandra* | *enodis* |
| | *Cyathochaeta* | *avenacea* |
| | *Gahnia* | *trifida* |
| | *Lepidosperma* | *calcicola* |
| | *Lepidosperma* | *gladiatum* |
| | *Lepidosperma* | *effusum* |
| | *Lepidosperma* | *longitudinale* |
| | *Lepidosperma* | persecans |
| *Dasypogonaceae* | *Dasypogon* | *bromeliifolius* |
| *Dilleniaceae* | *Hibbertia* | *hypericoides* |
| | *Hibbertia* | *subvaginata* |
| *Epacridaceae* | *Brachyloma* | *preissii* |
| *Ericaceae* | *Leucopogon* | *conostephioides* |
| | *Leucopogon* | *parviflorus* |
| | *Leucopogon* | *propinquus* |
| *Frankeniaceae* | *Frankenia* | *pauciflora* |
| *Haemodoraceae* | *Phlebocarya* | *ciliata* |
| *Iridaceae* | *Orthrosanthus* | *laxus* |
| *Loranthaceae* | *Nuytsia* | *floribunda* |
| *Poaceae* | *Spinifex* | *hirsutus* |
| | *Spinifex* | *longifolius* |
| | *Sporobolus* | *virginicus* |
| | *Triodia* | *epactia* |
| | *Triodia* | *wiseana* |
| *Proteaceae* | *Conospermum* | *stoechadis* |
| | *Conospermum* | *triplinervium* |
| *Ranunculaceae* | *Clematis* | *linearifolia* |
| *Restionaceae* | *Desmocladus* | *flexuosus* |
| | *Dielsia* | *stenostachya* |
| | *Hypolaena* | *exsulca* |
| | *Lepidobolus* | *preissianus* |
| *Rutaceae* | *Diplolaena* | *dampieri* |
| | *Diplolaena* | *angustifolia* |
| *Santalaceae* | *Exocarpos* | *sparteus* |
| | *Leptomeria* | *preissiana* |
| | *Santalum* | *acuminatum* |

## RELEVANCE TO IPPS AND THIS AUDIENCE

### Potential for New Members from the Native Plant and Revegetation Sector

There is potential for sharing of specific information across the jurisdictions and I am keen to continue my visits to discuss techniques with other IPPS connected growers.

My limited reading suggests that there are some propagation challenges within the suite of endemic New Zealand plants. I made a list of 13 genera where some common ground exists. I hope we can share now and into the future.

In a business sense, it seems logical to me for growers to continually seek out niches in the market by going down paths different from their competitors.

Whilst we are not retailers, there is much potential to bring new and rarely seen plants to a broader audience.

## CLOSE

Everyone here understands how important plants are to the world and all other life forms. I hope that you as growers realise how important you are to the health and wellbeing of the environments in which we live. All of us should feel very good about what we do.

The sharing of knowledge and information and competition within in our respective markets is a difficult balancing act. We are here to share and at the same time, obliged to protect our personal commercial interests. Passing on knowledge within our industry is important and we need to recognise that the next generation will see the world very differently from the way we see it. Personally, I am still trying to determine if I will be able to find anyone to continue our work with passion and commitment. The challenge is with us to find a way. It may be done differently but what will never change is the need to belong and communicate.

Meantime, we have been diligent in recording all we have learned about the plants that we have grown and look forward to sharing more over the times ahead.

Thanks to IPPS and our Kiwi hosts. I hope that all of you will look hard at attending future IPPS conferences and especially the 2017 event that we will host in Perth, Western Australia. Put it on your must do list and we will make sure you are well looked after.

# Running a High-Health and Trueness-to-Type Programme©

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## BACKGROUND

A number of crops have high health schemes to ensure that plants sold meet consumer expectations. Fruit crops have tended to lead the way because of the risk of disease spread, the relatively large number of units sold, and the importance of ensuring that plants sold are subsequently productive and true to type. In recent years, New Zealand government backed schemes have largely disappeared. This means that industry groups have had to take responsibility for high-health schemes where this is considered desirable. In berry crops, there are schemes for strawberries and blackcurrants and a blueberry plant scheme is being developed.

At the moment, there are around 14 million strawberry plants sold annually in New Zealand. Plant numbers peaked at 21.5 million in 1999 but fell as growers changed to new cultivars that were more vigorous and needed more space. Despite lower plant numbers, areas planted in strawberries have actually increased since 1999 and total production has increased from an estimated 7100 tonnes to 8800 tonnes this year (2013-2014).

The Strawberry Runner Plant Scheme was set up in 1985 in conjunction with strawberry runner growers by the Ministry of Agriculture and Fisheries. It was initially established for the New Zealand Berryfruit Growers Federation but ownership has since passed to New Zealand Berryfruit Propagators Ltd. (NZBP) which is a limited liability company, 100% owned by Strawberry Growers New Zealand Inc.

Because the scheme has no government association, control is achieved by contractual arrangements with the four main plant growers. As part of the license contract to allow production of what are mostly University of California cultivars, growers must accept to produce according to the scheme in order to get a license.

## OUTLINE OF THE SCHEME

The scheme is based on a 3-year propagation cycle starting with a nucleus plant. This may be a plant directly released from quarantine, a plant sourced from tissue culture stocks held by the scheme, or a recycled tested nuclear plant produced the previous year. Initial stocks are established in spring. The subsequent nuclear plants produced are sold (usually the following September) to the licensed plant growers and these are placed in elite beds where they are multiplied for a further year before going into runner beds. The following May, the runners produced are sold to fruit growers.

A single strawberry plant can produce up to 400 daughters in a single season. Multiplication rates are often lower than that and for nucleus stock plants we work on average production of 50 nuclear plants. These 50 nuclear plants, planted in elite beds could produce 10,000 elite plants which subsequently could be multiplied in the runner beds to give 2,000,000 plants for sale to fruit growers. The health of this last generation will depend upon both the health of the original stock plant and subsequent care at each stage of the scheme.

## HIGH HEALTH ASPECTS

The focus of the programme is on those pest and diseases that can affect production of the plants when they reach the customer — in this case the fruit grower. The list of these pests and diseases is regularly reviewed and is added to if threats from newly arrived pests and diseases are discovered.

The present list of designated serious diseases includes: 17 viruses; 14 phytoplasmas; 2 fungal diseases, of which the most important is *Phytophthora cactorum;* and nematodes. Fortunately there are no bacterial diseases on the list at the moment, but we are on the

look-out for *Xanthamonas fragariae* that is a potential threat to strawberries but is not in the country, as far as we know, at present.

The programme deals with these threats through a combination of testing and preventative measures. All nucleus stock plants are hot water treated at 46°C for 10 min. to control nematodes and cyclamen mite before going into the nuclear stock unit. At this stage, the first *Phytophthora* test is taken from roots and potting mix from each plant. During the season, leaf samples are taken and tested for viruses and phytoplasmas by molecular methods carried out by MPI, and this testing is supported by grafting each of the 17 cultivars on to three indicator clones, which we do ourselves. A second *Phytophthora* test is carried out prior to sending the plants out.

Elite and runner beds are inspected annually and the nuclear unit has been audited three times in recent years. Finding people with appropriate knowledge of strawberry high-health programmes within New Zealand to audit the nuclear unit in a meaningful way has been a problem. However we do cross check our systems with the potato high health unit centred in the same glasshouse complex at Plant and Food Research at Lincoln.

For woody plants, there are increasing concerns about fungal diseases that have the ability to be carried without showing symptoms on propagation material. What happens subsequently in fruit production fields is that under specific conditions, these diseases then express, often at great cost to the grower. This is highly relevant for our woody berry propagation programmes. Diseases that have this ability include *Peronospora* sp. (downy mildew) and *Cercosporella* sp. (boysenberry decline) in *Rubus* species, and *Chondostereum purpureum* (silver leaf) and *Botryosphaeria* sp. in blackcurrants and blueberries We are still in the process of developing systems that include checks of propagation material for freedom from these diseases in these crops. We know that *Peronospora* will happily multiply in tissue culture stock and with its ability to infect roses as well, is a disease to be wary of.

Virus diseases and phytoplasmas are the others that can turn up in otherwise healthy appearing plants at a later date. As an example, raspberry bushy dwarf virus (RBDV) is causing problems at the moment in plants distributed a few years ago. These incidents remind us of the importance of having high-health systems for propagation

## TRUENESS TO TYPE

It is now over 10 years since the last court case occurred involving a mix up with strawberry plants. Co-incidentally we introduced a trueness-to-type programme around the same time and this has prevented mix ups getting through to the fruit production stage and in recent years, the trial results have been used to circumvent a possible court case. However, we have had a recent mixed cultivar experience with blackcurrants which has created changes to our operating systems for this crop.

The strawberry trueness-to-type programme has multiple objectives. The first one is to ensure that all plants sold to commercial growers will perform as expected for that cultivar. The trial plots are also used to test relative performance of cultivars and demonstrate any differences between propagators. The plots are also used as test sites for Plant Variety Rights (PVR) descriptions. We run two sites for strawberries, one in Auckland for short day cultivars and one in Canterbury for day neutral cultivars. Plants from all elite beds and the nuclear stock unit are included in the replicated and randomised trial plots.

## CONCLUSION

Running a high-health and trueness-to-type programme is not cheap. Having plants that don't perform at a later date with associated court cases over health and trueness-to-type issues can be much more expensive. The key is to identify the issues that are likely to impact on subsequent performance of nursery stock and have systems in place that demonstrate that when plants left the nursery, they were fit for purpose.

# Light Management during Cutting Propagation in New Zealand©

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## INTRODUCTION

Propagation of cuttings with sunlight as the sole light source is the most common situation in commercial plant nurseries. In that situation, greenhouse shading is the most important factor to manage in order to ensure that light is in an acceptable range for rapid root and shoot growth. When excess shade is applied, light is limiting to photosynthesis and growth. In contrast, excess light is likely to result in dehydration and heat stress of plants.

Studies in both commercial and research settings provide guidelines for lighting during propagation. The objective of this article is to provide light-level guidelines, and show how ambient light levels in New Zealand affect shading strategy. These guidelines must be adapted to local climate conditions, depending on whether high light leads to excessively warm air and plant temperature, and a resulting need to mist frequently or open vents and lose humidity. The greenhouse technology is also important. Movable shade can be closed during hot and sunny hours during midday, and open during morning and afternoon or cloudy weather. Movable shade therefore has greater ability than fixed shade to increase light level without resulting in heat stress. With fixed shade, the key decision is typically which month to apply or remove shade. Because of microclimates and differences in greenhouse types, growers should trial new shade levels before applying to the entire crop.

## LIGHTING GUIDELINES

Most growers are familiar with measuring instantaneous light intensity, meaning the light level that would be measured at one point in time using a light meter. One challenge in comparing measured light against recommended levels is the wide range of units used to describe light intensity.

For the photosynthetically active range of the light spectrum [400 to 700 nanometers (nm)], units are micromoles per square meter per second ($\mu mol \cdot m^{-2} \cdot s^{-1}$). For sunshine, 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ equals 520 foot candles, 5,600 lux, or 5.6 klux of visible light (380-770 nm), or 48.3 Watts/$m^2$ of light energy (280 to 2,800 nm). These conversion factors vary for different light sources such as different types of electric lamp (Both, 2002).

There is a tradeoff between having adequate sunlight intensity for maximizing photosynthesis rate versus heat stress. Typical light levels under mist during formation of callus and root initials are 200 to 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (11.2 to 16.8 klux). Excess light during the mist phase leads to dehydration of cuttings, and the grower may have to overcompensate with more frequent mist irrigation to keep the plants from wilting. This can create several problems. Media will become saturated, cold, and depleted of both oxygen and nutrients, making for slow rooting or plants that are nutritionally deprived.

The optimum light level may increase to 500 to 600 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (28.0 to 33.6 klux) or more after plants are well rooted, off mist, and being hardened off for transplant. Because optimum light level varies during crop growth, this can be achieved by having 2 or 3 climate zones with increasing light level, often coupled with decreasing temperature to harden off plants. For many floricultural crops during the finished phase after transplant, a light level of 500 to 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (28.0 to 56.0 klux) is acceptable (Heins and Runkle, 2004). For greenhouses that are poorly vented, or are in a location with high air temperatures, light levels need to be on the lower end of these ranges.

Daily light integral (DLI) during propagation can also significantly affect adventitious rooting of cuttings. The DLI refers to the accumulated light energy in the PAR range in moles per square meter per day ($mol \cdot m^{-2} \cdot d^{-1}$). A datalogger can be used to continuously

measure light level, and calculate the accumulated DLI. A suitable battery powered datalogger is the WatchDog 2475 Plant Growth Station available from <specmeters.com>. Most computerized environmental control systems can also log DLI, but this ideally requires a light meter to be placed inside the greenhouse.

When the DLI is below 4 $mol \cdot m^{-2} \cdot d^{-1}$ inside the greenhouse during mist propagation, rooting can be reduced or inhibited because leaves are unable to intercept enough light for adequate photosynthesis. When light levels are too high (above 8 to 12 $mol \cdot m^{-2} \cdot d^{-1}$) during mist propagation, transpiration is increased, and drought stress or excess misting can inhibit rooting. After plants are rooted and off mist, shade should be reduced or plants moved to a higher light zone. Finishing cuttings at a DLI of 8 to 14 $mol \cdot m^{-2} \cdot d^{-1}$ enhances rooting, branching, flowering, and post-transplant performance.

During winter months, sunlight can be limiting to plant growth. Long nights, overcast weather, and low incident angle of the sun greatly reduce the amount of light that plants receive. During this time, shading is often not necessary, particularly during cloudy days.

In the late spring and summer months, shading is applied not only to reduce light levels for unrooted cuttings, but also to lower the greenhouse temperature, reduce venting, and maintain air humidity. Beware, however, in creating very soft (poorly toned) cuttings through the combination of warm and dark conditions. Most plants that will be grown under full sun in the landscape or finished container should ideally be hardened off without shade before transplant, unless they become excessively heat-stressed.

The shoulder seasons of spring and autumn are often the most challenging, because of changeable weather. This is where fixed shade becomes most inefficient because over-shading will occur on cloudy days if the shade cloth remains closed.

## LIGHT LEVELS IN NEW ZEALAND HORTICULTURE

Table 1 shows DLI data adapted from historical climate data at 29 weather stations in New Zealand. Original data from the National Institute of Water and Atmospheric Research (NIWA) were collected using light sensors that measure total global radiation (approximately 280 to 2,800 nm). This spectral range differs from PAR light (400 to 700 nm) that is relevant for plant growth. A conversion factor was therefore applied of 2.08 $mol \cdot m^{-2} \cdot d^{-1}$ of PAR light for each $MJ/m^2$ of total radiation from sunlight, based on Both (2002).

The light levels in Table 1 represent full sun, with no shade from the greenhouse structure, covering material, or other shading materials such as shade cloth or white wash. Clean glass reduces light transmission (i.e., provides shading) by about 10%, and any areas receiving shading from the gutters, sash bars, or other overhead fixtures receive less light (Heins and Runkle, 2004). Because plastic reduces light more than clear glass, maximum light levels will be even lower in a double polyethylene-covered greenhouse. Shading by a factor of 50% is common in double-polyethylene greenhouses without additional shade during winter months because of the low incident angle of the sun. Use of whitewash, saran, aluminized, or other shade cloth provide further shading.

The amount of shading that occurs in a grower location can easily be measured using a hand held light meter. Over at least 3 days that have either cloudy or sunny conditions, measure the light level outdoors in the morning, midday, and afternoon (whatever units used by the meter are fine). Immediately after each outdoor measurement, also measure light level inside the greenhouse with the shade open and shade closed so there are triplets of data (full sun, greenhouse without the shadecloth closed, and greenhouse with shadecloth closed). Enter into the worksheet in Table 2, and average each column. Repeat in both the winter, and in the summer.

Table 1. Estimated daily light integral of photosynthetically active radiation in $mol \cdot m^{-2} \cdot d^{-1}$ in full sun (with no shade). The data were converted from mean daily global radiation ($MJ/m^2$) climate data from the National Institute of Water and Atmospheric Research (NIWA) for the 1981-2010 period for weather station locations having at least 5 complete years of data (Source: <https://www.niwa. co.nz/education-and-training/schools/resources/climate/radiation>). The conversion factor was 2.08 $mol \cdot m^{-2} \cdot d^{-1}$ for each $MJ/m^2$ based on Both (2002).

| Location | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kaitaia | 45 | 40 | 34 | 24 | 18 | 15 | 16 | 21 | 28 | 35 | 41 | 46 | 30 |
| Whangarei | 44 | 38 | 32 | 23 | 17 | 15 | 15 | 21 | 28 | 35 | 41 | 42 | 29 |
| Auckland | 47 | 41 | 33 | 24 | 17 | 14 | 15 | 21 | 28 | 36 | 43 | 46 | 30 |
| Tauranga | 49 | 42 | 34 | 24 | 17 | 14 | 15 | 21 | 28 | 37 | 43 | 46 | 31 |
| Hamilton | 46 | 40 | 33 | 24 | 16 | 13 | 14 | 20 | 27 | 35 | 42 | 45 | 30 |
| Rotorua | 47 | 40 | 33 | 24 | 17 | 13 | 15 | 19 | 27 | 35 | 42 | 45 | 30 |
| Gisborne | 49 | 40 | 32 | 23 | 16 | 13 | 14 | 20 | 29 | 39 | 45 | 48 | 31 |
| New Plymouth | 50 | 44 | 35 | 24 | 16 | 13 | 15 | 20 | 27 | 36 | 45 | 46 | 31 |
| Napier | 48 | 40 | 33 | 23 | 16 | 13 | 14 | 21 | 29 | 39 | 45 | 47 | 31 |
| Wanganui | 49 | 42 | 33 | 23 | 15 | 12 | 14 | 19 | 27 | 35 | 44 | 47 | 30 |
| Palmerston North | 46 | 41 | 32 | 22 | 14 | 11 | 13 | 18 | 25 | 32 | 41 | 44 | 28 |
| Masterton | 46 | 39 | 31 | 21 | 15 | 11 | 12 | 18 | 27 | 35 | 44 | 46 | 29 |
| Wellington | 48 | 42 | 32 | 21 | 13 | 10 | 12 | 18 | 26 | 35 | 42 | 46 | 29 |
| Nelson | 49 | 43 | 33 | 24 | 16 | 12 | 13 | 19 | 28 | 35 | 43 | 47 | 30 |
| Blenheim | 49 | 42 | 35 | 24 | 16 | 12 | 14 | 20 | 29 | 39 | 46 | 48 | 31 |
| Westport | 45 | 40 | 31 | 20 | 13 | 10 | 12 | 17 | 24 | 32 | 42 | 42 | 27 |
| Kaikoura | 45 | 38 | 31 | 21 | 14 | 11 | 12 | 18 | 27 | 36 | 45 | 46 | 29 |
| Hokitika | 44 | 38 | 30 | 20 | 13 | 10 | 12 | 17 | 24 | 32 | 40 | 42 | 27 |
| Christchurch | 45 | 38 | 29 | 20 | 13 | 10 | 11 | 16 | 25 | 35 | 43 | 45 | 27 |
| Mt Cook | 46 | 41 | 31 | 21 | 12 | 9 | 11 | 16 | 23 | 35 | 45 | 44 | 28 |
| Lake Tekapo | 50 | 43 | 33 | 22 | 14 | 11 | 13 | 18 | 28 | 39 | 49 | 49 | 31 |
| Timaru | 42 | 35 | 29 | 20 | 13 | 11 | 12 | 17 | 26 | 34 | 41 | 43 | 27 |
| Queenstown | 49 | 43 | 32 | 21 | 13 | 10 | 12 | 18 | 27 | 38 | 46 | 50 | 30 |
| Clyde | 47 | 42 | 32 | 20 | 12 | 9 | 10 | 17 | 27 | 37 | 46 | 49 | 29 |
| Manapouri | 45 | 39 | 28 | 18 | 11 | 8 | 9 | 15 | 23 | 34 | 43 | 46 | 27 |
| Dunedin | 40 | 35 | 26 | 17 | 10 | 8 | 9 | 14 | 22 | 32 | 38 | 40 | 24 |
| Invercargill | 41 | 36 | 26 | 16 | 9 | 7 | 9 | 14 | 23 | 32 | 41 | 44 | 25 |
| Chatham Islands | 42 | 36 | 27 | 18 | 11 | 8 | 10 | 15 | 23 | 31 | 40 | 43 | 25 |
| Antarctica, Scott Base | 52 | 28 | 9 | 1 | 0 | 0 | 0 | 0 | 5 | 22 | 48 | 60 | 19 |
| Average[1] | 46 | 40 | 32 | 22 | 14 | 11 | 13 | 18 | 26 | 35 | 43 | 46 | 29 |

[1]Average includes all weather stations other than Chatham Islands and Antarctica.

Table 2. Work sheet to calculate the shade level in a greenhouse location with and without the shadecloth closed.

| (A) Light level outdoors | (B) Light level inside, without shadecloth closed | (C) Light level inside, with shadecloth closed | % shading without shadecloth closed | % shading with shadecloth closed |
|---|---|---|---|---|
| (A) | (B) | (C) | (1 – B/A)*100 | (1 – C/A)*100 |
| Example: 10 klux | Example: 6 klux | Example: 3 klux | (1-6/10)*100 =40% | (1-3/10)*100 =70% |
| 1. | | | | |
| 2. | | | | |
| 3. | | | | |
| 4. | | | | |
| 5. | | | | |
| 6. | | | | |
| 7. | | | | |
| 8. | | | | |
| 9. | | | | |
| Ave. (1 to 9): | Ave. (1 to 9): | Ave. (1 to 9): | Ave. (1 to 9): | Ave. (1 to 9): |

By comparing the light levels in Table 1 against recommended levels in Table 3 and other resources such as Faust (2011), it is possible to consider appropriate shading strategies and appropriate shade levels. The average light level in the darkest months (June, July) of 13-14 $mol \cdot m^{-2} \cdot d^{-1}$ was approximately ¼ the light level during the sunniest months (December and January) at 46 $mol \cdot m^{-2} \cdot d^{-1}$. This light range emphasizes the need to reduce shading during winter months. There was greater variation in light level between locations during winter months than in summer. During winter, the average light level in Invercargill (southern South Island, 7 $mol \cdot m^{-2} \cdot d^{-1}$) was approximately half the light level in Kaitaia (northern North Island, 15 $mol \cdot m^{-2} \cdot d^{-1}$), emphasizing the need to customize winter shade level in different locations.

Table 3. Guidelines for optimum daily light integral levels for floriculture production. For more information on finished plants, refer to Faust (2011).

| Production phase | Daily light integral range ($mol \cdot m^{-2} \cdot d^{-1}$) |
|---|---|
| Propagation (unrooted and under mist) | 4 to 8 |
| Propagation (rooted to hardening off) | 8 to 14 |
| Finishing of most flowering crops | At least 10 |
| Finishing of orchids, ferns, tropical foliage | 6 to 10 |

Most South Island and southern North Island locations had less than 12 $mol \cdot m^{-2} \cdot d^{-1}$ of full sunlight during the darkest months, indicating minimal need for additional shading during winter. September to April had high light levels and greatest need for shading during propagation, with the shoulder months of May and August being intermediate.

In winter (June), Figure 1 shows that greenhouses applying 75% shade (including both the covering material, greenhouse structure, and shade cloth) would result in light levels 2 to 4 $mol \cdot m^{-2} \cdot d^{-1}$, which is below the recommended DLI even for low light crops or the mist propagation phase (from Table 3). No more than 50% total shade should be applied during winter, which in many greenhouses with double-polyethylene or fiberglass covering would not require shade cloth. Cuttings could be hardened off during winter

with no shade at all. In contrast, during the summer at least 75% shade cloth is likely to be needed during the mist phase.

As a demonstration, we placed a WatchDog 2475 data logger in an orchid production greenhouse in south Auckland during April 2014. *Phalaenopsis* orchid is a low-light crop (Faust, 2011), and a target threshold was set at 3 to 6 mol·m$^{-2}$·d$^{-1}$ during propagation. Measured light level averaged 1.5 mol·m$^{-2}$·d$^{-1}$, and ranged from 0.8 to 2.8 mol·m$^{-2}$·d$^{-1}$ during the cloudiest and sunniest days, respectively, with around 90% shading of ambient sunlight. Based on these measurements, the grower reduced the shade level during May by removing one layer of fixed shade, in order to increase growth rate.

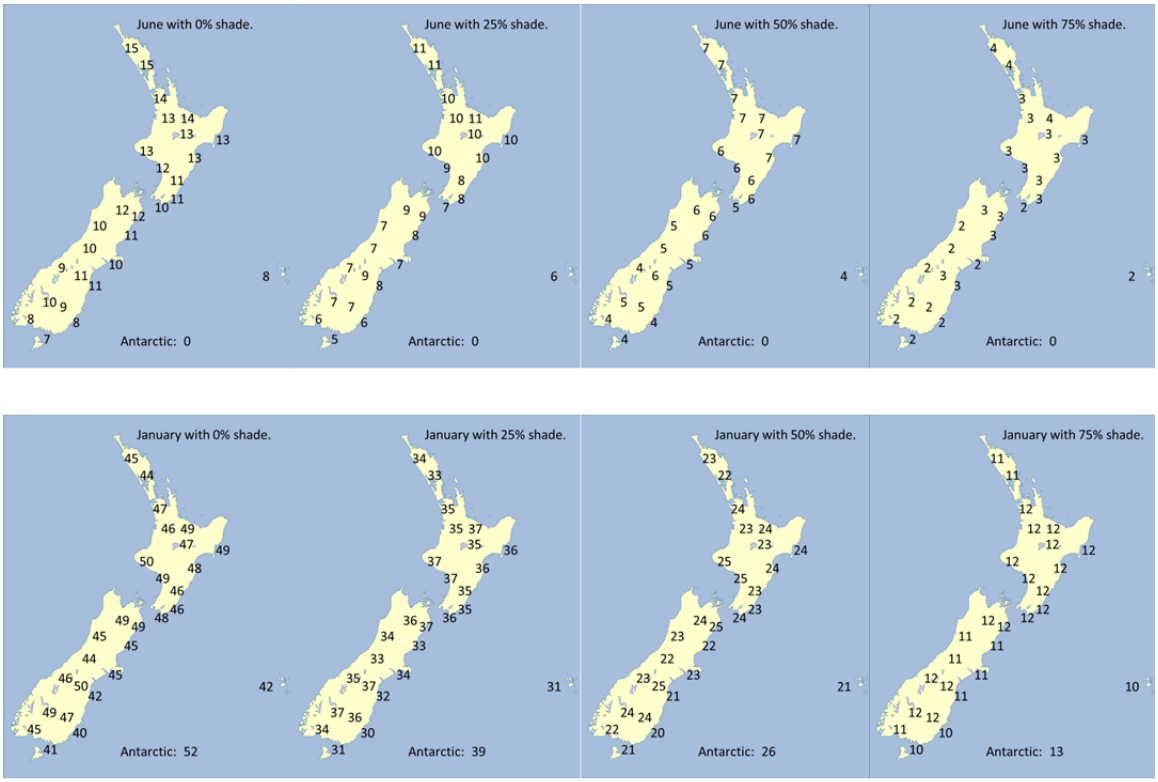


Fig. 1. Estimated daily light integrals (mol·m$^{-2}$·d$^{-1}$) with four levels of shading (0, 25, 50, and 75%) during minimum (June) and maximum (January) sunlight months in New Zealand. Data were calculated by multiplying the full sun DLI in Table 1 times (1 – shade level). For example, in Kaitaia during June the full sun DLI was 15 mol·m$^{-2}$·d$^{-1}$. With 75% shade, this would be reduced to 15 * (1-0.75) = approximately 4 mol·m$^{-2}$·d$^{-1}$.

## CONCLUSION

The climate data in both Table 3 and represented as light maps in Figure 1 provide useful information to help guide shading strategies. Although heavy shade is needed in New Zealand during summer months for propagation, it is easy to over-shade during the winter. During the darkest months, shade cloth should in many cases be completely removed, particularly when hardening off cuttings and finishing many floricultural crops.

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# Light-Emitting Diode (LED) Lighting in Plant Propagation©

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## INTRODUCTION

In 2013 at the IPPS Australian Region Conference Karen Brock presented a paper on the use of light-emitting diode (LED) lighting in her propagation facility. There was not much detail on the potential benefits for a propagation nursery so a commercial trial was set up with the following aims:

- To identify the difference in strike rate (the number of plants to successfully set roots) between an LED lit and an unlit bench. Making it easy to quantify the cost benefit such a system will provide by improving strike rates.
- To identify the length of time for root initiation in days between the LED lit and the unlit trays. This will outline the potential turnover and efficiency gains the LED lights will give the propagation house.
- To ultimately measure the cost benefits of installing lights to improve productivity of a green house compared with building more production space.

## BACKGROUND

We were contacted by Powerplants Australia, who was bringing out a European representative of Phillips lighting as part of their initiative to introduce LED lighting in to the Australasian horticultural market. We had a meeting with Philips and Powerplants and had a close look in to the technology that European, American, and Asian growers were adopting. I was able to recall the similar presentation at the 2013 Melbourne IPPS Conference by Karren Brock on the set up of LED lighting in her propagation house. Although Karen's trial was extremely interesting it hadn't quantified the potential benefits for a propagator or nursery should they adopt the technology.

I contacted Powerplants and Philips and asked if they would both be interested in supplying enough material to set up LED "grow light" technology over one of our propagation benches, which is capable of holding 16,000 cuttings per week. I proposed this to both companies with the understanding I would conduct a full scale propagation trial, record the results and present the paper as an entry for the Rod Tallis Award for the 2014 IPPS Combined Australia and New Zealand Conference.

## METHOD

- The trial commenced on 14 Jan 2014.
- Propagation for the trial was 2 trays per taxon with the same number of cuttings per tray.
- There was a range of plants each week to give a good cross section, including trees shrubs, grasses, perennials, and succulents.
- Each trial tray was produced on the same day, by the same propagator, from the same mother stock, using the same hormone but placed on separate benches. Both benches were in the same location of the green house and experienced the same watering, misting, fertilisation, and growing environments.
- The only variable within the trial was one bench being lit by red and blue LED lights as designed and installed by Phillips. These plants placed under LED lights experienced 16 h of LED light per day. The control plants on the unlit bench received normal day light regulated by the automatic shade screens, as required by the propagation house between January and April.
- Daily recordings of the greenhouse conditions were made using the greenhouse management software program. Included in these conditions were inside and outside light levels. A light photometer was used at the same time every day to measure the available light to all plants, both the LED bench and the unlit control bench. In addition,

each day the following measurements were recorded; actual sunlight hours each day outside of the greenhouse (to gain an understanding of the difference between inside and outside light differentials), the atmospheric temperature, media temperature, and humidity levels inside the green house.

**RESULTS**

Lighting the initial stage of propagation increased strike rate across the range by 7%. Put in to context a 7% rise in strike rate over the 1,900,000 cutting grown plants produced annually would result in an extra 136,500 plants through the nursery. On one of the major lines in blueberries there was a 12% increase in strike rate. A raise in the strike rate of the blueberries by 12% a year would result in $26,000 extra per year for the business (Table 1).

Table 1. Species propagated with strike rate and duration.

| Plant name | Week propped | Strike rate (%) | | Weeks in propagation house | | |
|---|---|---|---|---|---|---|
| | | Lit | Unlit | Weeks in propagation | Mansfield average | Weeks faster |
| *Agonis flexuosa* 'Nana' | 4 | 38 | 47 | 13 | 12 | -1 |
| *Banksia spinulosa* × *B. ericifolia* 'Giant Candles' | 7 | 99 | 97 | 5 | 15 | 10 |
| Blueberries (*Vaccinium*) | 6 | 83 | 37 | 11 | 21 | 10 |
| *Vaccinium corymbosum* 'Sunshine Blue' | 7 | 62 | 46 | 8 | 21 | 13 |
| *Callistemon citrinus* 'Endeavour' | 7 | 46 | 42 | 8 | 14 | 6 |
| *Cupressus macrocarpa* 'Wilma' | 6 | 54 | 49 | 8 | 15 | 7 |
| *Grevillea* 'Poorinda Royal Mantle' | 4 | 70 | 53 | 7 | 14 | 7 |
| *Pandorea jasminoides* | 7 | 93 | 89 | 4 | 6 | 2 |
| *Philotheca myoporoides* | 5 | 57 | 38 | 9 | 9 | 0 |
| *Photinia* × *fraseri* 'Robusta' | 5 | 46 | 36 | 13 | 30 | 17 |
| *Scabiosa columbaria* 'Mauve Delight' | 5 | 84 | 100 | 9 | 7 | -2 |
| *Westringia fruticosa* | 5 | 84 | 84 | 6 | 7 | 1 |
| *Westringia fruticosa* 'WES06', Low Horizon™ coastal rosemary PPAF | 3 | 65 | 70 | 6 | 7 | 1 |
| | | 68% | 61% | 8 weeks | 14 weeks | 5 weeks |
| | | 7% better | | | | improvement |

By lighting the propagation house crops were ready for tubing 2 weeks earlier on average. If that was across the board the total amount of cutting grown plants to move through that house would go from 2.7 million to 3.2 million without expanding. It is expected that by also lighting the second stage, crops would be ready 4 weeks earlier than with unlit propagation.

**CONCLUSION**

The trial has proven that LED lighting for propagation works! It's a matter of the fit out cost compared with the gains that that will benefit from the application. The LED lights have grown healthier, stronger plants in a shorter space of time.

So if you are at capacity in your house and need to expand, the lights are a great way to go. If you're looking to increase strike rate the lights are worth investigating further.

I would like to thank the companies who have allowed me to complete this extensive trial: Powerplants, Phillips, Mansfield's Propagation Nursery, and Tissue Culture Australia.

# Staying Competitive (and in Business) as a Small Nursery©

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## INTRODUCTION

Nursery owners can be considered as being on a spectrum from "factory owners" producing large numbers of perfect plants of a low range of taxa to "plant lovers" who love growing plants for others to enjoy. The former have capital intensive operations with the prime consideration being profit per plant. This is good business but does not require a particular affinity for plants, although that is not necessarily absent.

The plant lovers grow plants primarily because they have a passion for them and want to see them grown and enjoyed by others. They are often running small nurseries and compared to the past very few of them are left. Obviously to stay in business and to continue growing and distributing the plants they love they must make a profit.

I consider myself to be more of a plant lover having grown up in Western Australia (WA), one of the world's great biodiversity hotspots, with a huge range of species, many of which occur nowhere else and are also quite spectacular in flower.

## STAYING IN BUSINESS

There are only a few people who are still growing these great Western Australia (WA) plants; so many have ceased for a number of reasons.

These include:

- Increasing Value of Land. It's no longer worth growing plants compared to profits to be gained from selling the land.
- Costs of Inputs. Western Australia has endured a "boom" in mining activity and to get anything done requires work from people who have had prices inflated by mining companies' activities and effects.
- Decreasing Suburban Block Sizes and Bigger Houses on Those Blocks. Not the room to plant plants anymore.
- Changing Culture. Whereas gardening used to be considered an enjoyable hobby in the past, the current generation generally seem to consider it a tiresome chore. People are too impatient to do work now and wait for things to grow before they can get the benefits.
- Rise of Box Stores. Many interesting small retail nurseries have been squeezed out by homogenous box chains all selling the same stuff to an uncaring public.
- Factory Wholesalers. They're good businessmen and plant growers - just boring, with a limited range of plants at a low price.
- Difficulty of Obtaining and Retaining Skilled Labour. Mining boom again.
- Discounting. Too much stock is dumped and drags prices down for everyone else.

## SOME THE THINGS WE ARE DOING

So then, wanting to continue to produce interesting plants but needing to turn a profit in a tight market what are the things we are doing, and wanting to do in the future, to keep ourselves competitive.

The first thing we see as a competitive advantage is our use of a range of propagation facilities.

An old brick sided tunnel, unheated and a bit drier with respect to fogging, produces great results with WA natives especially some of the trickier grevilleas (Fig. 1).

A second poly tunnel has little ventilation and gets too hot for most purposes but produces excellent results with tropical grevilleas and some South African leucospermums (Fig. 2).

Fig. 1. This is the old, low tech prop shed.

Fig. 2. This is the hot tunnel, good for another range of plants especially tropical grevilleas.

A third facility has most of the modern applications, including automatic venting, extraction fans, and aluminiumised shade screens above the plants (Fig. 3). These screens can be set to open and close automatically but in practise are left shut in summer and open in winter. In this tunnel we have Netafim misters on the plants and a fogging system in the upper space to help cool the structure in hot weather, which is a large part of the year

in WA. With a gas-fired hot-water system providing bottom heat another whole range of plants can also be successfully grown in this tunnel.

The second thing we see as an advantage is the use of a range of approaches with seed germination.

Fig. 3. “Bells and whistles” facility good for most cutting grown plants.

Many WA natives have dormancies that need to be overcome and a range of methods must be employed. We are constantly experimenting to discover ways of improving germination or maybe even any germination.

Methods include:

- Direct Heat. Using direct heat in an oven at 120° for half an hour or more.
- Smoke Treatments. Treatment with smoke water and/or direct application of smoke. The discovery of the effect of smoke on many WA natives, especially monocots, has probably been the single biggest breakthrough in germination.
- Using Refrigeration. Many WA natives are designed to only germinate in winter when follow up rain is likely and temperatures are cooler. These natives respond to a period of chilling prior to sowing. Banksias are very particular about this.
- Physical Scarification. In the past many genera were treated with hot water to crack hard seed coats. We have greatly improved germination with physical means instead of the heat.
- Weathering. Leave the seed trays for long periods – sometimes two years or more.

There are other small things we do that we believe help keep us in the business. These include:

- Using a small diesel burner to generate steam to sterilise all containers before they are reused. We save a lot of money reusing pots. We also believe in recycling the pots to keep them out of landfill which is where so many end up.
- Growing nearly all of our cuttings in a 100 cell tray and instead of dibbling holes individually we have made a board of MDF (medium density fibreboard) with 100 large screws in the right pattern to place on the tray and make all the holes at once (Fig. 4).
- We have a program and printer from Tytag Australia to print many of our own labels. This was just for emergencies and short runs however with a recent corporate takeover in the Australian label printing industry one of the two main companies has become almost unusable. We are now making more of own than ever. Although the cost is

similar to commercial labels and the quality is not quite as good, they are far better than nothing and a great aid to our business.

- We do most of our own welding. I did a 5 week night-school course and learned enough that we are able to make our own trolleys, benches (Fig. 5), and many repairs. All plants are grown on benches to make them easier to work on and to keep them above splash zones for better hygiene. The construction method we have evolved over the years gives us a sturdy bench at a reasonable cost and is good for our business.
- Something else we do but which can be a two edged sword is that we grow a number of species that are difficult to propagate and have low survival percentages. We are obviously always trying to improve these percentages. Several of these plants are only grown by us. While it is unlikely we make any money out of these they give us something special to sell to our best customers and they give us a certain credibility as the only place you can get some of these desirable, hard-to-get plants. We look at them the way a supermarket looks at a "lost leader."

In this vein we have spent several years finding out how to grow grafted *Corymbia ficifolia* plants. *Corymbia ficifolia* is a WA native, endemic to a few hundred acres near the south coast but now widely grown in temperate climates around the world. It has a range of flower colours which cannot be predicted when grown from seed. They can also take 10 years or more to flower from seed. Red is generally the most desirable colour and people will pay a good premium to know they are getting a red-flowering tree. Grafting has become the best way of producing plants with a known flower colour.

Fig. 4. Dibble 100 holes at a time.

Fig. 5. Make your own benches.

Several years ago when the myrtle rust was discovered in eastern Australia imports of all myrtaceous material was prohibited into Western Australia. Many grafted gums were being produced in eastern Australia, imported to WA and used widely but the supply was stopped overnight. Having worked out how to do them in good numbers we are now profiting from our research in this area.

Finally a big tip and advantage that we have is that we are active members of IPPS. This is a marvellous organisation, full of friendly helpful people who have been extremely generous with advice and information that has given us a head start in many ways. The more you put into it the more you get out of it!

# Profit, Not Turnover©

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## INTRODUCTION

My wife Claire and I have a small nursery. It is not big and grand, more like small and pokey. But it is profitable relative to its size. A big turnover is not important to me — what matters is a profit, because no business big or small will last long without a profit. Our nursery is located on State Highway 3 in central Te Awamutu in the South Waikato (Fig. 1). The property is less than 2 acres; about a quarter acre out the back is waste land, so the nursery only uses about 1½ acres.

A few years ago we sold wholesale and retail but now it is almost only retail. Our retail customers come from all over the Waikato and beyond, but primarily from south of us, including from as far away as Taupo, the Ruapehu area, and New Plymouth. We do not advertise. All we do is arrive at work, open the gate, and make it up as we go along.

Fig. 1. View from the south-west boundary.

Prior to the global financial crisis (GFC), our annual profit almost reached $200,000 per year. When the GFC happened profit dipped a bit but lately things have normalized. In recent weeks sales have been record breaking. This is probably much the same for everyone here.

So what is it that makes us — or any of us profitable? There are of course many reasons. One of those reasons is management, and in our case, our management approach, and business model, is based on economics.

## THE BUS TICKET DILEMMA

A bus owner is barely surviving. Should the bus owner put the price of tickets up, which risks losing market share and a decline in revenue? Or should the bus owner put the price of tickets down and hopefully attract more fare paying passengers, but also risks a decline in revenue?

The inherent question with the "Bus Ticket Dilemma" is what is best for profit: prices going up or prices going down? Everyone will have an opinion on this. My answer though involves some simple economics. Products with a high price elasticity of demand tend to increase in profit as their prices decrease, but only if costs are constrained. Nursery plants have high price elasticity of demand which is a measure of responsiveness

to changes in price. Profit increases as prices decrease, but only if costs are constrained. I think everyone in our industry should memorise this statement.

The demand for a product like plants rises or falls for many reasons. However, there can be no doubt there is one factor that influences spending like no other factor and that is the price of the product.

Some here may already be familiar with this graph, possibly the most basic and well known diagram in the entire field of economics. So what does this diagram tell us about the nature of demand of nursery plants?

The curve (which is really a straight line) slopes downhill and shows an inverse relationship between price and quantity demanded by the market (Fig. 2). At low prices (P1) there is a relatively high demand (Q2). As prices rise (P1 → P2), market behavior changes — in effect moves back up along the curve, so that less product is wanted or demanded (Q2 → Q1). We are of course, all familiar with this phenomenon already, if only intuitively though some here may not have seen it presented this way before.

Similarly as prices decline there is movement the other way on the curve and demand increases.

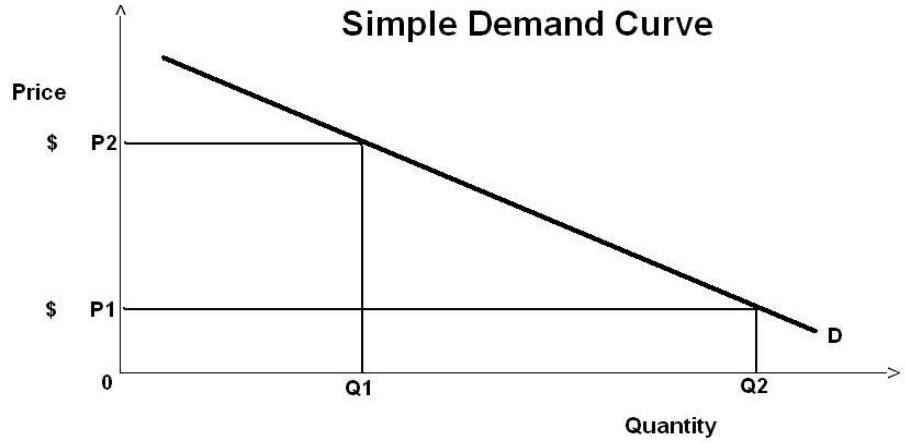


Fig. 2. Demand curve showing relationship between price and quantity.

What this diagram does not show so clearly, is this phenomenon applies to all levels of degree. At the micro level it applies to a single product line and it applies to all the aggregate products of a single business like a nursery or garden centre.

At the macro level, it applies to all the aggregate products of an entire industry. So if all nurseries in the entire industry were to move their prices up — why would anyone expect total demand to increase or even stay the same? The effect of raising all prices is to lower total aggregate demand. This must over time shrink the size of our industry.

Those that advocate higher prices do so for their own reasons, but the aggregate effect of higher prices is to lower total demand. I am not an advocate of higher prices. My blunt reality is: the needs of my business can only be met by giving my customers what they want at the price they are willing to pay for it.

If there is low demand for any specific product, then there is low demand only at a specific price. In my experience if price is reduced, then demand tends to escalate rapidly. I believe the issue of price is an issue (but not the only issue) facing our industry. It is an internal issue.

I also think it is a major mistake to compare prices today with what prices were in 1980. Yet some do. Surely though, what happened in 1980 is largely irrelevant today.

You see we are not competing with each other. The fact is, as a retailer, my biggest competitor is China. Because this country is being flooded with cheap products of everything and anything from China and elsewhere and it makes locally manufactured plants look expensive. It is a matter of relativity and perception.

My bottom line is: if I escalate my retail prices my customers will shop elsewhere and switch to alternative products which provide for equal satisfaction and allow the dollar to go further.

## RETAILER RISK FACTORS IN BUYING WHOLESALE PLANTS

I wish to mention about retailer risk factors in buying wholesale plants because in my experience, buying wholesale plants is a problem.

When a retailer buys wholesale plants the profit or loss is not determined by the retail price or retail margin. The profit or loss is actually determined by the amount that ends up in the waste bin. All the profit and more can easily end up in the waste bin.

The reason is simple because as prices rise, the demand falls. Yet plants in containers have a limited shelf life. They are a perishable product. This makes buying wholesale plants very high risk and getting riskier.

This problem is not unique to me. Neither is it a new problem as it has been risky for years. And over the years retailers have developed several strategies or techniques to try and manage the risk. I have identified five techniques and to some extent these techniques are already known by most garden retailers.

## GARDEN CENTRE RETAILER RISK MITIGATION TECHNIQUES

1) Reduction Technique: Carry less stock — smaller bitsy wholesale purchases — maybe make no purchases.
2) Substitution Technique: Replace nursery stock with other lines such as giftware or pet supplies, or a cafeteria.
3) Price Humping Technique: Put retail prices up and be damned even if prices hit the stratosphere. The idea is an increased margin covers any stock losses.
   a) Then the grower sees the high prices and thinks wow, if it is worth that as a retail price then to keep parity I need to hump up my wholesale price which of course increases the risk to the retailer who further increases the retail price. This leads to a higher wholesale price which raises the retail price etc. This process is insane. But it happens.
   b) Does anyone stop to think raising prices can lower sales further thereby increasing losses? This option over time becomes a downward death spiral. High retail prices where they exist are a symptom of a problem not the problem itself. The underlying problem, the real problem is the perishable nature of plants and the risk of investing in wholesale plants by the retailer. The real problem is one of time decay of plants.
4) Discount Technique: With the discount technique the retailer has taken control of supplier nurseries and exercises that control by insisting on a discount at the wholesale price level. This lowers the risk to the retailer, and provides a competitive advantage by encouraging lower retail prices thereby under cutting the competition. This in turn both accelerates and increases throughput, and hopefully lowers any losses. However a couple of awkward questions:
   a) If it is feasible for growers to sell to one or a few retailers at a lower price, then why not sell to all at the lower price and expand the overall market?
   b) And second, why do growers play favorites and encourage a single retailer to cause damage to other retailers when the other retailers being adversely affected are also grower's wholesale customers?
5) Transfer the Risk Technique: This is the interesting one. Why not transfer the risk back to the wholesaler or grower. The transfer of risk option includes sale or return which has several variants. Why not have the growers carry all or some of the risk? Of course I have no clout to make this happen but others do.

## ECONOMIC MODELLING

Those five techniques previously listed are actually examples of small economic models used to try and solve a difficult problem — the problem being how to reduce unacceptable risk to the retailer. It is no coincidence that every one of those models has at

some point been created by retailers and imposed on growers — whether growers like it or not.

There are multiple techniques or multiple economic models that can be designed and used to solve a single problem and there may be other models available that have not yet been tested or even designed.

Economic modeling is a powerful tool, but as the list showed, its use tends to be haphazard and informal. But if its use is taken to its full potential then for many management problems that may arise, system design may be the way to go. I think it is not enough to just keep increasing wholesale prices and to expect retailers and retail customers to accept it.

**Economic Modelling-System Design**

I think it is not enough to just keep humping up wholesale prices and to expect retailers and retail customers to accept it. A really smart grower would recognize a problem exists and would actually stop (and think) and attempt to design a solution to everyone's advantage. But will it ever actually happen? Will growers ever go beyond the traditional economic model of maximum extraction of revenue from retailers? Is it no surprise independent retailers are steadily disappearing? Is the traditional economic model the industry uses slowly destroying grower's access to the retail market? And what happens when the era of the box stores has passed?

It is not enough for growers to argue that if they do not get enough for their stock then retailers may lose their lines of supply. Such argument tells only half the story.

Consider if retailers do not get enough return to justify the risk when investing in the supply — then growers may lose their lines of access to the market.

But it gets even more complicated. Because both grower and retailer in this inter-dependent relationship are totally reliant on a willing end use customer, not occasionally as an act of freakishly good luck, but every minute of every day, all the time, year after year.

Instead though, what do we actually get? The end use retail customer tends to be forgotten about unless it is for the maximum extraction of revenue. And growers and retailers face off with mutual suspicion, each considering their respective position, while assessing how to manage the other.

I am not averse to buying in wholesale plants but I have a big question mark about how to manage the risk. As things exist it is difficult to near impossible to make a profit from the investment. In fact it can often be difficult to simply do a cost recovery that is get no more than your money back.

And if my predicament applies to most retailers everywhere — which to some extent I think it does — including the box stores — then growers should expect them to react. And it will not be pretty.

As a retailer of plants, I should, in theory at least, be able to buy in all my stock as wholesale purchases and make a reasonable return from the investment. The harsh reality though is I am not given rebates, discounts, or other benefits afforded to others, the playing field is not even, and if I were to buy in all my stock, retail prices would be such that over 90% of my customers would leave — without buying anything.

Of those that did buy something their purchases would be very small — in other words selling less product to less customers — our reputation would die very quick — our market would collapse — frustrated or latent demand would increase — and the general public would spend their recreational dollar elsewhere — probably not even on plants. This cause and effect is well documented in economics, referred to as the substitution effect or the Slutsky effect.

Back then to my little nursery in Te Awamutu. Having a second look at this image some things may not be that obvious (Fig. 3).

Fig. 3. View of nursery from State Highway 3.

First, this property is both our retail site and our production nursery at the same time. It is basic and has no frills, but it does those two jobs. There are no big shade houses, no crop covers, no big flashy propagation facilities, and our only building is the granny cottage at one end. In effect we have the ability to manufacture a reasonable quality product on site using next to nothing. By not having complex facilities there is no capital cost involved, no maintenance cost, and no running or operational cost that go hand in hand with complex facilities.

Another point of interest is just about the entire nursery site is palletized (Figs. 4 and 5). Nearly all stock is processed onto and stored on pallets which can be moved using a forklift on a tractor. The result is huge labour saving. All double handling of stock is avoided as much as possible.

Fig. 4. Nursery site is palletised and easy to move.

Fig. 5. Palletised plants.

For PB 5's (planter bags of about 2.8 L) the cost of using pallets is less than 3¢ per plant over the life of the pallet. Our pallets enhance productivity significantly. So much so that over the years, we can go for months even years without needing a single employee. Claire and I alone can produce 60,000 or more plants per year although it can get a bit tedious doing it all ourselves.

**LOW COST PROPAGATION**

The last "innovation" I wish to discuss is our propagation setup, which has to be the ultimate in tacky systems.

In 1982 I worked as a technician in another nursery which had big propagation facilities using crop covers, misting systems, and hot beds. The facilities were expensive to build, expensive to maintain, expensive to run, and took up a lot of space. The electricity cost for the hot beds alone was $1300 per month and that was back in 1982!

Right from the beginning I decided I did not want that sort of propagation setup. Again I wanted to keep it simple, keep it low cost, but still be highly effective. So years and years ago we built these (Fig. 6)!

Fig. 6. Low-cost propagation houses at Payless Plants.

Simple cold frames — no misting required — and no hot beds. These frames you see here cost us $200 each and that was over 20 years ago. Over the life span of our propagation setup, the maintenance and running cost is no more than $100 per year! These cold frames are very simple. Each covers 10 $m^2$, and is 1 m high at the apex. They are designed to hold 54 propagation trays in each frame (Fig. 7).

Fig. 7. Construction detail for low-cost propagation houses at Payless Plants.

Examples of propagation success rates examples are shown in Table 1. This list gives some idea of the effectiveness of our cold frames. They are very successful and in some ways better than high tech systems. But I would be first to admit that they are definitely not sexy. From this list, we find that some rhododendrons are near impossible to propagate but many cultivars are very easy. We used to also buy in *Olea* or olives as growing on lines and grow them on, but the supplier kept humping up the price so we started propagating our own.

Table 1. Examples of propagation success rates.

| Plant | Rooting (%) |
|---|---|
| Azalea (evergreen) | 99 |
| Azalea (deciduous) | 50 |
| *Camellia* | 99 |
| *Adenandra* | 60 |
| *Griselinia* | 99 |
| *Pittosporum* | 99 |
| *Rhododendron* | 0-99 |
| Conifer | 60-99 |
| *Olea* | 99 |

In summary our nursery is not lean, it is skeletal, and it is done on purpose — because it makes us profitable. Complexity creates costs. The profit comes from keeping it simple. We have our own economic model, where our costs are constrained, our prices are kept down, and our profit is kept up.

We can produce a 2.5-L thermo pot for an average cost of only $1.00, or if employees are used, the average cost jumps to $1.85. The marginal cost of this plant is 65¢.

So anything above our average cost is profit. We do not try to maximize profit per plant. We work to a defined profit and try to maximize profitability by maximizing production and numbers sold.

At normal garden centre prices a smaller grade of this product (Fig. 8) from another nursery retails for $22.00. But at $22.00 we would only retail five plants per year instead of 400. Five plants with a margin of $20.00 provides an annual profit of $100, whereas 400 of the same plants with a margin of only $5.00 gives an annual profit of $2,000, which is a 2,000% profit increase.

Fig. 8. A typical garden center *Adenandra uniflora* (China flower) plant in a 2.5-L thermo pot.

If you think back to the demand curve, prices have to be kept down in order to shift the volume. But if we can shift our volume while still making say a $4.00 or $5.00 profit per unit, then over 60,000 units the potential profit, even for a small 1.5 acre nursery, is about $250,000 per annum.

I would not expect profit to increase by making our product smaller. All we would be doing is lowering the value. Neither would I expect profit to increase by putting our prices up as all we will do is sell fewer products to fewer customers.

We define an acceptable margin per unit and arrange our affairs in such a way that we produce it for the lowest possible cost and sell it for the lowest possible price with the margin being built in as part of the cost per unit. And that is the way it works for us and it works well.

Success is not a secret — it is a system and I want it to be perpetual and sustainable, which means I have no interest in bleeding my customers dry or encouraging them to go elsewhere.

So by now, some here may want to throw something at me! But before you do, ask yourself if I am right or wrong? Is there a better way for us to operate? Maybe, but I have no idea what it is.

Size is not a guarantee of big profit. In many cases though, size will be a guarantee of big costs. Maybe the million dollar profits exist for some, but for others it is an illusion. My question then is where to from here — for us, for you and for our industry?

I'm not sure I have the answer to that. But I do know our pokey little nursery has provided us with no debt for many years, we have substantial accumulated funds, and equity of some millions. Others may not like it, but I know our business model works so if you know of an idea or opportunity that may exist out there, maybe we should have a beer together and explore options.

# Deep Planting: a Radical New Idea for Sustainable Gardening©

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## INTRODUCTION

If I were to advise you to dig a planting hole one metre deep and bury the stem of a new planting of a shrub or tree way below ground level, most horticulturists would be horrified. The conventional wisdom is that this would be a death sentence for the plant, dooming it to demise by collar rot of the submerged stem. A few years ago I would have agreed wholeheartedly, but a meeting with electrical engineer and amateur horticulturist Mr. Bill Hicks a few years ago has completely changed my thinking on establishing plants in areas where supplementary irrigation is difficult or non-existent.

## A RADICAL NEW IDEA

About 20 years ago Bill Hicks developed a technique called "long stem planting" through his interest in environmental restoration projects in the New South Wales Hunter Valley. Eroded river banks had traditionally been stabilised by planting exotic willow trees (*Salix* species) in the degraded areas. Alarmed at the way these willows had been seeding themselves and spreading like wild fire as environmental weeds, Bill experimented with indigenous native plants as a substitute. To overcome the problem of the native plants being washed away by floods, he experimented with planting them much deeper than normal. To the surprise of the professional horticulturists, not only did the trees survive, they thrived and in most cases the establishment rates and subsequent growth far outstripped that of conventionally planted trees of the same species. Bill's website <http://www.longstemtubestock.com/longstem-application.html> explains his technique very eloquently and is well worth viewing. His work inspired me to experiment and adapt the technique to other circumstances such as everyday garden situations. So a couple of years ago I began trials with as many plant species as I could lay my hands on. The results have been extremely encouraging and whilst there have been some failures; the majority of species have been very successful.

There appear to be a number of reasons why planting more deeply often achieves quite spectacular improvement in plant establishment and subsequent growth. The greater planting depth puts the root ball from the potted plant down into a deeper part of the soil profile that usually has a reservoir of moisture that does not dry out as readily as at the soil surface. The greater planting depth also insulates the roots from drying out if there is no rain or if irrigation is not possible. Over time the plant also forms a new root system along the buried stem that complements the original root ball. This extra root system gives the plant a much greater surface area to take up water and nutrients from the deeper part of the soil profile it is planted into. The extra root system would also replace any malformed or damaged roots that often result when plants are raised in pots.

## DEEP PLANTING APPLICATION

Deep planting is not for every situation but there are certainly several important applications where its use can offer significant advantages as follows.

### Erosion Control

Another great application for deep planting lies in stabilising embankments and other erosion prone areas. Great success has been achieved with deep planting of various Australian native shrubs such as wattle (*Acacia*), bottlebrush (*Callistemon*), and paperbark (*Melaleuca*) in such situations. An excellent example was documented in the use of *A. longifolia* in sand dune restoration works on the NSW Central Coast (Bakewell et al., 2009). Long stem plantings had a survival rate of 79% versus 53% for conventional planting.

**Protecting Plants from Vandalism and Wildlife**
Urban horticulturists sometimes have the unfortunate experience of planting expensive trees and shrubs, only to find them ripped from the ground by thieves and vandals. Deep planting provides a cure for such antisocial behaviour as it also does for animals such as rabbits and possums that often dig out or graze on new and established plantings. Deeper planting makes it much harder for them to wreak their havoc. Even if plants are taken back to ground level they will often still sprout from vegetative buds below the ground.

**Establishing Trees and Shrubs in Situations Where Irrigation Is Limited or Non-Existent**
I have had good success establishing a wide range of ornamental plants such as wattles (*Acacia* species), gum trees (*Eucalyptus* species), coastal rosemary (*Westringia fruticosa*), bottlebrush (*Callistemon* species), paperbark (*Melaleuca* species), as well as fruit plants such as pomegranate (*Punica*) and the native finger lime (*Citrus australasica*). This wide range of species is thriving without any supplementary watering whatsoever (although it is important to say that I live in a climate with reasonably regular rainfall). I used potted plants (generally 50 mm up to 140 mm diameter containers), and planted them such that approximately 75% of the above ground stems were buried after first removing the leaves from those parts of the stem that went underground. Before planting, I first dunked the whole pot into a bucket of water to make sure the root ball was fully saturated and then watered the plant in thoroughly. No further watering was given after that.

**Deep Planting Is not for Every Plant or Soil Type**
Whilst this very interesting idea has great potential for a range of planting situations, it is very important not to dismiss the conventional time-honoured planting technique, as I have found there are some species and certain circumstances where deep planting does not work. Species that do not root readily as cuttings are less likely to succeed than ones that do. Also, plants with a clumping habit such as kangaroo paws and irises do not have elongated stems that can be buried for obvious reasons. Also, in poorly drained soils that are subject to periodic waterlogging I have had failures as well as a lack of oxygen will drown the roots of many common garden plants. My suggestion is to first trial the technique with species of interest in your own soil and environmental conditions.

**SUMMARY**
In the right circumstances and for a wide variety of species deep planting may be applicable to your situation and my personal experience is that it a very useful tool to add to your kit of planting techniques. It can help to improve survival rates, save water and create stronger root systems to make your plantings more sustainable and dramatically reduce maintenance.

Production of long stem tubestock can provide an interesting specialist avenue for professional propagators, especially to supply environmental restoration projects.

**Literature Cited**
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# The New Zealand Plant Collections Register©

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This paper outlines the creation of a plant collections register and an associated cultivated plant names resource for New Zealand. This project was officially launched at the "Up the garden path" conference in Wellington on 3 March 2015.

## WHAT IS THE PLANT COLLECTIONS REGISTER PROJECT?

The project provides a free online system to manage and deliver information on living plant collections throughout New Zealand. It is available for use by botanic gardens, arboreta, garden groups, plant societies and private collection holders for entering and updating information on plant collections. These records are viewable and shared online with anyone interested in cultivated plants, both native and exotic.

In addition to managing living (and historic) plant records, the project has provided an extensive source of cultivated plant names – more than 40,000 – including botanical names (e.g., genera, species, subspecies, varieties and cultivars), synonyms and common names. These names are sourced from New Zealand nursery catalogues and other horticultural literature.

## WHY DO WE NEED THIS PROJECT?

The collections register aims to resolve several issues surrounding cultivated plants. First and foremost, there has been a major lack of knowledge and poor cataloguing of which cultivated plants are present in New Zealand. We still don't fully know: what is in this country, what it's called, or where it's growing.

In comparison to the extensive diversity of plants found only in cultivation, New Zealand's much smaller flora of native (endemic and indigenous) and naturalised (weedy) species are well known and documented comprehensively. A running total (<www.nzflora.info>; accessed May 2015) indicates that there are about 3046 native representatives compared with about 2618 fully naturalised vascular plant taxa.

Dr. Keith Hammett, ornamental plant breeder and current President of the Royal New Zealand Institute of Horticulture (RNZIH), summed up the cultivated plants problem by saying "Managing the country without knowing everything in the flora is like managing a supermarket without knowing everything on the shelf" (Hammett in Dawson, 2010).

Lack of knowledge and ineffective cataloguing of which cultivated plants are present in New Zealand severely hampers biosecurity management, both pre- and post-border, as well as impairing effective management of living collections and horticultural practices.

Pre-border problems arise for plant-breeders and growers trying to import plants under the Hazardous Substances and New Organisms (HSNO) Act (New Zealand Government, 1996). For importation, the MPI Plants Biosecurity Index (PBI; <www1.maf.govt.nz/cgi-bin/bioindex/bioindex.pl>) is the database used to determine if a species is already in New Zealand. However, the PBI is incomplete and lists about 29,000 species out of more than 40,000 exotic plant taxa thought to already occur in New Zealand. (The estimate of the number of exotic taxa in New Zealand will become more accurate, including a breakdown into the numbers of genera, species, subspecies, varieties and cultivars, when we combine several plant names datasets generated for this project. Accurate quantification of the numerous cultivars is likely to raise the total number of taxa estimated for New Zealand.) Furthermore, the PBI lacks author authorities for plant names and seldom lists synonyms or names below the rank of species (Dickson, 2009). These shortcomings mean that importers are faced with trying to prove that a species is already in the country or else pay for what may be an unnecessary and expensive full

assessment for release through the Environmental Protection Authority (about NZ$17,250 per application). As a consequence, the importation of new plant species and germplasm have effectively ceased, severely restricting New Zealand's abilities to produce new plant selections for its agricultural, horticultural and forestry industries. In 2002/2003, exports from these three land-based plant sectors earned the country $18.5 billion (MAF, 2003). The importation difficulties for plants have been highlighted by several interest groups and authors (e.g., Cave, 2004; Douglas, 2005; Johnson, 2006; Hammett, 2009).

Post-border problems arise because the greatest source of new weeds is not new biosecurity border incursions but plants that are already here "jumping the fence" and escaping from cultivation. Many of these horticultural escapes are through the careless disposal of garden waste, and a rise in the popularity of cottage and herb gardens and wildflower plantings (Heenan et al., 2002). This is a growing problem and every year several species become new weeds in New Zealand. Inadequate knowledge of these potential new naturalisations hampers effective weed management. In 2004/2005, the cost to New Zealand of dealing with weeds was estimated to be $100 million per year (Local Government and Environment Committee, 2006).

In addition to economic values associated with pre-border biosecurity and post-border weed management, there are significant aesthetic, conservation, cultural, educational, and social values of native and exotic plant collections. As stated by the late conservationist Dr. David Given et al. (2006): "Good quality nationally important collections of plants, whether native or exotic, need to be recognised as national treasures just as much as works of art and buildings." Despite the value of these collections, there has been a lack of up-to-date, well resolved and publicly accessible information covering genus-based collections, ethnobotanical and taonga (traditionally prized) species, rare plants and heritage cultivars (on the other hand, notable trees are accommodated to a large extent by the Notable Tree Register, managed by a trust of the RNZIH, the New Zealand Notable Trees Trust, <www.notabletrees.org.nz>).

For example, New Zealand is recognised as an important international repository for cool-temperate exotic biodiversity collections – species and genotypes that may be rare or endangered in their original countries (especially Asia, Europe, and North America). However, our knowledge of these exotic species and cultivars and where they are cultivated in New Zealand has been remarkably poor and there are few, if any, active conservation management strategies for them. Biodiversity management of living collections provides germplasm for plant breeding and propagation material for ensuring continuity of valuable selections.

We also need to take better stock of our long-term living collections. The total range of plants held in cultivation is much wider than stock being offered for sale from commercial plant nurseries in any given production year, especially given the current trend to market a narrow range of in-fashion plants. Sadly, several historic cultivars have already become lost to horticulture before their rarity in New Zealand became known.

Key issues that the New Zealand Plant Collections Register project aims to resolve are:

- Lack of knowledge and poor systems to catalogue the cultivated flora
- Lack of access to information
- Poor validation of plant names and identifications
- Declining or inaccessible expertise
- Lack of funding and resources to identify, describe, and catalogue cultivated plants.

## WORKSHOPS AND FUNDING

These aforementioned issues were clearly identified at a workshop held in Wellington (9 September 2009), entitled "The cultivated plant names problem: towards a multi-agency solution" (Dawson, 2010). A follow-up workshop was also held in Wellington (29 July 2010), entitled "Scoping the new Plant Collection Register" (Sole, 2010). Both workshops brought together a wide range of stakeholders to seek practical solutions. Groups represented included attendees with various roles (e.g., database developers, horticulturists, policy managers, private professionals and scientists), organisations (e.g.,

the Department of Conservation; Eastwoodhill Arboretum; the Environmental Protection Authority; Landcare Research; local government; the Ministry of Primary Industries; the Ministry of Business, Innovation and Employment; universities and polytechnics), key interest groups (e.g., Botanic Gardens Australia and New Zealand, the New Zealand Organisms Register, New Zealand Tree Crops Association, Plant Imports Action Group and the Royal New Zealand Institute of Horticulture) and several sectors (e.g., plant breeding, botanic gardens, research and the regulatory sector).

These workshops and proceedings documented the case for a funding application which was prepared by the author (MD) on behalf of the RNZIH. As a result, in November 2011 the Terrestrial and Freshwater Biodiversity Information System (TFBIS) programme provided a $175k grant for 3 years. The TFBIS Programme is funded by the Government to help achieve the goals of the New Zealand Biodiversity Strategy, and is administered by the Department of Conservation.

A co-funded project, to digitise Duncan & Davies nursery catalogues and make them available as online PDF's, is supported by the Sir Victor Davies Foundation and Peter Skellerup Plant Conservation Scholarship (2012, $10k), the George Mason Trust (2013, $5k) and a Lottery Environment and Heritage grant (2014, $28.5k). Duncan & Davies was New Zealand's largest nursery and founded in the late 1800s (Jellyman, 2011). This associated project is providing access to the historically significant series of catalogues (<www.rnzih.org.nz/pages/nurserycatalogues.html>) and is contributing a major source of cultivated plant names.

## A PIONEERING PLANT REGISTER

This project builds upon a pioneering register developed by the RNZIH from 1989 to 1993 (Hammett, 1993; Table 1). The plant collection group responsible at that time included Dr. Keith Hammett, Dr. Marion MacKay, Mike Oates and the late Winsome Shepherd.

The original register was based on questionnaires returned by collection holders throughout New Zealand. This was a well-founded initiative but limited in scope. It provided an index to collections and was a genus level survey with no cultivars or individual plants listed – although supplemental paper-based information was filed. Of course, living plant collections are always subject to change over time as old plants die and new ones are planted. Valuable collections are also lost when institutions lose interest or custodians become too old to maintain them. The 1993 register is now more than 20 years old and is consequently out-of-date.

This first register was ahead of its time now that internet technologies such as online databases and other tools have come of age. These new systems provide the best means of delivering and managing plant collection information.

## HOW HAVE WE CREATED THE NEW REGISTER?

We have followed several key concepts in this project:

- Federated data (information that draws on and is shared in different ways by component databases)
- Shared platforms (sharing pre-existing platforms and solutions)
- Open source coding (where programme code is freely available to the world community of developers for adapting and enhancing)
- Multi-contributor and collaborative (e.g., "Citizen science" and "Crowd-sourcing").

By following these concepts we have avoided creating stand-alone systems that do not interconnect, are developed by too few contributors, and which may have a short or vulnerable product life.

There are two major components to the project: the plant collections register itself and digitising of cultivated plant names.

Table 1. The first 20 records of the 1993 Plant Collections Register (genus listing).

| No | Collection | Spp. | Cvs. | Records* | Holder | Town | AIS** |
|---|---|---|---|---|---|---|---|
| 1 | *Abies* [1] | 59 | 6 | | MacKay Survey '90 | Countrywide | |
| 2 | *Acacia* | 31 | 1 | P/Cp | Dunedin Bot Garden | Dunedin | + |
| 3 | *Acaena* | | | C/Cp | Landcare | Lincoln | - |
| 4 | *Acca* | | | | Hort Research Inst | Palmerston Nth | |
| 5 | *Acer* | 25 | | | Dennis Schwarz | Wanaka | - |
| 6 | *Acer* | | | | Harrisons Trees | Palmerston Nth | + |
| 7 | *Acer* | 16 | 19 | | New Plymouth DC | New Plymouth | - |
| 8 | *Acer* | 23 | 17 | C/H | Timaru Bot Gardens | Timaru | + |
| 9 | *Acer* | 7 | 14 | C/H | Tupare QEII Trust | New Plymouth | + |
| 10 | *Acer* [1] | 90 | 63 | | MacKay Survey '90 | Countrywide | |
| 11 | *Actinidia* | | 155 | | Hort Research Inst | Palmerston Nth | |
| 12 | *Adiantum* | 6 | | | Mrs A. Lau | Paraparaumu | + |
| 13 | *Aesculus* | | | | Harrisons Trees | Palmerston Nth | |
| 14 | *Aesculus* [1] | 16 | 10 | | MacKay Survey '90 | Countrywide | |
| 15 | *Agapanthus* | | | P/H/Cp | Auckland Bot Gdn | Auckland | - |
| 16 | *Agapanthus* | | | | Bill Dijk | Tauranga | + |
| 17 | *Agathis australis* | | | | Cornwall Park Trust | Auckland | - |
| 18 | *Agave* | 55 | | | Martin Walker | Port Charles | + |
| 19 | *Agave* | | | | S. Miehe | Rotorua | - |
| 20 | *Albizia* | | | | Harrisons Trees | Palmerston Nth | |

*Records: C = Complete, P = Partial, H = Hand records, Cp = Computer records.
**AIS = Additional information supplied (+).

**Plant Collections Register**

This part of the project provides a comprehensive and easy to use system for the New Zealand horticultural community to manage and share their collections online for free. Some of the larger datasets of living plant collections in New Zealand include:

- Auckland Botanic Gardens (>44,000 records)
- Eastwoodhill Arboretum (>17,000 records)
- Hamilton Gardens (>15,000 records)
- Wellington Botanic Gardens (>8000 records).

Rather than providing just a list of names, the New Zealand Plant Collections Register delivers a collection management tool. The register provides plant collection curators, from major botanic gardens to private collection holders, a free set of tools to manage and share their collections and images online. The platform used is vastly superior to the limited choices available to most collection holders. Until now, many plant inventories held by private collectors relied on non-networked PCs and inadequate software such as spreadsheets or stand-alone databases. These records were seldom backed up on servers and were vulnerable to loss.

The New Zealand Plant Collections Register has been created by using the open source codebases for NatureWatch NZ (<http://naturewatch.org.nz>) and its international, US-derived parent iNaturalist (<www.inaturalist.org>). Both of these resources are primarily for natural history observations that include plant, animal and insect sightings in the wild, but they also accommodate cultivated plants and have the full functionality needed for this plant collection subset (Figs. 1-4). Current functionality is rich and includes, to name but a few features:

- Project creation and description. A project in the Plant Collections Register corresponds to a particular collection
- Locality information, integrated mapping and user-defined area polygons. Polygons provide the ability to draw a defined area such as the boundaries of a garden on a map
- Pre-defined and custom (user created) observation fields, both text (e.g., dead or alive, wild or planted) and numeric (e.g., number of individuals)

- Image upload (from hard-drive or using a Flickr interface)
- Public contributions or an "invite-only" facility
- Community identifications and comments
- Spreadsheet import and export
- Inbuilt mail client for contacting others.

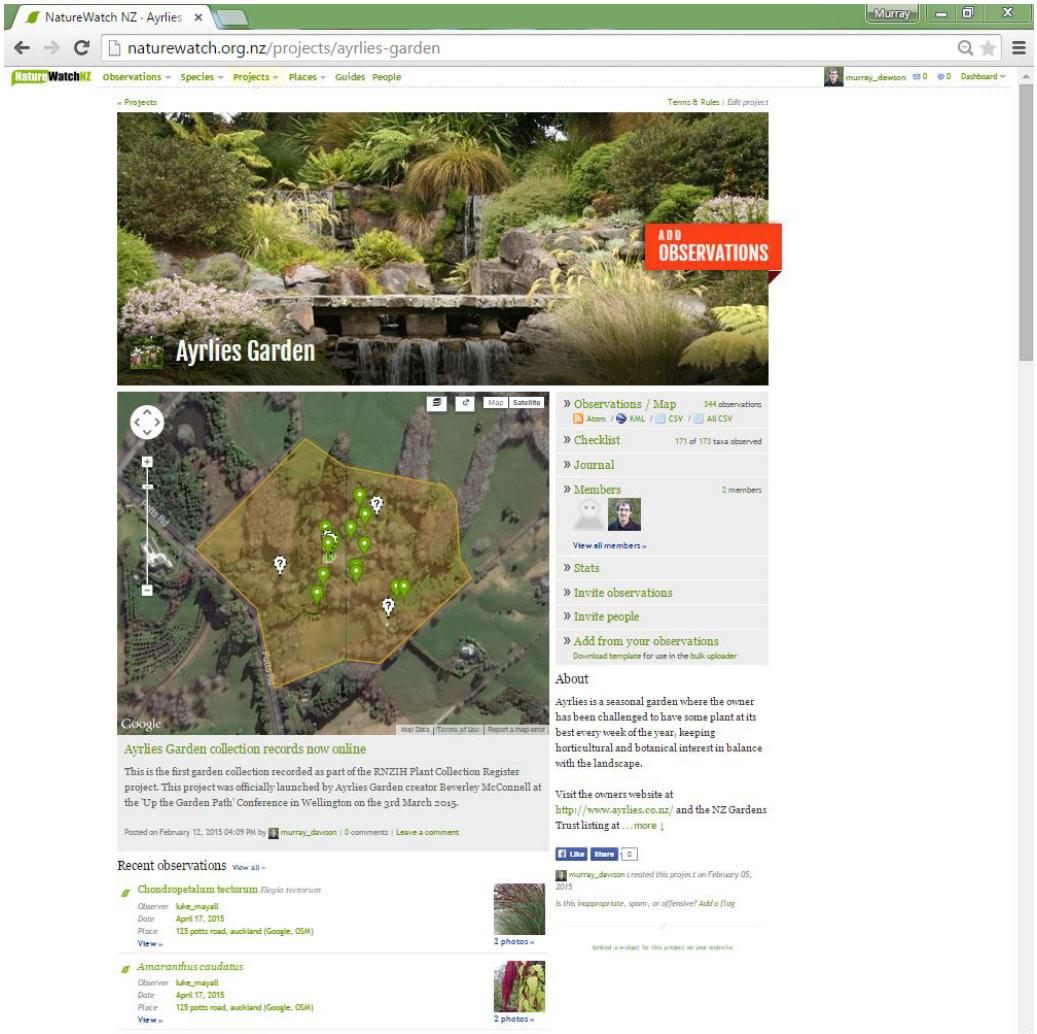


Fig. 1. Screenshot of the Ayrlies Garden collection, the first recorded as part of the New Zealand Plant Collections Register project. Note the polygon which has been drawn to define the area for the project, "pins" on the map that show individual observations, and a list of plants with images. Additional functionality appears on the right hand side.

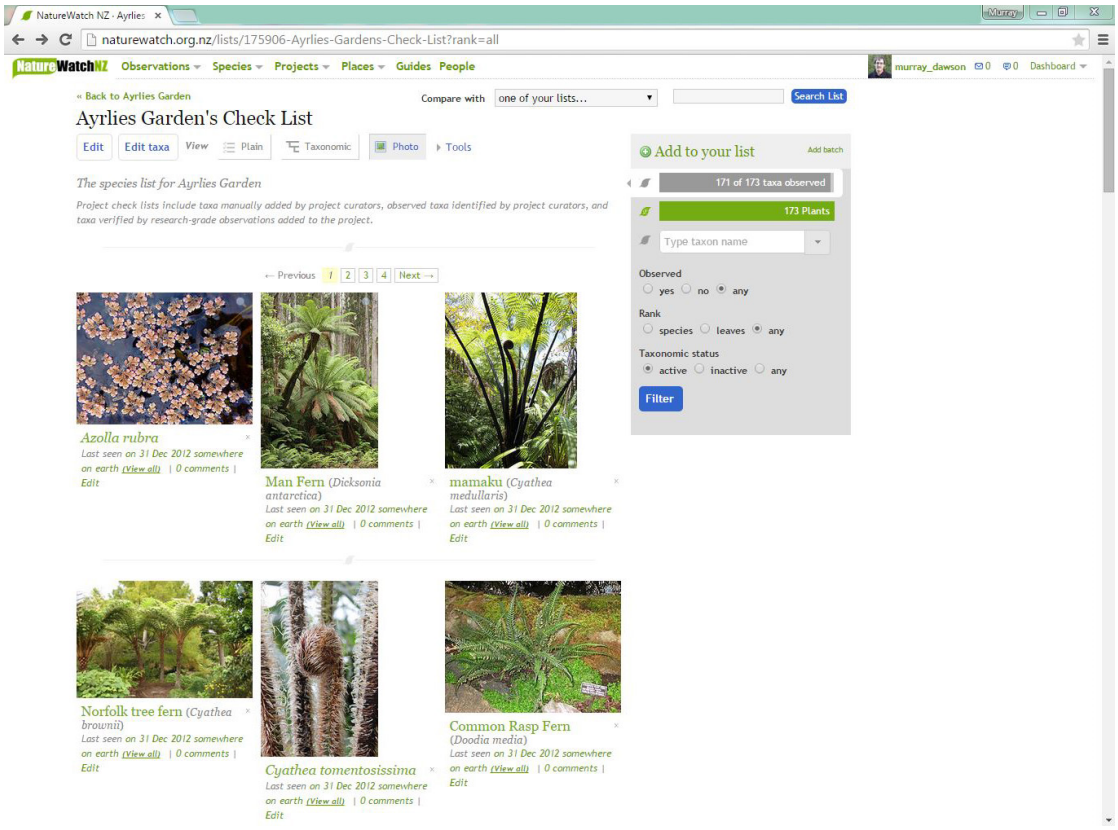


Fig. 2. Screenshot of the Ayrlies Garden Check List, showing verified species and stock (Creative Commons) images for them.

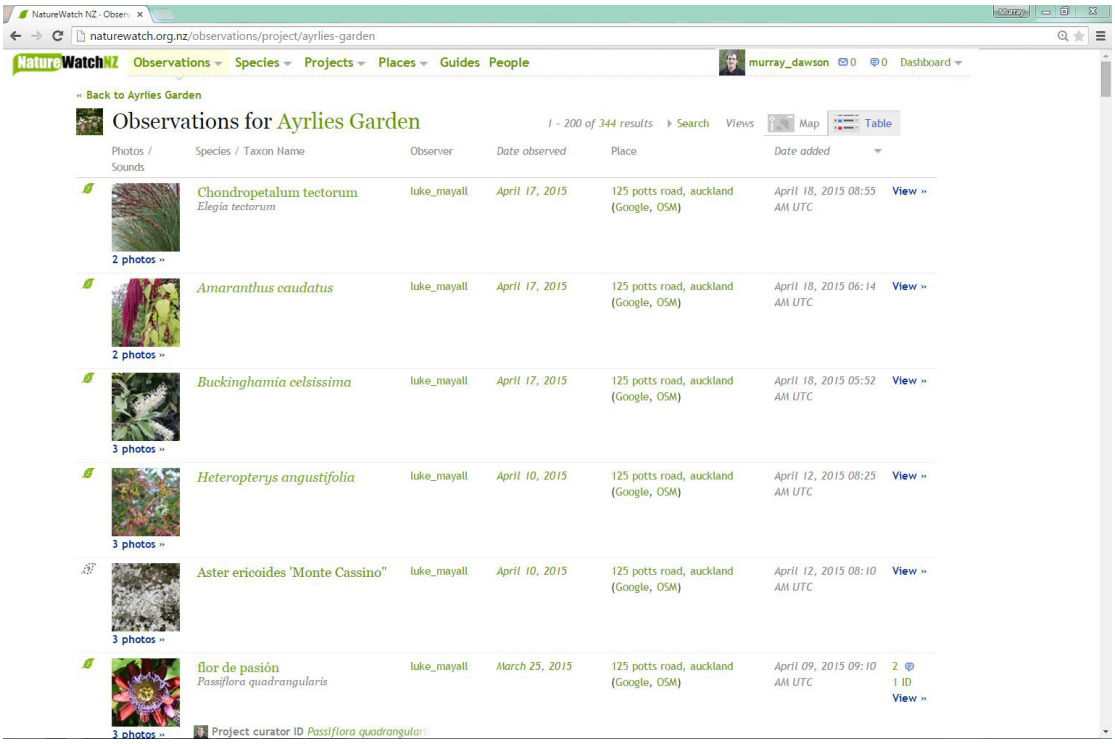


Fig. 3. Screenshot of observations within the Ayrlies Garden collection.

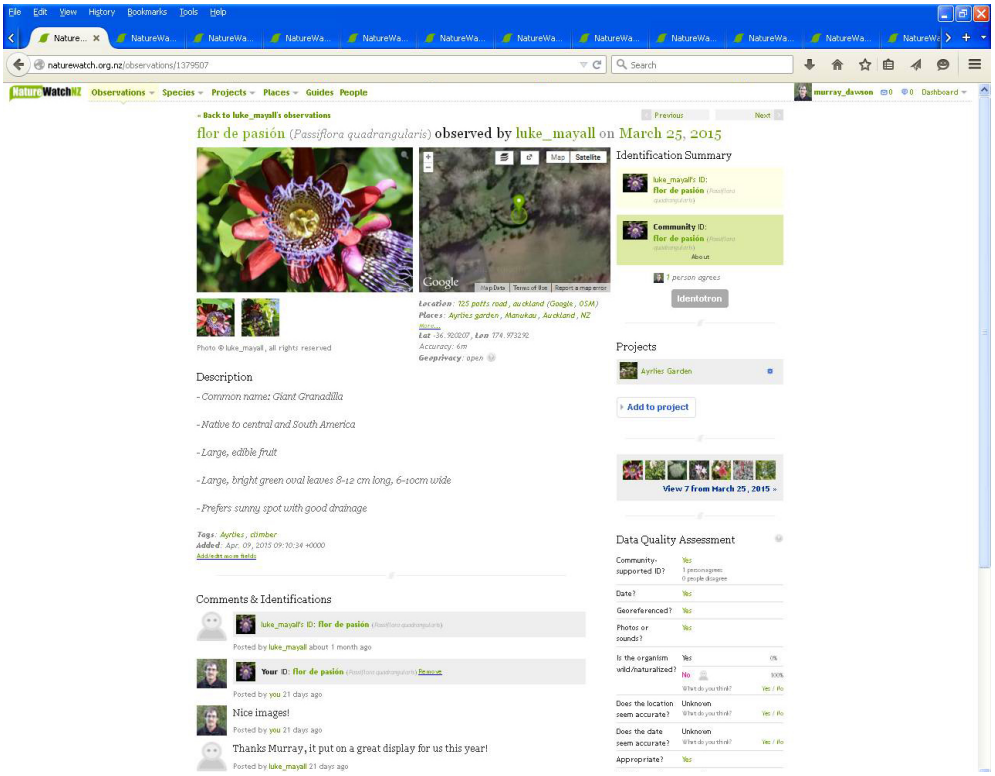


Fig. 4. Screenshot of an individual observation of *Passiflora quadrangularis* within the Ayrlies Garden collection, with description, tags, and identification comments. When there is a consensus in identifications, the data quality changes from a casual observation to research grade.

Other functionality includes the ability to add "widgets" (embedded previews) of individual projects onto other websites to usefully interconnect resources (Fig. 5). While cultivated plant records from all collections are centralised on one platform, widgets allow them to also appear on the contributors own websites and third party websites. For example, widgets are used for a working list of plant collections held throughout New Zealand (<www.rnzih.org.nz/pages/plantcollections.html>). This page is intended to provide an overview of the collections.

Rather than relying on the more broadly focussed NatureWatch NZ (and iNaturalist) front-end, it is possible to build a custom API (Application Programming Interface) front-end aggregating the New Zealand cultivated plants projects together on one dedicated website. If we implement an API for this purpose, the website address will be <www.plantcollections.org.nz>. Plant collection projects on this new API would also propagate through the NatureWatch NZ and iNaturalist websites.

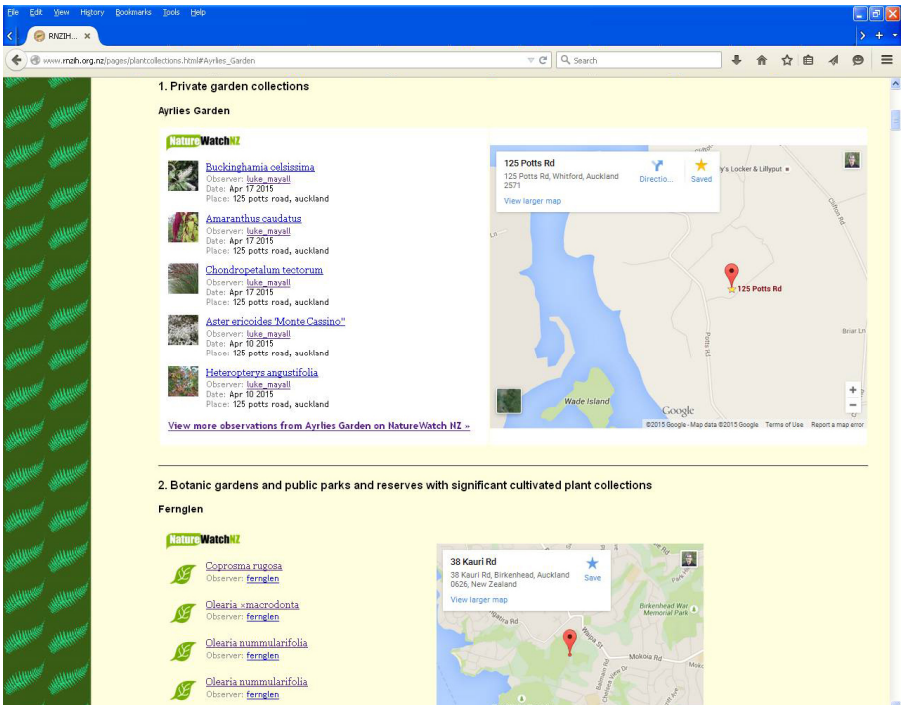


Fig. 5. An example of a "widget" of the Ayrlies Garden collection added to the RNZIH plant collections page (<www.rnzih.org.nz/pages/plantcollections.html>). This embedded preview could be added to other related websites – in this case the owners' website (<www.ayrlies.co.nz>) and the NZ Gardens Trust listing (<www.gardens.org.nz/auckland-gardens/ayrlies>).

Also available "off the shelf" is a handy smartphone app for recording onsite observations that synchronises to the platform. This tool is available from Google play (<https://play.google.com/store/apps/details?id=org.inaturalist.android>) and iTunes (<https://itunes.apple.com/us/app/inaturalist/id421397028?mt=8>). It allows users to take photos of individual plants in their collection with a smartphone or tablet, look up the plant name and add notes (Fig. 6). The GPS data is automatically added from the smartphone location and the observation data can then be uploaded onto the platform.

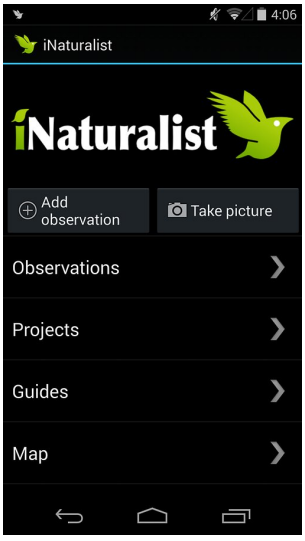


Fig. 6. A screenshot of the smartphone app for recording observations.

A selection of cultivated plant collection projects (currently through the NatureWatch NZ interface) for New Zealand includes:

- Ayrlies Garden (<http://naturewatch.org.nz/projects/ayrlies-garden>)
- Fernglen Native Plant Gardens (<http://naturewatch.org.nz/projects/fernglen-native-plant-gardens>)
- H.E. Hart Arboretum (<http://naturewatch.org.nz/projects/h-e-hart-arboretum>)
- Plants cultivated in the Canterbury Agriculture and Science Centre (CASC) grounds (<http://naturewatch.org.nz/projects/casc-gardens>)
- National NZ Flax Collection, Lincoln (<http://naturewatch.org.nz/projects/national-nz-flax-collection>)
- Magnoliaceae Collection at Lincoln University (<http://naturewatch.org.nz/projects/magnoliaceae-collection-lincoln>).

Many other projects are actively being created throughout New Zealand.

**Cultivated Plant Names Resource**

The second major part of the project is to generate cultivated plant names. These names provide an extensive "pick-list" for those using the Plant Collections Register to enter their collection records.

This is being achieved by digitising and assembling cultivated plant names from the New Zealand horticultural literature (Figs. 7-8), including authoritative plant books (e.g., Gaddum, 2001; Palmer, 2007; Vogan, 2003), cultivar checklists (e.g., Metcalf et al., 1963; Heenan, 1991a, b; Metcalf, 2001; Dawson and Heenan, 2010) and nursery catalogues (e.g., the Duncan and Davies nursery catalogues). Copyright is being respected because we are only providing bibliographic indexing to the plant names – i.e., citing a plant name, page number, and the title of the reference. The exception is the Duncan and Davies catalogue collection, for which we have express permission to fully digitise and make them available as online PDF's (<www.rnzih.org.nz/pages/nurserycatalogues.html>) for non-commercial purposes.

Nursery catalogues in particular could be considered as "grey literature" because of their limited print runs, restricted availability, and seasonal focus. However, beyond their short term original purpose, they provide an invaluable resource for documenting when and where cultivars and species were first recorded in cultivation and how rare or common they became. Until recently, the most notable New Zealand nursery catalogue collection was housed in the Plant & Food Research library at Mt Albert, Auckland (Boyd, 1992). In 2014, these catalogues were relocated to the Lincoln University library to ensure their long-term security. This collection remains available to the New Zealand Plant Collections Register project.

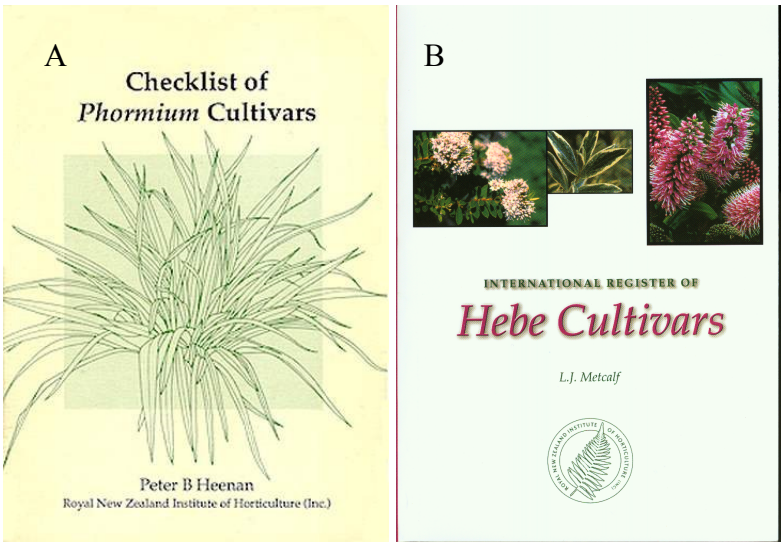


Fig. 7. Book covers of cultivar checklists on *Phormium* (Heenan, 1991a) (A) and hebes (Metcalf, 2001) (B). These technical books were published by the RNZIH as part of the Institute's International Cultivar Registration Authority responsibilities. They are valuable and authoritative compilations indicating the correct names of cultivars up to the time of publication.

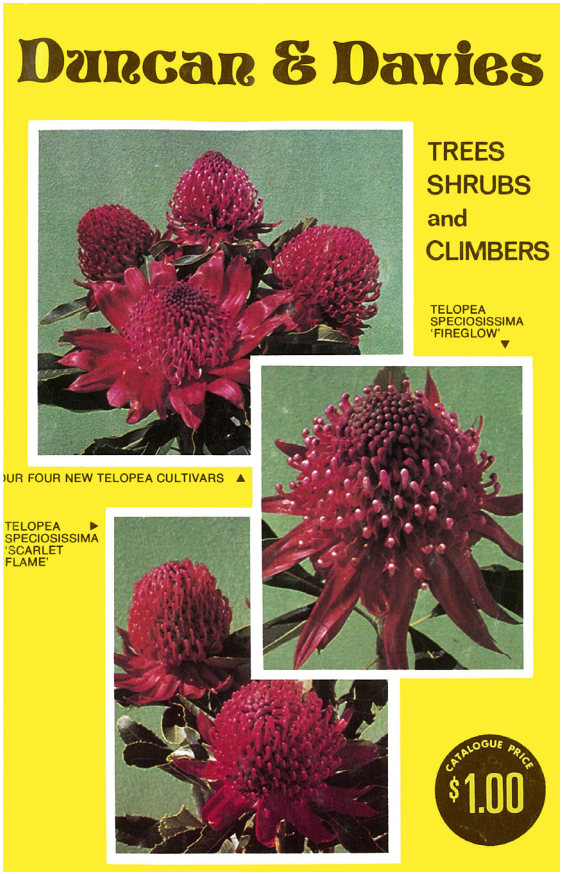


Fig. 8. Cover of a 1978 Duncan & Davies nursery catalogue, one of more than 240 catalogues dating from c. 1916 to 2004. Available catalogues are currently being digitised to produce online PDF versions.

Assembling plant names has been time consuming because of the numerous names involved, extensive proof reading required, and the need to resolve them into accepted names, synonyms, orthographic errors and misapplications.

Following the concept of federated data, cultivated plant names generated from this project are being mobilised and exchanged with the New Zealand Organisms Register (NZOR; <www.nzor.org.nz/search>) and international database initiatives (e.g., Species 2000, Catalogue of Life and the Global Biodiversity Information Facility).

Like the New Zealand Plant Collections Register, NZOR was also funded by TFBIS. NZOR provides a "names clearing house" that focuses on the wider biota (e.g., plants, animals, fungi and bacteria). Cultivated plants have been one of the largest data gaps in NZOR. The vision for NZOR is to create an accurate, authoritative, comprehensive and continuously updated catalogue of the c. 140,000 names applied to New Zealand biota. NZOR has two fundamental components, the network of data providers and the information infrastructure to collate and deliver data to end-users.

**SUMMARY**

The New Zealand Plant Collections Register provides important new resources allowing better management of plant collections and their names. By providing clarity to New Zealand's cultivated flora, both native and exotic, the project will assist in conservation of rare plants and heritage cultivars, and facilitate plant exchange and availability of germplasm for plant breeding. It will also assist in the management of potential weed escapes and should allow better importation and biosecurity decisions.

For the first time, we are building a freely accessible and accurate record of New Zealand's cultivated plant stock, how common or rare a plant is in cultivation, and where it is (or was) growing. Custodians of plant collections are able to log-on and directly manage their records online. This is supported by an authoritative and comprehensive database of cultivated plant names that indicates accepted names and their synonyms.

Although this is a New Zealand funded initiative, the Plant Collections Register draws upon open source software and could show a way forward for future Australian and international projects which have the same challenges in managing and sharing cultivated plant collection records.

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# Is there a Role for Glycine Betaine in Cutting Propagation?©

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## INTRODUCTION

Glycine betaine (GB) is a compound naturally synthesised by some higher plants in response to abiotic stresses. Its role when produced in these plants is an osmoprotectant, helping protect cells, proteins, and enzymes from stress due to drought, salinity, heat, and freezing temperatures. In addition, GB has been proven to protect the Photosystem II complex in some plants under various abiotic stress situations (Papageorgiou and Murata, 1995; Murata et al., 1992). Glycine betaine is synthesised in the chloroplasts, and research has proven it to be a nontoxic, non-perturbing, very water-soluble, and electrically neutral compound with a molecular weight of 117.15 $g \cdot mol^{-1}$ (Sakamoto and Murata, 2002). A plant's natural ability to synthesise GB isn't defined by its membership in a particular taxonomic group, these plants are spread over a number of plant families. In addition, a small number of plants, including sugar beet, wheat, and spinach, are known to be natural GB accumulators (Bohnert et al., 1996). It is only relatively recently that the chemical pathway for the synthesis of GB in higher plants has been confirmed, but the exact way in which it protects the plant from abiotic stresses is still unknown.

In addition to plants, GB naturally occurs in a wide range of other organisms, including all seaweeds, marine invertebrates, many microorganisms, and all mammals, including humans. Glycine betaine has two roles in human metabolism, one of which is as an osmoprotectant, helping protect the kidneys, liver, and heart. The kidneys can synthesise this compound, but more often it is taken in as part of a diet, as many foods contain glycine betaine. There is also building evidence that GB plays a role in athletic performance (Craig, 2004).

My introduction to GB was in 2005 when I returned to Lincoln University after a break of many years to sit some applied science papers, one of which was plant physiology. Glycine betaine was talked about in some of our lectures, and this prompted my interest in finding out more. Much of what was published that I read on the subject at that time seemed to focus on the possibility of genetically engineering the GB synthesis pathway into plants. The potential for alleviating abiotic stresses on crop plants through the application of GB in a world with increasing water supply problems and large areas of saline and sodic soils had been noted (Flowers and Yeo, 1995; Mäkelä et al., 1996). There were no references I could find at that time directly relating GB to ornamental plants or to their propagation, but as a plant propagator at heart that was where I saw the potential. If drought stress in cuttings could be reduced by applying GB, a natural plant product, then this would be a great extra tool for propagators to have.

Finally, 9 years after first learning about GB, I set about doing three very basic, low-input experiments. Due to the complexity of the factors involved there may not ever be a simple answer to the question posed in the title, but this is my initial attempt to come up with one.

## MATERIALS AND METHODS

A lack of relevant information meant that the following had to be decided for these experiments:

- Is GB best applied as a foliar spray, full cutting immersion, or basal end soak?
- What strength solution should be used?
- How long should the application time be?
- Which plants should be used?

The glycine betaine used in these experiments was purchased from Sigma-Aldrich. A product of Finland, it is a by-product of the sugar beet industry, where it is refined from

the sugar beet molasses by chromatographic separation. Glycine betaine in the crystallised form like this has to be kept refrigerated. Solutions of 0.5 M and 1.0 M GB were used in these experiments.

**Experiment 1: Examine the Effects of Repeated Foliar Application of 1.0 M Glycine Betaine on *Griselinia littoralis* Cuttings**

This plant was chosen because it is an industry standard in New Zealand and a very popular native plant that is able to grow in a wide range of environmental conditions. The leaves are shiny, smooth, and a little leathery, providing a test for whether or not the GB would be effective as a foliar application. Seven days of spraying was possibly excessive, since 1.0 M is a strong solution. However, I was hoping there would be a good visual difference between the two trays at the end of the 3-week trial period.

- Leafy tip cuttings approx. 25 cm long were taken in mid-December. No leaves were removed.
- All were wounded on one side and given a 5 s dip in Liba, 10,000 softwood (1,000 ppm IBA).
- Cuttings were stuck into Jiffy 7 coir pellets. There were two trays, 49 cuttings per tray.
- Trays were placed in an enclosed plastic tent on a 22°C heat pad with intermittent mist.
- Each day for the first 7 days the GB treatment tray was sprayed with a very fine mist of 1.0 M GB solution. The control tray was sprayed with water at this time.
- All cuttings were assessed and the experiment finished at 21 days.

**Experiment 2: Examine the Effects of Glycine Betaine on *Lavatera* × *clementii* 'Barnsley' and *Penstemon* 'Alice Hindley' Cuttings Covered Only for the First 3 Days**

- Four treatments consisting of:
  - Soak basal end of cuttings for 1 min in 0.5 M GB solution.
  - Soak basal end of cuttings for 1 min in 1.0 M GB solution.
  - Immerse cuttings for 1 min in 0.5 M GB solution.
  - Immerse cuttings for 1 min in 1.0 M GB solution.
  - Plus a control with no GB treatment for the *Penstemon.*
- Tip cuttings of *Penstemon* approximately 12-15 cm long were taken in late January.
- Tip cuttings of *Lavatera* consisting of non-flowering axillary shoots approx. 5-8 cm long were taken in mid-January. These were quite hard to obtain as *L.* 'Barnsley' tends to be in full bud and flower throughout summer. No leaves were removed on any of the cuttings.
- All cuttings were given a 5 s dip in Liba 10,000 softwood (1,000 ppm IBA) after their GB treatment.
- *Lavatera* was stuck into Jiffy 7 coir pellets and *Penstemon* was stuck into Jiffy 7 peat pellets.
- All cuttings were placed in a shallow, slightly opaque plastic storage bin and the lid placed on it. The bin was placed in a well lit room at ambient temperature and no direct sun on it.
- After 3 days the cover was removed, and the cuttings left fully uncovered until the experiment ended. During this time the pellets needed to be gently watered only once.
- All cuttings were assessed and the experiment finished at 21 days.

**Experiment 3**: **Examine the Effects of Glycine Betaine on Uncovered Cuttings of *Lavatera* × *clementii* 'Barnsley' and *Penstemon* 'Purple Passion'**

- The same treatments were used as in Experiment 2.
- *Penstemon* 'Purple Passion' replaced *P.* 'Alice Hindley' due to a lack of available plant material.
- Cuttings were taken in late February.
- All cuttings were placed in the same shallow, slightly opaque plastic storage bin and the bin placed in the same area as used in Experiment 2, but no lid was placed on it.

- At 14 days all dead cuttings were removed.
- The remaining cuttings were assessed and the experiment finished at 21 days.

## RESULTS

### Experiment 1

Application of a 1.0 M GB foliar spray on 7 successive days to *Griselinia* cuttings had a negative effect on those cuttings. Leaves on some of the treated cuttings were noticeably starting to yellow by Day 7. Figure 1 shows the cuttings on Day 14, when not only were there yellowed leaves on many cuttings but dark brown patches on a few leaves as well. There were no signs of disease, this appeared to be physiological. The control cuttings in the same environment showed none of these signs, they remained green and healthy. At Day 21, 8 out of 49 treated cuttings had formed roots whereas 22 out of 49 control cuttings had formed roots (Fig. 2). The root mass of the treated cuttings tended to be smaller than those of the controls. All 30 rooted cuttings were potted into 0.75-L pots, and 4 months later all plants were growing well; however, 3 of the 8 treated plants had suffered from tip necrosis as shown in Figure 2 and were shorter plants.

Fig. 1. Experiment 1: The 2 trays of *Griselinia littoralis* cuttings at 14 days. Some treated cuttings in the left tray show signs of deteriorating foliage.

Fig. 2. Experiment 1: Rooted *Griselinia littoralis* cuttings after 21 days. Treated cuttings are on the left (8/49 rooted) and untreated cuttings on the right (22/49 rooted). Note the brown tip on the 3rd from the right treated cutting; there were a number of treated cuttings with similar darkened growth tips, dead at the tip, but none of the controls displayed this.

**Experiment 2**

On Day 3, when the cover was removed, all cuttings were in good condition (Fig. 3). Unfortunately in my quest to ensure big, leafy cuttings in order to maximise any drought effects, I had made the *P.* 'Alice Hindley' cuttings too tall for the bin, resulting in the tips being bent under the lid. It was too late once I realised my mistake, as the cuttings had all been treated and I had no spare GB to make shorter cuttings. They never recovered from this, and remained bent once the lid was removed. However this did not affect their survival rate. The total *P.* 'Alice Hindley' survival rate was 28 from 30 cuttings, with 2 from the 1.0 M cutting immersion group not surviving the potting up due to very small roots. Twenty-six of the 28 *Lavatera* cuttings formed roots and survived (Figs. 4 and 5). Three months after potting up, all plants were well grown with no visible differences between the treatments.

Fig. 3. Experiment 2: All cuttings are in good condition at 3 days, immediately after lid removal.

Fig. 4. Experiment 2: Rooted *Lavatera* cuttings after 21 days. Cuttings immersed in 1.0 M GB are on the left and 1.0 M GB basal-soaked cuttings on the right.

Fig. 5. Experiment 2: Rooted *Lavatera* cuttings after 21 days. Cuttings immersed in 0.5 M GB are on the left and 0.5 M GB basal-soaked cuttings on the right.

**Experiment 3**

The *P.* 'Purple Passion' cuttings took several days to show any noticeable deterioration but then their demise was rapid, and at Day 14 they were all dead. There were no signs of disease on them. The *Lavatera* struggled too, and at 14 days all cuttings from both the 0.5 M and 1.0 M immersion treatments had died. These were removed and the other *Lavatera* were left for another 7 days before the experiment finished and they were assessed. At Day 21 the *Lavatera* cuttings still alive included all seven controls, six of the 0.5-M base-soaked cuttings, and five of the 1.0-M base-soaked cuttings. At that stage only two had formed roots; a control and a 1.0-M base-soaked cutting. I had decided to end all three experiments after 21 days to allow for continuity between the experiments, but since these few surviving *Lavatera* were in a place where they could be left for longer, that is what I did. The container was left in its original position but each afternoon the sun started to directly hit the plants through a glass window. Leaves on the control plants wilted slightly each afternoon the sun shone on them, whereas the remaining *Lavatera* from both treatments did not wilt as much. This can just be observed in Figure 6, with the control plants on the left hand side of the picture. Thirty-five days after the experiment started I potted all the remaining *Lavatera* with roots into 0.75-L pots. There were two controls, four 0.5-M GB base-soaked rooted cuttings, two of which have since died, and three 1.0-M GB base-soaked rooted cuttings.

Fig. 6. Experiment 3: At 14 days all the *Lavatera* cuttings from both the 0.5 M and 1.0 M immersion treatments had died. The photo shows the surviving cuttings from the control and basal-soaked treatments.

## DISCUSSION

The 1.0 M solution applied in Experiment 1 is many times stronger than the foliar spray concentrations of 0.05, 0.1, and 0.14 M used by Mäkelä et al. (1998) on field tomatoes, and another trial using 0.1 M GB foliar spray on glasshouse-grown summer turnip rape, soybean, pea, tomato, and wheat (Mäkelä et al., 1996). Without the benefit of laboratory equipment to test for minute traces of GB in leaves and other plant parts for proof of its uptake, I assumed Experiment 1 would have a big effect on the cuttings, and this effect observed and noted so that it could then be used as a standard for making future comparisons. Results from Mäkelä et al.'s glasshouse trials in 1996 showed that GB translocation through the sprayed plants started very soon after spraying, with the GB moving to the roots first and then to the other plant parts. Overall results from these trials using HPLC and autoradiography showed that GB was xylem-phloem mobile but the translocation itself depended on light and humidity conditions. Surfactants were used in the trials, and they noted that the physical structure of the leaves also played a role in the success of GB uptake (Mäkelä et al., 1996). There were a couple of differences here; the application rate they used was 1/10 or less rate that I used, and it was applied only once to entire young plants with a full and functional root system. However despite these differences it has provided me with future plans for more experiments.

In Experiment 2, I wrongly assumed many of the cuttings would die over the days immediately following the lid removal on Day 3. The control *P.* 'Alice Hindley' survived just as well as the treated *P.* 'Alice Hindley', so there did not appear to be any drought relief needed from the GB treatment. Unfortunately I did not have a control line of *Lavatera*, but all four different GB treatments had good survival rates for the cuttings. The results from Experiment 2 show that *P.* 'Alice Hindley' and *Lavatera* can be propagated successfully using the method outlined above. I liked using the Jiffy pellets in these experiments, as they provided a good WHC and good porosity, so vital for root formation. In addition, in Experiment 3 I could remove the dead cuttings simply by lifting out those pellets.

Future plans include applying GB to cuttings at rates similar to those used by Mäkelä et al., both by immersing the cuttings and soaking the bases, and placing the cuttings in a range of drought stress-inducing conditions. Larger numbers of cuttings will be propagated so that results can be analysed and presented rather than just reporting trends.

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# IPPS Japanese Exchange©

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I haven't been overseas before, so to find out that I had been chosen to visit Japan on an exchange trip was an exciting chance of a lifetime. I left Nelson on Sunday 5 Oct., flying to Auckland then to Hong Kong before arriving in Narita, Japan. I was met by Mr. Ishii, a member of IPPS Japan; we travelled from Narita through Shinagawa to Nagoya. There I was met by Mr. Uchida and we drove to his farm in Suzuka, where I stayed for 3 days. I worked on his strawberry farm, deleafing, weeding, and planting strawberries ready for Christmas harvest. Mr. Uchida grows strawberries two ways; the traditional way in the ground inside greenhouses, and the more modern way in raised polystyrene troughs also inside a greenhouse. I left Suzuka on Wednesday and travelled to Tsu where I met Mr. Fujimora from Akatsuka group. The next day I travelled to Makuhari Messe to visit the International Flower Expo (IFEX), what a huge expo! It took a whole day to walk around, with stalls ranging from cut flowers and nursery plants to horticultural products, tools, water purifying systems, irrigation, and machinery. The following day, Friday, I was met by Mrs. Mizutani who took me to Tokyo by train for 2 days of sightseeing. It was amazing, so many people, such a busy place and stunning at night with all the buildings lit up. I was then driven to meet Mr. Suzuki where I worked on his herb farm, The Power of Herb, for 2 days. I worked with a great group of ladies trimming, tidying and pricking out a range of herbs into small pots. The Power of Herb grows an extensive range of herbs for medicinal uses and also common herbs for everyday kitchen use. The whole operation is in a glasshouse and very much automated in the way of spraying, feeding, and watering. All benches are stainless steel and the floor is all weed matted, meaning virtually no weeds at all. During this time a typhoon passed through the area with heavy rain and high winds. I left Hamamatsu on Thursday 17 Oct. and travelled to Gifu where Mr. Onishi picked me up and we visited his business, Central Rose Company, the largest potted mini rose company in Japan. I worked for Central Rose packing roses for market. The roses are all gift wrapped, with a portion wrapped "Halloween Style." Central Rose Company produce 2 million immaculate roses per year in a very efficient operation. The team of propagators produce 50,000 cuttings daily which are then watered and covered with plastic for 2 weeks. After this time 90% of cuttings have taken root. All roses are produced in temperature controlled glasshouses, cooled during the summer days and heated during the winter nights. On Saturday the IPPS Japan Region's Conference began, with seminars during the day and a formal dinner and auction in the evening. Sunday was a day of field trips to cut flower growers — *Gerbera* and roses, then off to a hydroponic lettuce farm, Central Rose Company, hot house tomato growers, and finally back to the train station where I travelled with Mrs. Mizutani to Kyoto. We had 2 days in and around Kyoto and Nara visiting temples, shrines and my favourite, The Golden Temple. On Tuesday 22 Oct. Mrs. Mizutani and I travelled from Kyoto back to Nagoya by train to the airport. It was a full-on 2 weeks, extremely enjoyable and an experience of a life time in such a beautiful country with so much history. I feel honoured that I was chosen to represent New Zealand IPPS in Japan, and am thankful to those who supported and encouraged me in New Zealand and to my wonderful hosts in Japan.

# Welcome to Ontario and the Royal Botanical Gardens

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## ROYAL BOTANICAL GARDENS

### Mission
Royal Botanical Gardens' mission is to promote the public's understanding of the relationship between the plant world, society, and the environment.

### Vision
Royal Botanical Gardens (RBG) to be a recognized and supported global leader in how we use plants in bringing people, place, and sustainable behaviours together.

### Funders
Royal Botanical Gardens is funded by the people of Ontario through RBG members, The Auxiliary of RBG, many corporations, foundations, individuals, Ontario Ministry of Tourism and Culture, City of Hamilton, and Regional Municipality of Halton.

### Overview
The Royal Botanical Gardens has a long history in Canadian horticulture. Established in 1931, RBG is the most visited tourist destination between Burlington and Niagara. Royal Botanical Gardens is also Canada's largest botanical garden based on area at 1,100 ha (2,700 acres) in size. Of that, 121 ha (250 acres) are of cultivated gardens and 971 ha (2,450 acres) are of natural lands (Fig. 1). The natural lands space includes 27 km of trails, 30 km of shoreline, 24 streams, 17 bridges, 7 boardwalks, and over 1100 spontaneously occurring plant species within natural forests, wetlands and meadows. Of the approximately 1100 plant species, over 750 are native to Ontario which represents 37% of Ontario's native plants and 19% of Canada's native plants. The cultivated gardens and living collections feature over 8000 taxa of plants in over 40 different gardens and collections. At the forefront of these collections are the historically significant Katie Osborne Lilac Collection which features over 700 taxa and is home to the International Cultivar Registration Authority (ICRA) for *Syringa* (Fig. 2). The entire space is home to approximately 250 birds species, 68 fish species, 37 mammal species, 13 reptile species, 9 amphibian species, and an undetermined number of insect species. This diverse and rich region can be considered a biodiversity hot spot and is home to 50 species that are "at risk" in Canada.

Royal Botanical Gardens environmental mandate is to be a living laboratory for science, connect children and adults with nature, demonstrate sustainable gardening practices and undertake ecological restoration and plant preservation. There is continually much work going on at RBG, with the gardens and natural lands constantly evolving. The latest evolution for RBG is the multi-million dollar renovation of RBG's first garden, the historic and cherished Rock Garden (Fig. 3). This garden is currently under construction and will open with anticipation in 2016.

Fig. 1. RBG has five major garden areas dispersed along Plains Road West (shown here) and York Boulevard through Hamilton and Burlington. Image oh Hendrie Park garden and RBG Centre taken in 2013.

Fig. 2. Royal Botanical Gardens is the International Cultivar Registration Authority for *Syringa*. The Old Lilac Collection is featured in this historic image from around 1960.

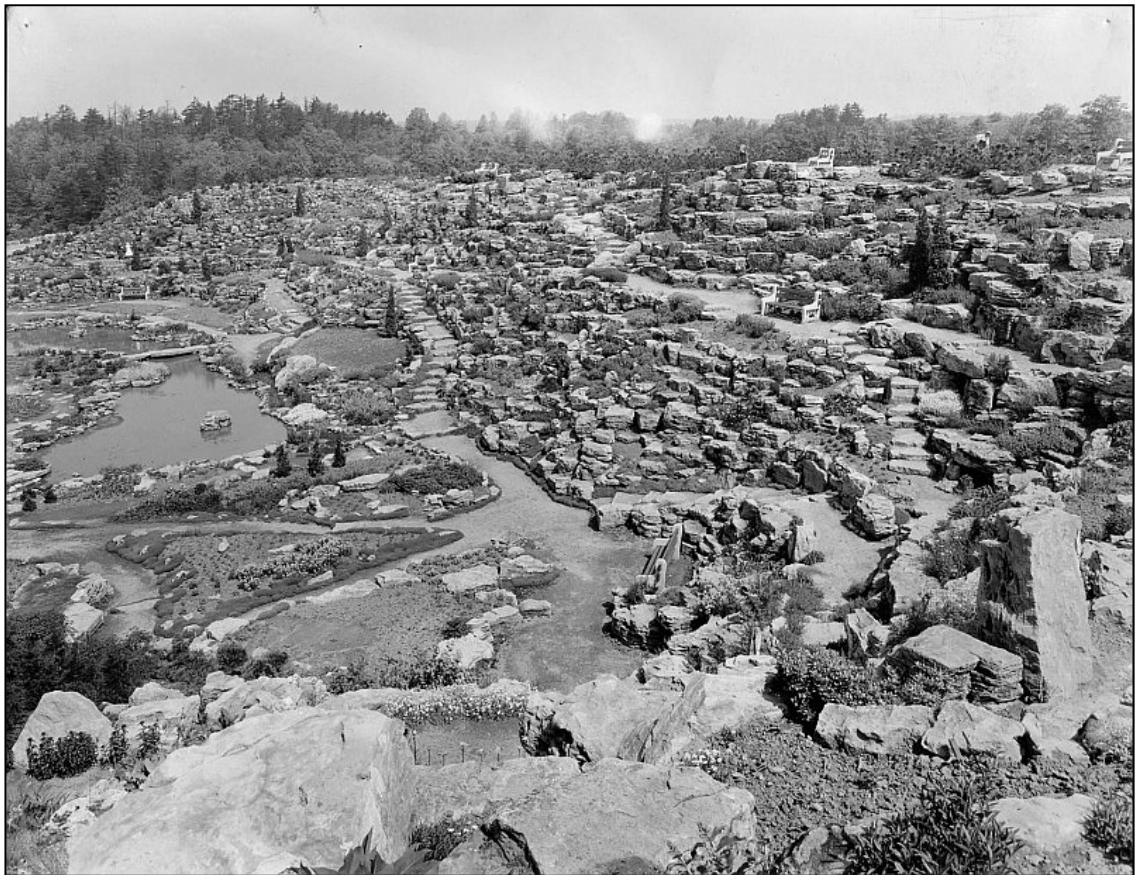

Fig. 3. The Rock Garden, opened to the public in 1932, is currently undergoing renovations for reopening in 2016.

**CONFERENCE**

It was an absolute honour to host "The Botanical Pre-Tour" on Wednesday for many delegates from your Society. We were pleased we could show off some of our garden attributes and we appreciated your enthusiasm, comments and suggestions. I was also honoured to be asked to open up the presentations on Thursday to provide an overview of RBG and highlight some statistics from the Canadian and Ontario nursery industry.

As I mentioned at the end of my presentation, I believe the public garden "world" and the nursery "world" could do a better job of collaborating and sharing of relevant information in order to move forward in our respective missions. The relationships may be strong between particular gardens and nurseries but not all, not in my experience at five major public garden institutions across North America. I think there are plenty of mutual benefits we could all gain from a closer relationship and I would look forward to more discussion of this topic in the future.

It was excellent to be surrounded by so many great plants people, local and international industry professionals, and individuals who I have only read about and who have inspired me for years. (I can't believe I officially met the legendary Tim Brotzman!!!) Thank you to the organizing committee and to everyone involved with IPPS for including the Royal Botanical Gardens in the IPPS Eastern Region Conference 2014.

# Lean Flow at North Creek Nurseries: Establishing a Culture of Lean©

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"The three rules of work:
- Out of clutter find simplicity;
- From discord find harmony;
- In the middle of difficulty lies opportunity."

Albert Einstein

In 2008, North Creek nurseries had its best year ever. Having built a business over a 20-year period, we had grown rapidly, eventually working on two farms. Realizing this growth, and being cramped for space, we felt that we needed to expand our operation. We knew this would allow us to remain relevant in an increasingly competitive marketplace. We felt the need to increase our production capacity and efficiency. In exploring our potential for expansion, we worked with a friend, Robert Hayter, a landscape architect. After pertinent discussions, he asked this question of us: "Had we ever analyzed our processes?" Our answer was that we had not done a thorough analysis, or the due diligence necessary to understand our work processes, product movement, or work flow. We came to the conclusion we needed to delve deeper into understanding our manufacturing processes.

Upon doing so, we discovered our methods were very inefficient and that a simple expansion would not have allowed us to become more efficient or more profitable. Expansion at that point would have only created more expense. As a first step, Robert suggested we look into some training through the JP Horizons "Working Smarter Training Challenge." This program, developed by Jim Paluch, is based on lean principles and the 5S process. It was being used successfully by many landscape contractors to train their employees on efficiency and time management. We started the program in 2010.

As an outgrowth of this training, we began to investigate, understand, and employ 5S principles. In this work process (5S) all debris and unnecessary items are removed and every tool has a clearly marked storage space, is visible from the work area, and has the support to stay that way. The 5 Ss stand for: Sort, Shine, Set in Order, Standardize, and Sustain.

1) Sort. Reduces the number of items in a work area to those that are essential.
2) Shine. Cleaning and "shining" your work space, desk, office, truck, bay, or wherever you perform your work (Fig. 1).
3) Set in Order. Evaluating and taking actions to improve work flow, reduce motion, and increase efficiency in the setup of your work space (Fig. 2).
4) Standardize. Making sure the key steps are understood by everyone — or how to keep the work place like we use the first 3 Ss.
5) Sustain. Making sure all employees are trained in the standard procedures to keep the area clean and clutter free while also using visuals like charts and graphs to measure current conditions.

North Creek began a training program to implement the Working Smarter Training Challenge which set us on the course to train our employees in the concepts of Lean and Lean Manufacturing. What we learned is that it is very important that companies attempt to employ lean principles in their work place by making a concerted effort to expose and educate their employees to this understanding thereby developing the mindset so they comprehend, embrace, and adopt lean management principles. This point cannot be overstated.

Fig. 1. Shine.

Fig. 2. Set in Order.

Over the course of this process we had consulted with other companies who had gone through lean manufacturing processes. It peaked our interest and we needed to learn more about lean manufacturing. As North Creek ventured into the educational process of Lean through the Working Smarted Training Program, I attended the IPPS Eastern Region Meeting in 2010 in Rhode Island. Here I heard two talks on this process. One talk was given by Dave Van Belle, of Van Belle Nurseries, and the other by Gary Cortes of FlowVision. Dave Van Belle explained how they implemented Lean Flow at their nurseries and he expressed how successful it was for them. Gary Cortes explained in detail the concepts of Lean and how Lean manufacturing can be employed in the nursery trades. After these talks, I was able to speak with both men along with Dale Deppe of Spring Meadow Nursery who had also employed Lean Flow at his nursery. I left that encounter knowing that if North Creek didn't start to make changes and implement lean in its business, we would eventually lose our edge. Coincidentally, this all happened during the start of the "Great Recession." It was a difficult decision to invest the necessary funds to adopt these processes with a notable reduction in our gross sales.

We hired Gary Cortes of FlowVision that next spring to do an analysis of our methods and two of our primary processes—shipping and plug production. Our propagation facilities lacked a head house and would need a substantial outlay of cash for facility improvements. Realizing this, we turned our attention to our shipping facilities. Our thinking was that we could implement Lean Flow in our shipping process with few initial upgrades. We were encouraged to read books, primarily, "The Toyota Way" as lean manufacturing is based upon principles employed at Toyota Motors. One very important lesson of lean production is learning to do more with less. Another key principle is learning about the seven wastes that need to be eliminated from every process; these are:

1) Over production
2) Transportation
3) Motion
4) Waiting
5) Processing
6) Inventory
7) Defects

By not analyzing and eliminating these wasteful processes, your company actually creates one more waste: lost opportunity. This can be the most damaging, as it can prevent a company from realizing its' full potential. The seven wastes are at the root of all unprofitable activity, and all tools of lean should be focused on getting rid of these wastes.

After understanding these concepts and with the help of FlowVision, we set about to train our employees. We learned about progressive assembly and were given the tools to implement these processes in our shipping department. One of the first things we changed

was how we used our employees to process shipments. Prior to implementing Lean, our staff did the majority of their work in the hoop houses where plants were stored prior to shipment. We pulled and prepared the flats we intended to ship that week outside in all weather conditions. Our employees worked bent over or sitting on buckets (Fig. 3). They spent hours moving and touching plants, but adding no real value. Gary suggested we change that process by bringing the work to our employees in a central location, our gutter connected shipping warehouse. Now, the numbers of flats we needed to ship in a week, plus additional donor flats, were gathered by a small crew. They were brought to a central location in the shipping greenhouse where a production line was employed to clean and organize materials and made ready for shipment (Fig. 4). Each flat of plants would be groomed to insure a full count and the highest level of quality. This process was known as "Progressive Assembly" and implemented by small teams of employees, usually three working together. Work could be better supervised and scorecards were used so we knew how many flats we needed to have ready in a day and also in a shipping week. This enabled us to improve the quality of the materials we intended to ship by employing the Progressive Assembly process to make work flow balance so there was less time, motion, and waste in the process. We could also balance our labor force by adding or subtraction employees depending on the work load. From here, plants were moved to a "Super Market" and organized and assembled on vertical carts so that the shipping crew could easily pull and ship in a highly organized fashion (Fig. 5). One other important thing to note was the elimination of excess inventory. We only cleaned and assembled the flats we needed to ship that week and on a daily basis only built boxes one at a time, as needed.

Fig. 3. Inefficiencies and wasteful practices assessment.

Fig. 4. Central location in the shipping greenhouse where a production line was employed to clean and organize materials and made ready for shipment.

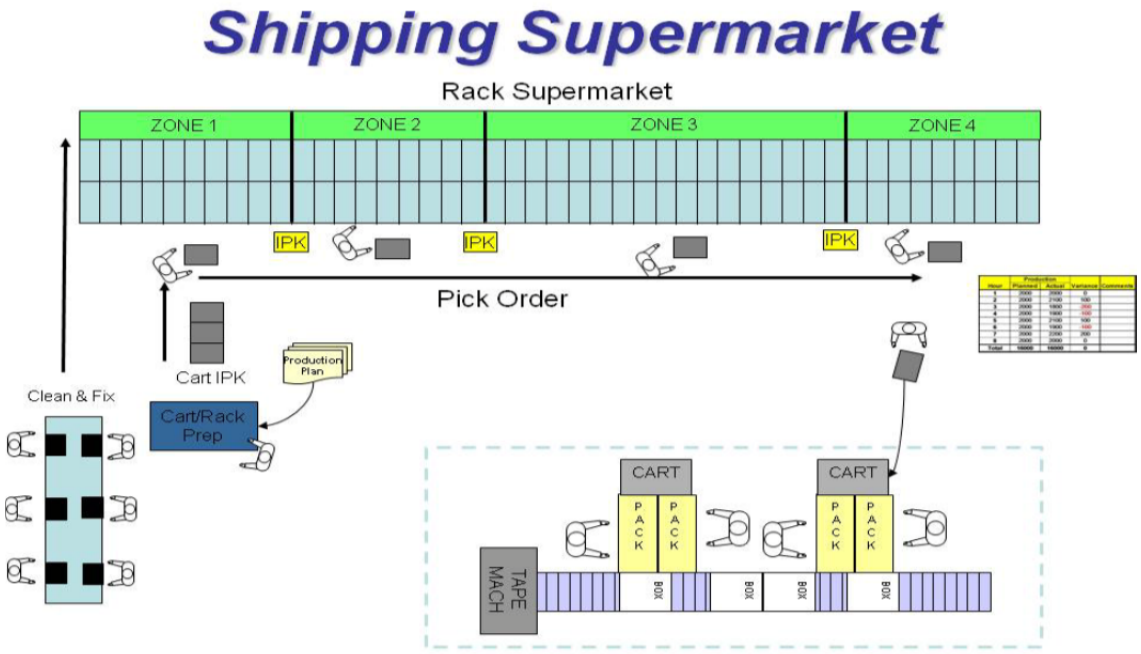


Fig. 5. Supermarket which allows the shipping crew to easily pull and ship in a highly organized fashion.

Prior to implementing Lean Flow in our shipping process we were limited to shipping roughly 6000 flats per week. The effort it took to ship 6000 flats in a week meant overtime for our staff, often working 7 days and often over 10 h a day. In total, after employing the Lean Flow methods, we were able to reduce our work force by as much as 40% during our peak shipping weeks while increasing the number of shippable flats by up to 10,000 units. One of the biggest gains was that our staff was working in a more

hospitable environment, 5 to 6 days per week depending on volume, typically in an 8-h day. I want to reiterate that the quality of the products also improved tremendously. Customers were pleased. We continued to work with the process and refine our methods so the following year we upgraded our facility which added increased efficiencies and more comfortable work environment. We continue to look at other process and brought increased efficiencies to our plant tag organization and fulfillment. As an ongoing process, we continue to chase bottlenecks, thereby allowing us to improve upon any problem we discover.

This year we are finally able to build a new gutter connected propagation facility on our Landenberg farm. Here we designed the entire propagation process using our knowledge of Lean principles and progressive assembly. We look forward to increased efficiency and labor savings moving forward.

In closing, I want to remind everyone about the value of investing in your most important asset — your employees. Spend the necessary time and effort to get your workforce trained. Analyze how they process their work and engage them in how they can improve their work environment. Collectively they will make the largest impact on your bottom line.

# Some Considerations for Fertilizing Container Nursery Crops©

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## INTRODUCTION

Ornamental horticulture is an economically important industry in Canada, with consumer retail spending tallied at nearly $6.3 billion for ornamental horticultural products and another $1.8 billion on landscaping services in 2007 nationwide (Deloitte, 2009). In addition, nursery operations have considerable input needs, for example 93.3% of the annual water usage by the Canadian ornamental horticulture sector is by nursery operations (Zheng et al., 2009). Excess fertilization and irrigation is not only costly, but can also injure plants and cause unnecessary water and nutrient runoff, resulting in environmental damage. However, insufficient fertilization can cause plant nutrient deficiencies, reduce crop productivity, and eventually reduce the efficiency of other resource inputs during nursery crop production. When optimal fertilizer application rates are used, nursery crops will perform at their best, and growers will be able to increase their profit margin, while minimizing environmental impacts. For different growing substrates, plants, and climate combinations, optimal fertilization rates will vary. As fertilizer companies continuously improve their products and release new products, research is needed to identify optimal fertilizer rates for nursery crop production. Conducting on-farm trials, with industry-standard cultural practices, is essential for understanding the response of crops to fertilizers, and the fate of the fertilizers (i.e., from application in the growing substrate to plant uptake or runoff to the environment). However, this type of on-farm research is rare, especially in temperate climate regions such as Ontario, Canada, and some states in northern USA.

To meet the research needs of the nursery industry, and provide growers with recommendations on optimal fertilization rates for container-grown nursery crops in temperate climate regions, we conducted extensive on-farm trials in 2012 and 2013. The trials were conducted at four commercial nurseries, located in different regions within Ontario, and at the Vineland Research and Innovation Centre. Four fertilizer types, two application methods (i.e., incorporation and topdressing), and 21 crop species were tested during production in both 1- and 2-gal containers. Based on the large amount of information obtained from these trials, the following results merit particular emphasis in order to increase fertilizer use efficiency and minimize negative environmental impacts during container-grown nursery crop production.

## DIFFERENT SPECIES HAVE DIFFERENT FERTILIZATION REQUIREMENTS

Results from different sites with both the 1- and 2-gal pot sizes showed that individual species responded differently to fertilizer application rates (Agro, 2014; Agro and Zheng, 2014; Clark and Zheng, 2014). For example, when plants were grown in 2-gal pots and fertilized with Polyon® 16-06-12, 5-6 month controlled-release fertilizer (CRF) at multiple rates, euonymus' response to increasing fertilizer application rates was not as positive as observed for hydrangea plants (Fig. 1). As a result, the optimal fertilization rate for euonymus was identified as 0.60 $kg \cdot m^{-3}$ N and 1.49 $kg \cdot m^{-3}$ N for hydrangea (Clark and Zheng, 2014).

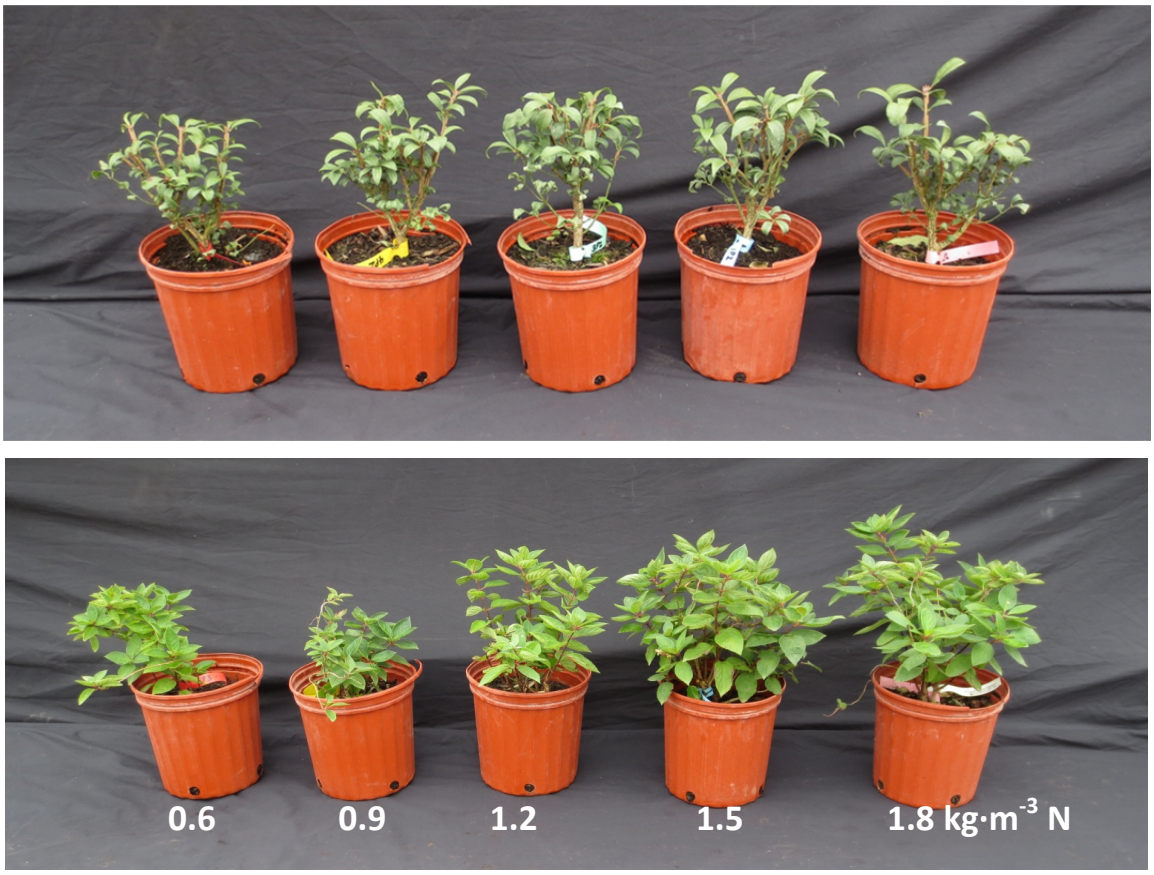


Fig. 1. Response of euonymus (*Euonymus alatus* 'Compactus'; above) and hydrangea (*Hydrangea paniculata* 'Grandiflora'; below) plants to five fertilization rates. Plants were transplanted on 5 June 2013 into 2-gal containers having incorporated Polyon® 16-06-12, 5-6 month controlled-release fertilizer at five rates. Photos were taken in September 2013.

By understanding species-specific responses to fertilization and unique optimal fertilizer rates for individual nursery crops, growers can divide crops into fertilizer requirement groups (i.e., low, medium, and high groups). Groups of crops with different fertilizer requirements can be potted with their optimal fertilizer rates at different times, to ensure planting efficiency. By doing so, growers can easily optimize plant growth and minimize excessive nutrient loss from over-fertilization. Based on our observations and discussions with growers, many Ontario nursery operations are currently applying one fertilizer rate for all plant species on the same farm, and some operations are grouping their plants according to water demand, which is a good practice. Growers may like to use these species-specific optimal fertilization rate results (Zheng et al., 2013), and information from other sources, to determine appropriate nursery crop grouping during production.

**FERTILIZER CAN BE USED TO ACCELERATE OR SLOW PLANT GROWTH**

Our research showed that increasing the application rate of incorporated CRF can significantly shorten the time for some crop species to reach marketable size. For example, when growing ninebark (*Physocarpus opulifolius* 'Nugget') plants in 2-gal containers from June to September, the acceptable CRF application range is from 1.2 to 1.5 kg nitrogen per $m^3$ of growing substrate ($kg \cdot m^{-3}$ N); however, when CRF rate increased to 1.8 $kg \cdot m^{-3}$ N, production time was reduced by at least 14 days (Clark and Zheng, 2014). Applying an appropriate high fertilizer rate is able to shorten production

time, compared to lower rates, thereby saving water and labour costs. However, fertilization rates should be selected to finish crops based on the anticipated shipping schedule, otherwise over-fertilization may cause excess plant growth and resulting labour costs associated with maintaining and pruning plants.

## INCREASING FERTILIZER APPLICATION RATE CAN INCREASE NUTRIENT LOSS TO THE ENVIRONMENT

By measuring the differences between total nitrogen (N) and phosphorus (P) inputs, and the N and P remaining in the growing substrate and plant tissues, we observed nutrient losses to the environment. For all plant species grown in 1-gal pots at all production sites, increasing fertilizer application rate increased N and P loss to the environment (Agro, 2014). For example, the amount of N and P lost per container increased linearly with increasing fertilizer application rate (Fig. 2). To reduce nutrient loss to the environment, these results suggest that it is a good practice to apply the lowest possible fertilizer rate. However, the rate should provide adequate nutrition for plant growth, since nutrient deficiencies can cause crop failure or prolonged production time, potentially resulting in wasted resources or environmental damage.

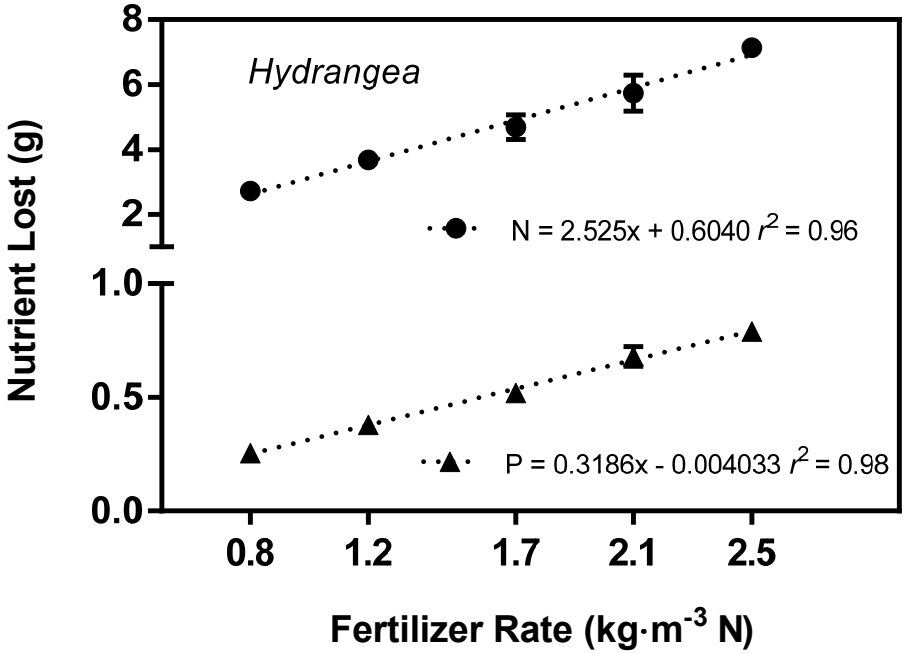


Fig. 2. The nitrogen (N, ●) and phosphorus (P, ▲) lost to the environment ($g \cdot pot^{-1}$) from *Hydrangea paniculata* 'Bombshell' grown with five rates of Polyon® 16-06-12, 5-6 month controlled-release fertilizer (Adapted from Agro and Zheng, 2014).

## TIMING AND METHODS OF FERTILIZATION

Determining when and how to apply CRF is critical in container nursery crop production. For example, CRFs are manufactured to release nutrients at different rates following application, with the expected nutrient release duration ranging from a few weeks to more than a year. An industry practice of applying a high rate of long-duration CRF in the first production year has been considered to avoid labour costs of topdressing in the second year; however, our research showed that this may not be a good practice. For example, when western red cedar (*Thuja plicata* 'Whipcord') liners were potted in 1-gal containers, and an 8–9 month CRF fertilizer was incorporated at multiple rates, the highest rate resulted in a high early-season substrate EC, but the EC quickly decreased during the first 2 months after transplanting (i.e., EC change of >8 $mS \cdot cm^{-1}$ to <1 $mS \cdot cm^{-1}$; Agro, 2014). Therefore, these results suggest applying less fertilizer more frequently to increase

fertilizer use efficiency.

To investigate different fertilizer application methods on the growth of container-grown forsythia (*Forsythia* × *intermedia* 'Spring Glory') and nutrient leaching to the environment, Alam et al. (2009) found that a dibble fertilizer placement is superior to both incorporation and topdress for plant growth, under drip irrigation. Greater concentrations of $NO_3$-N generally leached from containers with incorporated fertilizer, followed by dibbled fertilization, than from a topdressed application. In addition, splitting the CRF application into two application times greatly reduced $NO_3$-N in leachate.

There are many different CRFs available to growers, differing in nutrient release mechanisms, durations, and patterns, as influenced by climactic conditions. In addition, nursery production management practices, such as irrigation, influence nutrient release from CRFs. Recent research has shown that both timing and methods of CRF application are important to maximize nutrient use efficiency and minimizing nutrient loss to the environment; however, few research studies have addressed these topics (Alam et al., 2009; Agro and Zheng, 2014; Clark and Zheng, 2014) and more research is needed to best serve the nursery industry.

## LEAF TISSUE ANALYSIS ALONE MAY NOT BE ABLE TO IDENTIFY NUTRIENT DEFICIENCIES

Some extension publications suggest the best way of diagnosing nutrient disorders is by evaluating plant leaf nutrient content by conducting a tissue analysis (e.g., OMAFRA, 2014). This general practice may help to identify nutrient deficiencies for certain species under certain conditions. However, for some species leaf tissue analysis alone may not be able to identify nutrient deficiencies. For example, the overall appearance (Fig. 3) and the measured growth attributes of 'Nugget' ninebark clearly showed that plants fertilized with CRF at 0.6 kg·m$^{-3}$ N were inferior to plants fertilized at higher rates; however the leaf tissue nutrient analysis showed no differences in N, P, K, Mg, or Ca content among plants grown at different CRF rates (Clark and Zheng, 2014).

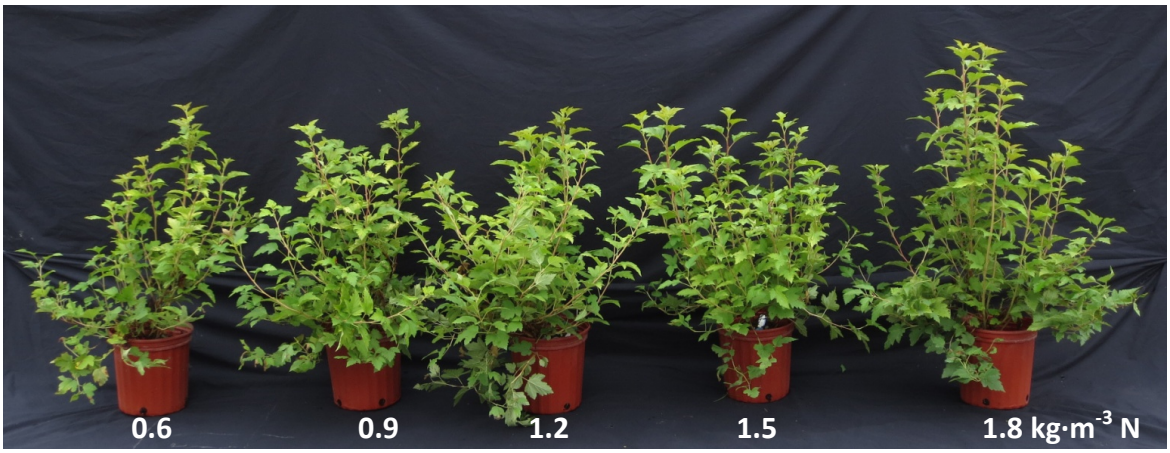


Fig. 3. Plant growth response of *Physocarpus opulifolius* 'Nugget' to a range of controlled-release fertilizer application rates. Plants were transplanted on 5 June 2013 into 2-gal containers having incorporated Polyon® 16-06-12, 5-6 month controlled-release fertilizer at five rates. Photos were taken in September 2013.

Also, leaf tissue nutrient sufficiency ranges are currently unknown for the majority of container nursery species (Plank and Kissel, 2006; Bryson et al., 2014), which limits the ability of growers to clearly determine tissue nutrient deficiencies from tissue nutrient analysis results. In our trials, even when tissue nutrient content values were within the published sufficiency range, poor plant growth and performance were observed at low fertilization rates (i.e., *Spiraea*); conversely, when nutrient contents were below the sufficiency range, no negative impacts were observed for plant growth or performance

(i.e., *Cornus*; Clark and Zheng, 2014). In addition, some commonly-grown nursery crops are not included in current nutrient sufficiency recommendations. Therefore, to determine nutrient deficiencies, nursery growers are limited to comparing tissue nutrient content data to generalized survey averages or ranges (Plank and Kissel, 2006; Bryson et al., 2014), or to tissue nutrient analysis results from other plants in their own nursery. Further research is needed to determine nutrient sufficiency standards for prominent nursery crop species, to develop standard tissue nutrient content benchmarks, and to investigate consistent, reliable nutrient disorder diagnostic methods.

## CONCLUSION

In conclusion, fertilizer can be used as a management tool in container nursery production to maximize profit margin and minimize negative environmental impacts. For example, fertilizer can be used to regulate production timing, either to slow plant growth and reduce pruning, or to accelerate growth and shorten production time. To effectively use CRF in container nursery crop production, several aspects need to be taken into consideration, such as fertilizer type, as well as application timing, method, and rate for individual species. During nursery crop production, leaf tissue nutrient analysis alone may not be sufficient to identify nutrient deficiencies. More research is needed on the topics discussed in this publication in order to provide reliable recommendations for improving fertilization practices in container nursery crop production.

## ACKNOWLEDGEMENT

This work was financially supported by Agriculture and Agri-Food Canada through the Canadian Agricultural Adaptation Program (CAAP), Landscape Ontario, and Agrium Advanced Technologies. Thanks to our southwestern Ontario nursery partners and Gro-Bark (Ontario) Ltd. for providing materials, time and expertise.

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# Coir and Peat: an Optimum Rooting Substrate for Propagation©

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An optimum rooting substrate for propagation should always consist of the proper levels of air and water (balanced levels), along with an adjusted proper pH level for nutrient uptake. The base of this substrate can be peat, coir or a combination of both. By providing an optimum rooting substrate for cuttings or finished growing containers, it will ensure that these items will get off to a strong start, while reducing or minimizing cultural issues that may arise over time in production due to the compaction of the substrate.

As with hydroponics, this holds true to the popularity that coir has gained in today's greenhouse and nursery industry, not only as a standalone growing medium for vegetables and cut flowers, but for production and propagation due to its organic origin. It is produced around the world in locations like Mexico, Dominican Republic, India, Sri Lanka, and Central South America. Coir in its raw form must be treated differently than other growing components. In its raw form, coir can have EC levels up to 8.0 mmhos·$cm^{-1}$. This is why proper care and treatment must be taken to reduce the amount of excess elements that can be harmful to crops, eventually leading to higher input costs. These elements must be balanced to provide an optimum level of guarantee that crop performance will be maximized.

Coir and peat in their raw forms are vastly different as seen below (Table 1), and as such they must be treated differently when being used as a growing substrate.

Table 1. Comparison of coir and peat in their raw forms.

| Coir: raw form (non-treated) | Peat: raw form |
|---|---|
| • pH 6-7<br>• Electrical conductivity (EC) 2-5 (can be 7-8 in non-treated coir<br>• Byproduct that must be processed to remove high salt content based on type<br>• RHP coir from Jiffy is treated<br>• Organic Materials Review Institute (OMRI) coir is washed<br>• Used heavily in hydroponics<br>• Can be used as a wetting additive to peat moss or growing alternatives<br>• Several types of coir available: pith, chunk and blended, shredded husk, or KG blocks | • pH 3.9-4.1, can vary based on locations throughout the world<br>• EC 0.10<br>• Considered a natural resource in parts of the world<br>• After harvesting, ready for storage and soilless mix production<br>• Wetting additive needed<br>• Several types available based on harvesting method and processing<br>• Seedling, container mixes, coarse mixes/blends, bedding flats, etc. |

The unique physical properties of stable coir provide added benefits in production that are positive when handled, harvested, composted, and stored in a strict quality control environment, as with Jiffy's RHP market offer in Jiffy-7C® pellets, Growblocks®, and Growbags®. Coir is easily re-saturated with water, and when mixed with peat, acts as a wetting agent. It becomes a very stable substrate if thoroughly composted and has high air content even when finely structured. In addition to finely structured coir, the addition of chunks or shredded husk to peat provides additional porosity to ensure proper root development of plants. This added benefit of water/air content remains positive compared

to peat as seen in Figure 1 (A) coir particle and coir fiber cross section (B). Water can enter the coir open structure, but cannot compress the air inside. This allows roots to enter the space of the particle so they have access to the oxygen inside. Because the structure is mainly lignin, it acts as a stable growing medium. Regarding easily available water (EAW), the more coir a substrate contains, the less EAW that is available to the plant, and conversely, the more peat a mix contains, the wetter the mix will be unless a component such as perlite is added for increased porosity. Organic substrates have a large volume of water buffer, which is not directly available to the crop. When adding water back to the substrate, only a small amount may be needed to be available for the plant again. With a lot of crops, little to no air in the root zone is not good, just as too much air is not good.

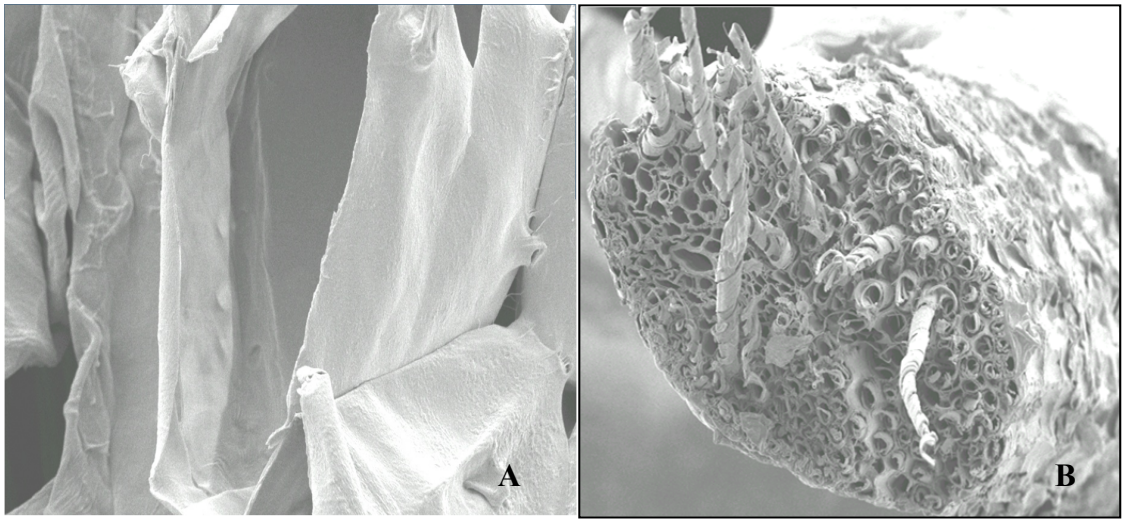


Fig. 1. (A) image coir particle. (B) image coir fiber in cross section.

RHP has developed an analytical method that provides "clear information on water uptake characteristics (WOK) of coir. This WOK analysis indicates the rate of water uptake of air dried samples. It also helps you get a grasp on crop management and growth" (Jiffy International: Superb quality of RHP coir. From water uptake characteristics (WOK) analysis as published with RHP: Certified for Horticulture. Jiffy International, Moerdijk Netherlands: Jiffy International B.V.). This can be seen in the water uptake characteristics (WOK) Figure 2.

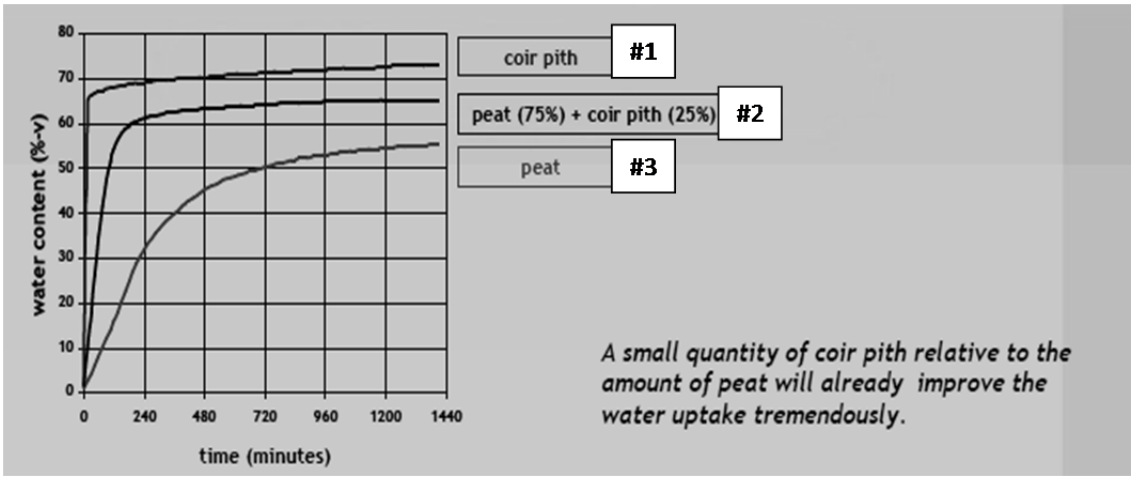


Fig. 2. Water uptake characteristics (WOK) by Jiffy International.

Based on water content, this clearly shows the speed of the three types of substrates over time verses the rate of absorption. Coir alone will absorb water much faster, as shown above (Fig. 2) on coir pith line #1, in comparison to peat (75%) + coir pith (25%) (#2), and 100% peat (#3).

When used in propagation, stable coir is best for cultivation that: when treated properly will achieve the desired level of nutrients. Without proper treatment and handling, unbalanced levels of potassium, sodium, calcium, and magnesium will lead to increased cultivation problems. This instability is very hard to correct.

Stable RHP coir also ensures a low weed content that is "moreover free of plant pathogens." If the product is stored in a non-controlled (contaminated) area for the aging process, it can lead to a high weed infestation, as shown in Figure 3.

Fig. 3. Weed contamination of coir from non-controlled (contaminated) area used for the aging process. (Jiffy International: *Superb quality of RHP COIR*. From WOK analysis as published with RHP: Certified for Horticulture. Jiffy International, Moerdijk Netherlands: Jiffy International B.V.).

Therefore, you need to control the aging process by keeping the area clean, and store it in bunkers for protection, not in fields.

In summary, clean, stable and buffered RHP coir can provide added benefits either as a standalone growing substrate, or when incorporated into mixes that will minimize the risks associated with coir from unknown sources. This is essential when growing unrooted cuttings in the propagation stages as well as hydroponics, tissue culture material, vegetables and perennials, based on the percentage within the substrate. It can easily be resaturated, and based on the percentage of incorporation with peat, acts as a wetting agent related to fast water uptake. Pith, chunk, or blends of coir as well as shredded husk can be used to increase the stability of a growing media that will not shrink under normal use over time.

The above information is based on the following:

- Personally conducted telephone interview: Van Leest, Arjan interview, by John Bonin. Jiffy International B.V. and PowerPoint data. China presentation. Jiffy's Global Product Manager. Hydroponics.
- Personally conducted telephone and interview: Gamalath, Sandeeptha. Interview by John Bonin.
- Jiffy. International B.V. known JSL data. Interview by John Bonin. Sri Lanka, Managing Director.
- Personally conducted telephone and interview: Roelof Buisman. Interview by John Bonin. Jiffy International B.V. and email data. Interview by John Bonin. Substrate Manager, Manufacturing. JBV.

- Jiffy International: *Superb quality of RHP COIR*. From WOK analysis as published with RHP: Certified for Horticulture. Jiffy International, Moerdijk Netherlands: Jiffy International B.V.
- Jiffy International: *Hydroponic Brochure:* 40 pg-EU-12 11LR, Moerdijk Netherlands: Jiffy International B.V.
- Jiffy Products International: Godfrey, 2014, personnel communication.

# New Plant Principals at North Creek Nurseries©

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## BACKGROUND

With all of the new plants hitting the market these days how does a young plant company/propagator figure out which plants are the best to add to their catalog and offer to the marketplace? In recent years, there has been a proliferation of plant breeding companies, plant breeder representatives, as well as, plant breeders themselves. All of these companies are promoting their plants as being superior to existing cultivars. At North Creek Nurseries (NCN), we have developed certain principals that define our process for introducing plants. This practice helps us define which plants we will ultimately introduce.

Our goal is to bring to market great new plants and offer the best value to our customers.

This objective is based on the following principles:

- Our plant introductions will be excellent garden and/or landscape performers in the mid-Atlantic region.
- Our plants are not invasive or aggressive.
- Once established in an appropriate site, our plants require no material input to maintain their ornamental value or garden worthiness.

As part of our evaluation, we ask: Is it a "North Creek Plant"?

Other factors that we consider in making this determination are these:

- Is the plant garden worthy, hardy, and a performer: does it "stand the test of time"?
- Is there currently demand, or can demand for the product be established?
- Does it have marketable qualities?
- Is propagation material available?
- Have propagation and production protocols been worked thorough to insure success?

Based on the outcome of the above mentioned criteria, the decision to introduce a plant is made.

## INTRODUCTION IS A TEAM EFFORT

At NCN, the following staff members are instrumental in gathering information, testing, and evaluating new products: the new products manager, plant trials coordinator, production manager, operations manager, the sales and marketing department as well as our customer service team all provide valuable input. Customers are also questioned when they visit us and express interest in a plant.

The new products manager gathers information on all plants of interest and creates a plant "fantasy list". Information comes from the introduction company, our nursery, botanic garden visits, as well as our customers' interests. These lists are then reviewed by our new-plant-committee members. As an outcome of those discussions, and a review of the plant selections, a decision is made as to which plants to trial. Anyone at NCN can add a plant of interest to our "Future Plant Fantasies" list. They just need to be able to defend their nominations by addressing the criteria mentioned above. Inventory information is managed through research and development accession numbers, which are managed by the new products and trials manager.

Plants in our trials are maintained by the plant trials manager and are evaluated for performance and garden worthiness on a monthly basis by the new products committee. Most plants are evaluated over a 3-year period to determine hardiness and cultural characteristics.

Plants sources are researched as necessary. Plants are further trialed for production worthiness and research is done on propagation type (tissue culture, cutting, divisions, or seed propagation) and scheduling. In the garden, photographs are taken for landscape

style, close up, and habit images. The top picks are advanced to the introduction queue list.

During our meetings, introductions are decided upon. The new products committee determines production goals, finished size, and target production quantities. This process is outlined on our process map (Fig. 1). The process summary includes:

- Plant names and detailed descriptions are added to the "Hot List" which is where we add potential new introductions. From here, we send meeting minutes to notify all pertinent NCN employees of the new Items.
- If the plant is patented, the breeder is notified and a license is obtained. A request for photography from the breeder or an introduction source may also be requested.
- Presentations are made to our sales and customer service department, as well as other members of our staff. Formatted photos are added to the NCN Image Library and Photo Share folder.
- An electronic new plant presentation (Power Point®) is created for marketing to customers and brokers.
- Webpages are created and content is added to our website.
- Plant tags are ordered based on production quantities and placed into inventory.
- Samples are sent to garden writers and key customers.
- The plant is added to our catalog.
- Communication begins with our customers and key accounts to promote these new introductions.
- The sales process continues, orders are placed, and plants are sold!

The plant introducer and breeder are happy and NCN can be proud that we can stand behind this newly introduced selection.

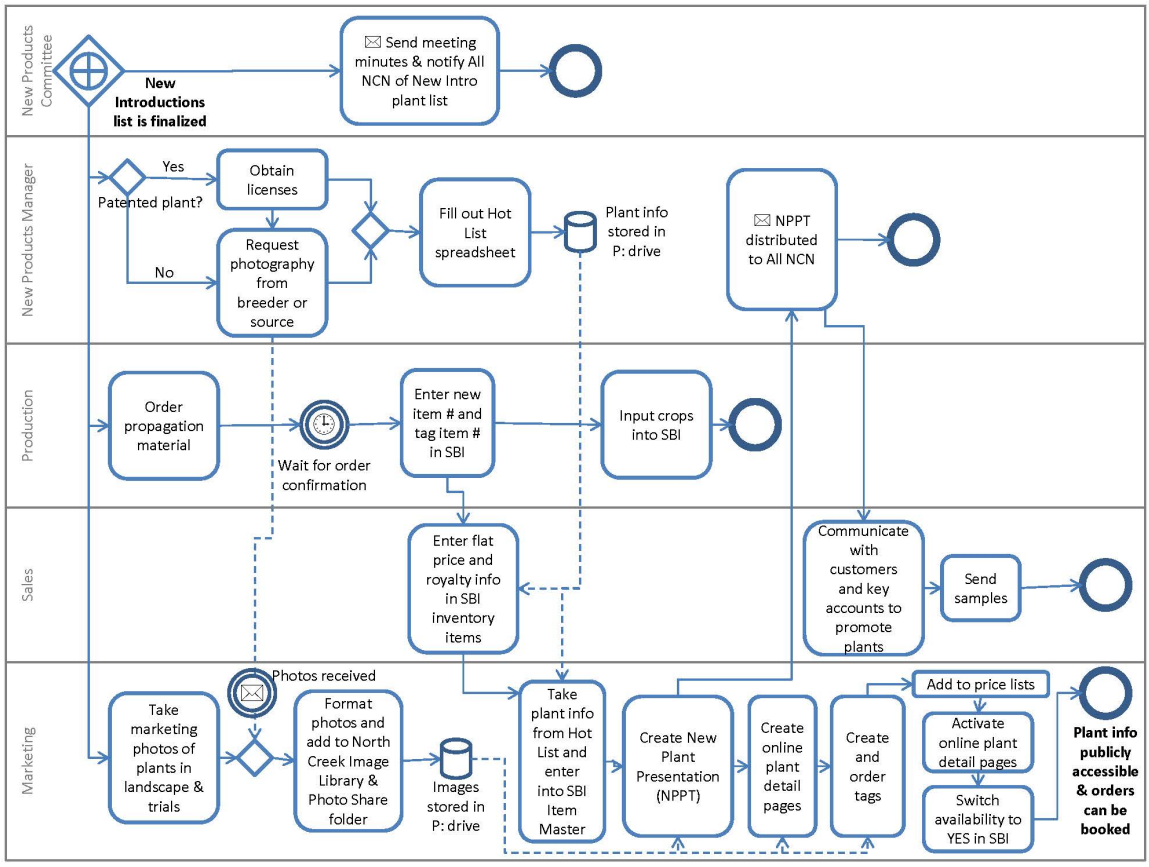


Fig. 1. Outline of our process.

# Growing Good Roots in the Nursery©

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I have been interested in roots during much of my professional career. Observing roots in natural settings, in water, in air, over granite rocks, provides a glimpse of how adaptable they are. In the nursery, we initiate them, prune them, and manage them in order to provide the best possible chance for them to grow and survive after they are sold. Sometimes nursery-grown root systems are inappropriately structured to enable the plants to provide the long term environmental and aesthetic benefits for which they were produced. This paper presents some reasons why growers should pay close attention to roots, some illustrations of good and bad roots, and repeats the cry for all nurseries to grow and sell the best possible root systems. Didn't Charles Darwin say "the root is the heart of the tree"?

Roots are opportunistic. When provided with water, air, a nutrient supply to keep the tree alive and no physical, biological, or environmental constraints, they survive and grow anywhere (Coder, 1998; Perry, 1982). That ability gets roots into trouble when they damage pavement, invade sewer pipes, and absorb water from some clay soils near building foundations (Watson and Himelick, 2013). We have all seen how easily roots explore the area beyond the drain holes of nursery containers. Yet that same ability allows trees to exist in many unique locations. Mangrove, bald cypress, and willow may come to mind in wet locations. Desert vegetation is an opposite contrast. In Ontario, not far from our meetings here in Niagara Falls, researchers have documented stunted, deformed examples of *Thuja occidentalis* that have been clinging to limestone cliff faces for nearly 2000 years (Kelly and Larson, 2013; Kelly et al., 1994).

Roots are not entirely geotrophic. As the radical emerges from the seed, the tap root responds to gravity. However, roots soon begin to grow laterally and even up. This down, up, sideways, any-which-way root growth pattern is clearly evident in many container-grown plants.

Much to our benefit, roots grow more roots as a result of natural or manipulated factors. Root pruning enables roots to form near the pruned point. Both mechanical and air pruning are common nursery practices. The number of new roots formed depends on the species as well as physiologic and environmental conditions (Watson and Himelick, 2013).

Growing plants in containers may result in circling roots (Appleton, 1998). Circling roots often have little adverse effect in the nursery. However, the circling begins the potential for circling roots to become girdling roots that may and often do affect tree longevity in the landscape (Watson and Himelick, 2013). When the physical constraint of the container is removed, subsequent root growth does not continue to circle (Fig. 1). This growth pattern allows plants with severely circling and constricted roots to establish and grow for some time in the nursery or landscape. However, the initial imprint of circling and girdling roots soon begin to restrict the flow of absorbed water and nutrients through the xylem as well as the downward movement of metabolites in the phloem. Early signs of root problems are reduced shoot elongation and abnormal leaf color during the growing season.

During my career, I have seen many bad roots, their configuration the result of poor nursery practice. Nurseries do not purposely grow or sell bad roots. Bad roots result from a number of causes like improper field and container planting practices, poorly designed containers and not up-sizing into a larger container. I think the up-sizing issue followed by container configuration are the greatest reasons for bad roots of container-grown plants.

We have all heard home gardeners say they "kill plants." My observation is that some of

their failed plants are not the homeowner's fault but the result of a bad root system from the nursery. Since it has happened in my home garden I am sure it has happened for others.

Fig. 1. A circling root system does not continue to circle after nursery field planting. However, this tree will die soon because of the severe root constriction.

For forest tree seedling growers, economy of scale often requires very small containers in the initial stages of production, some as small as 40 $cm^3$ (2.5 $in^2$) (Landis et al., 1990). "The major constraint on container volume is economical, not biological, because (A) larger containers take up more growing space, (B) seedlings grown in large containers require longer growing periods for the seedling root system to occupy the container completely, and (C) large containers are bulkier to handle during shipping and outplanting." (Landis et al., 1990).

Tree failures as a result of bad roots usually occur some years after planting (Fig. 2). That fact has deflected the blame away from bad roots to less than ideal urban soil and environmental conditions or inadequate maintenance. However, landscape architects, urban foresters, and municipal managers are becoming more aware that some tree failures are the result of bad roots originating from poor nursery practices. As these professionals come to your nursery to talk about roots, tell them about your production practices that ensure good roots. Show them examples (Fig. 3). Better yet, don't wait for them to come to you. Communicate to them. Sell your roots. One example is J. Frank Schmidt & Son Co. nursery in Boring, Oregon. Their colourful promotional material illustrates the containers they use to produce fibrous root systems with no circling.

James Urban, a well-known American landscape architect, is a passionate advocate of how to get trees to grow well in cities (Urban, 2008). He may have come to your nursery with his spade to check on root orientation and upper root depth. "Root safe containers" and certified growers are ways to ensure trees have quality root systems (J. Urban, pers. comm.). Since trees planted in cities originate in nurseries, better nursery trees will help to ensure better city trees.

Fig. 2. This pine, like others in the nursery field, was planted as a liner without checking the roots. Several years after planting the trees broke at the base because the circling roots severely constricted the stems.

Fig. 3. Propagation containers like this enable air root pruning and help to prevent circling and future constriction. It also enables visual inspection of developing roots.

Several conferences focusing on urban tree-root issues (Neeley and Watson, 1998; Watson and Neeley, 1994; Watson et al., 2009), have brought together "research scientists, growers, and landscape professionals (from) around the world working in earnest for better nursery production, site preparation, soil management, planting and arboricultural care" (Watson et al., 2009). Since very few nursery growers attend such conferences, root researchers such as Dr. Ed Gilman of the University of Florida, Gainesville, Florida; Dr. Gary Watson of the Morton Arboretum, Lisle, Illinois; and many others have written in trade publications and spoken at nursery meetings about the causes and implications of bad roots and ways to grow good roots. Some nursery growers have been innovative in their approach to producing better good roots and are happy to share their findings (A. Verbinnen, K. Warren and J. Winkelmolen, pers. commun.).

A constricted container root system leaves an imprint when the container is removed. The negative implications of failing to alter or manipulate the imprint include the lack of newly formed lateral roots from the imprint area and new roots that are too deep below the surface. Deep roots often have an adverse effect on stability, establishment and survival of landscape plantings (Gilman, 2012). An important production strategy is not to allow root abnormalities to occur. When they do occur, some sort of correction, such as shaving, is needed.

Beginning root "training" early is key. It starts at propagation, particularly when producing seedlings in containers. Tap-root manipulation by mechanical or air pruning to encourage laterals, container material and configuration to eliminate circling and encourage laterals, up-sizing before a root imprint forms and root ball shaving are "training" techniques. Gilman et al. (2009) have shown that shaving the outer edge of the root ball eliminates surface circling and helps to encourage horizontal root orientation when up-sizing and out-planting. Cull anything with a bad root. One nursery is so selective it culls as many as two thirds of its seedlings (K. Warren, pers. commun.).

Nurseries that bring in potted liners from other growers may be at risk of potting-up bad roots. Some of the plants that have failed in my landscape, and I'm sure others, have had bad roots initiated by the propagation grower and perpetuated by the subsequent grower (Fig. 4). Learn about the good root techniques of supplies and do random destructive root sampling. Even good roots without structural defects may benefit from manipulation prior to potting.

Fig. 4. This small tree grew more slowly each year after planting. Its demise was not the homeowner's fault. It was the fault of a bad root system from the nursery.

Many types of containers on the market encourage good roots (Appleton, 1998). Some are formed with many openings in the side wall and bottom or made of fabric to encourage air pruning, some are ridged to eliminate root circling, some are made of biodegradable material such as coir (coconut fiber) to allow root penetration and direct planting, while others are very deep in an attempt to accommodate tap rooted species. Each container type has production implications such as purchase price, irrigation frequency, stability, strength, longevity of use, and rooting-out.

The advantage of natural fiber and biodegradability may result in a false sense of the container's air pruning ability. Some coir (coconut fiber) containers have thicker bottoms than sides. This manufacturing flaw often leads to root circling at the bottom rather than root penetration and air pruning (Fig. 5).

Fig. 5. The thick base of this small, porous-walled coir (coconut fiber) container restricted root penetration and prevented air root pruning.

Tap rooted species such as *Carya* seeded in containers are a particular challenge. The lack of naturally formed laterals and the limited number of laterals formed from mechanical and air pruning quickly result in poor root structure (Fig. 6). Some growers have tried very deep, narrow pots in an attempt to provide more space for laterals along the tap root. However, such deep pots make future nursery and landscape planting awkward.

Auxin-type growth regulator applications to roots have been used in an attempt to increase root number (Lumis, 1982; Prager and Lumis, 1983). However, there has been too little positive benefit for their adoption and use in the nursery or in landscape planting (Watson and Himelick 2013).

Achieving good roots in the nursery is a challenge, especially for tap rooted species and for plants grown in containers. Understand the importance of good root architecture and achieve it. Your customers deserve and should demand good roots. Provide them with roots without defects to ensure long term survival and establishment in the landscape (Fig. 7). Begin early in the life of the plant and continue through different stages of production. Prevent and avoid constricted imprints that will jeopardize the plant's future. Discard plants with poor root structure. Grow the best roots possible.

Fig. 6. Getting a good initial root system in the first season on tap rooted species such as *Carya* can be a challenge. Note the lack of laterals.

Fig. 7. Good root structure like on this one-year-old red oak seedling should be the goal of every nursery and a requirement of every purchaser. The radical was pinched right after germination then the seedling was planted in a wide, non-restrictive container that enabled air pruning of the elongating tap root.

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# Getting to the Root of Tree Stress along Highways©

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**Soil compaction has been identified as a major contributor to urban tree failure. In order to develop criteria to increase rates of survival of outplanted trees in roadside environments this study investigated the influence of bulk density as an indicator of soil compaction on tree morphology and physiology. In 2012, four # 10 container-grown tree species were planted into a total of 37 quadrats at two highway interchanges in the Niagara Region, Ontario, Canada. Four data collection cycles were conducted and measurements included: tree height, caliper as well as chlorophyll content of leaves, soil moisture tension and stomatal conductance. The soil texture was mainly comprised of fine particles (clay and fine silt). Average soil bulk density for Site 1 was 1.45 g·cm$^{-3}$ and was 1.55 g·cm$^{-3}$ for the 0-10 and 20-30 cm depth respectively. For Site 2, the average soil bulk density was 1.49 g·cm$^{-3}$ and 1.67 g·cm$^{-3}$ for the 0-10 and 20-30 cm depth respectively. The results suggest soil bulk density was consistently above root limiting levels at both sites for samples collected at the 20-30 cm depth. These findings illustrate the importance of developing root systems with shallow structural roots that are radially oriented around the trunk in the nursery for trees that will be outplanted into urban soils.**

## INTRODUCTION

Many nursery growers are tasked with producing trees that will be transplanted into urban environments. In fact, in Canada, of the $644,677,730 total nursery sales reported in 2010 $73,344,000 (11%) were direct sales to the public, $158,838,795 (25%) were sales to landscape contractors, $40,960,970 (6.5%) were sales to government and public agencies, $86,570,130 (13%) were sales to mass retail stores (Statistics Canada, 2012). The lesson here is that trees produced in the nursery in Canada and elsewhere in North America will likely end up in an urban or residential setting where the soil has been subjected to construction practices that have altered the physical characteristics of the soil ecosystem. It is important for producers to understand the challenges that their material will face once outplanted into these types of environments in order to better condition the plant material for survival. One consideration that has been investigated is the influence that production-type (e.g. field-grown versus container-grown) has on survival of trees transplanted into urban soils, for instance work by Gilman and Anderson (2006) investigates how production methods influence growth post-transplant. Conversely, the soil that the trees will be transplanted into is another important consideration for growers that are marketing their products to locations that are heavily impacted by construction like an urban transportation corridor.

Overcoming the barriers that result in low rates of tree establishment after transplanting is critical for roadside ecosystem transplanting success (Haan et al., 2012). In fact, Nowak et al. (2004) found that tree mortality was higher in land types classified as "transportation" compared to other urban land classifications. Newly planted trees tend to die at a higher rate than established trees (Miller and Miller, 1991; Nowak et al., 2004) because the healthy soils that promote early vigorous growth are absent (Pavao-Zuckerman, 2008). Soil compaction at urban sites has been identified as a primary driver of tree mortality (Day et al., 2010; Haan et al., 2012; Oldfield et al., 2014). For instance, silty clay soils with bulk density values of 1.49 g·cm$^{-3}$ are root limiting and 1.58 g·cm$^{-3}$ and above are root restricting reducing the root and shoot growth of newly planted trees by 50% (Watson and Himmelick, 2013). During road construction the topsoil layer is removed and subsoil is returned to the site to be graded and compacted (Haan et al., 2012; Watson and Himmelick, 2013). In compacted soil, pore space is limited thereby limiting

oxygen and water (Sinnett et al., 2008). Oldfield et al. (2014) found that sapling growth and survival was improved across time after site preparation, which resulted in reductions in bulk density from ~1.4 to 0.72 $g \cdot cm^{-3}$.

Haan et al. (2012) illustrated that choosing appropriate plant species for roadside planting remains very challenging because of poor soil physical conditions and is exacerbated by the lack of post-transplant maintenance. Because safe access of highway planting sites requires preparation and planning and it becomes very expensive and the sheer volume of planted areas often makes it untenable. Death linked to transplant failure typically tapers off after 5 years (Koeser et al., 2013) but trees in poor site conditions begin dying in years 1-3 at higher rates (Nowak et al., 2004). In order to better understand the stress response of transplanted highway trees we designed a non-destructive study to mimic current practices in roadside tree planting contracts by planting the trees in to unprepared soil that tracks the transplanted trees for 5 years. So far we evaluated the survival and growth of four tree species at two sites from May to October of 2013 and again in June 2014. The aim of this study is to investigate the effects of soil compaction on bulk density and the potential influence of bulk density on: (1) growth, (2) soil moisture tension, (3) stomatal conductance and, (4) total chlorophyll content of leaves in Years 1-5 after transplanting.

## METHODS

### Study Sites

Two sites were selected along Highway 406 (southern Ontario, near Niagara Falls) at St. Davids and Beaverdams Road (hereafter known as Site 1 and Site 2, respectively). These sites were selected as they have been undisturbed since ~1965 when they were developed and the soil was compacted. For the region, mean annual temperature for 2013 was ~9°C with an annual precipitation of ~1100 mm (Table 1). Soil chemical analysis revealed that both sites had calcareous, low organic matter soil with low total salt concentrations (identified using soil electrical conductivity; Table 2).

In the fall of 2012, four cultivars grown in #10 containers were planted at both sites which included Freeman maple (*Acer* × *freemanii* 'Jeffersred', Autumn Blaze® Freeman maple), common hackberry (*Celtis occidentalis* L.), honey locust (*Gleditsia triacanthos* L.), and eastern redbud (*Cercis canadensis* L.). At both sites, trees were randomly planted in set blocks of 15 trees. At Site 1, six blocks of *A.* × *freemanii* and five blocks of *C. occidentalis*, *G. triacanthos*, and *C. canadensis* were planted. At Site 2, four block of each species were planted.

Table 1. Mean monthly temperature (°C) and total monthly precipitation (mm) for the Niagara region. Climate normal data for mean annual temperature and mean annual precipitation is also included (1981-2010; <http://climate.weather.gc.ca/>).

| Month | Temperature (°C) 2013 | Precipitation (mm) 2013 | Temperature (°C) 1981-2010 | Precipitation (mm) 1981-2010 |
|---|---|---|---|---|
| May | 15.10 | 88.00 | 12.79 | 76.35 |
| June | 19.10 | 142.60 | 18.27 | 84.90 |
| July | 22.60 | 111.40[a] | 20.85 | 100.66 |
| August | 21.00 | 61.50 | 19.95 | 79.16 |
| September | 16.70 | 76.40 | 15.83 | 81.85 |

[a]July 19th ~65 mm of precipitation fell.

Table 2. Soil chemical analysis for highway sites [N = 36 (Site 1) and 32 (Site 2)].

| Properties | Units | Site 1 | Site 2 |
|---|---|---|---|
| pH | | 7.79 | 7.77 |
| Organic matter | % | 3.82 | 3.20 |
| Total salt | $mmhos \cdot cm^{-1}$ | 0.44 | 0.41 |
| Phosphorus | $mg \cdot kg^{-1}$ | 8.65 | 6.66 |
| Potassium | $mg \cdot kg^{-1}$ | 94.72 | 91.07 |
| Calcium | $mg \cdot kg^{-1}$ | 4571.21 | 4357.27 |
| Magnesium | $mg \cdot kg^{-1}$ | 308.62 | 297.56 |
| CEC | $meq \cdot kg^{-1}$ | 2.69 | 2.57 |

**Field Sampling and Lab Analysis**

**1. Tree Response Analysis.** Repeated growth and stress parameters on a sub-set (219 of the total 552) of the planted trees were conducted at the beginning of each month from June to September. Prior to the field assessment, six trees were randomly selected per quadrat for repeated measurements. From the selected trees three branches were flagged for analysis. Growth parameters included tree height and caliper (at 30 cm for determination of trunk cross sectional area [TCSA]). Growth rates were determined for tree height and TCSA by subtracting the initial season growth (June data) from the final growth measurement taken in September. Chlorophyll content (-9.9 to 199.9) was measured using an indexed reading chlorophyll meter (SPAD 502 Plus Chlorophyll Meter, Spectrum Technologies, Inc., Aurora, Illinois) for the first three shoots of each flagged branch. Leaves for chlorophyll measurements were randomly selected along each shoot. Stomatal conductance ($g_s$; $mmol \cdot m^{-2} \cdot s^{-1}$) was measured using a steady state porometer reading (Decagon SC-1 Leaf Porometer, Decagon Devices, Inc. Pullman, Washington) in the upper exterior portion of the canopy on a leaf exposed continuously to sunlight. Porometer readings were only conducted on clear sunny days between 11:45 to 14:15.

**2. Soil Measurements and Analysis.** Soil moisture tension (-kPa) was measured using a tensiometer (2900F1L 18 Quick Draw Moisture Probe, Soil Moisture Equipment Corp., Santa Barbara, California) for each of sub-sample trees.

Soil chemical analysis was conducted on samples collected at a depth of 0-10 cm at both Site 1 (*n*=36) and Site 2 (*n*=32). Samples were sent to SGS Agrifood Laboratories <http://www.agtest.com/index.cfm> for chemical analysis; pH, organic matter percentage, total salt, phosphorus, potassium, calcium, zinc, magnesium, and cation exchange capacity (Table 2). Continuous (weekly) total salt content in the soil was also monitored during spring snow melt (monitoring period 17 Apr. to 1 May 2013) to access salt concentration and movement. However, we found that during spring melt, when highest concentrations of salt are entering the soil due to winter accumulation of de-icing agents (NaCl), total salt content (based on electrical conductivity) was low. Maximum conductivity was below 2 $mS \cdot cm^{-1}$, which is an indication that salt content was not entering the soil column but mostly removed by surface runoff.

Bulk density (Bd) soil samples were collected at two depths; 0-10 cm and 20-30 cm, using a hammer corer (core height: 51 mm and width 50 mm) at Site 1 (*n*=96) and Site 2 (*n*=64). These depths were selected to represent soil from the A and top of the B horizons. Prior to analysis samples were stored at 4°C. Bulk density samples were weighed; to determine field moisture weight before drying at 105°C for 24 h. Once dried, samples were weighed to determine dry weight and then sieved using a 2-mm sieve to remove any coarse debris (i.e., roots, rocks). Coarse fragments (>2 mm) were removed and weighed and the density of the coarse fragments (per sample) were also determined by measuring the water displacement of the coarse material. On all Bd samples, loss-on-ignition (LOI) was preformed to estimate organic matter content of the soil. Soils were ignited at 375°C for 16 h (Ball, 1964).

Soil texture [percent sand (2000-60 μm), silt (60-8 μm), and clay (<2 μm)] was determined using a Horiba Partica LA-950 Laser Diffraction Particle Size Analyzer (Whitfield and Watmough, 2012). A higher range for clay size was used (<8 μm) based off the recommendations from Konert and Vandenberghe (1997). The soil was not pretreated before analysis due to the low organic matter content. Soil particle density was determined following a similar method to Klute (1986) and Rowell (1994). Particle density was determined by water displacement in a volumetric flask at constant water temperatures (30-35°C). Samples were heated to remove any air bubbles, which could influence the sample volume. Porosity was then estimated by using the particle density and soil Bd.

**3. Statistical Analysis.** The relationship between average block soil Bd and tree growth could not be assessed due to the fact that the majority of the Bd samples were over the root limiting levels. Similarly, average block Bd could not be assessed to total chlorophyll content or stomatal conductance.

Regression analysis was carried out between soil Bd and moisture (g [water]/g [dry soil]) percentage. Regression analysis was also conducted between soil Bd and moisture tension (-kPa). Prior to regression analysis, variables were tested for normality using the Shapiro-Wilt test ($p>0.05$). All statistical analysis was conducted using Systat 13.1 (Cranes Software International Ltd.).

## RESULTS

### Survival

Winter survival of *A. × freemanii*, *C. occidentalis,* and *G. triacanthos* was high after the Fall 2012 planting. In contrast, *C. canadensis* had a low winter survival rate (Site 1 – 64% and Site 2 – 25%; Table 3). From June to September, at both sites for *C. occidentalis* and *C. canadensis* a few trees were lost due to accumulated stress. The September 2013 survival percentages represent survival rates 1 year after planting. In June 2014, tree survival was again assessed to evaluate the rate of survival after a second winter period. Survival rates decreased for all species, including *A. × freemanii* that had a 100% survival rate prior to the 2014 winter.

Table 3. Sites 1 and 2 tree survival (%) from June 2013 to June 2014.

| Species | Site 1 | | | Site 2 | | |
|---|---|---|---|---|---|---|
| | June (2013) | September (2013) | June (2014) | June (2013) | September (2013) | June (2014) |
| | Survival (%) | Survival (%) | Survival (%) | Survival (%) | Survival (%) | Survival (%) |
| *Acer × freemanii* | 100 | 100 | 90 | 100 | 100 | 90 |
| *Celtis occidentalis* | 96 | 93 | 79 | 97 | 90 | 86 |
| *Gleditsia triacanthos* | 99 | 99 | 84 | 98 | 98 | 86 |
| *Cercis canadensis* | 64 | 60 | 49 | 25 | 21 | 5 |

### Tree Growth

Tree growth (height) was determined to be higher at Site 1 compared to Site 2 for all species (Table 4). *Acer × freemanii* was determined to have the highest growth rate, compared to *C. occidentalis*, *G. triacanthos*, and *C. canadensis*. A slight decrease in average height was observed at Site 2 for *G. triacanthos* and *C. canadensis*, this was due to tissue dieback on the tree during the summer months. Overall for TCSA, positive growth rates were determined for all species at both sites.

Table 4. Average site growth rates for tree height, shoot length and trunk cross sectional area (TCSA).

| Species | Site 1 | | Site 2 | |
|---|---|---|---|---|
| | Height (cm) | TCSA ($mm^2$) | Height (cm) | TCSA ($mm^2$) |
| *Acer × freemanii* | 18.84 | 87.27 | 11.96 | 126.00 |
| *Celtis occidentalis* | 8.12 | 48.58 | 0.62 | 65.08 |
| *Gleditsia triacanthos* | 2.99 | 39.58 | -3.23 | 49.44 |
| *Cercis canadensis* | 3.78 | 32.14 | -9.31 | 23.43 |

**Soil Physical Analysis**

Average Bd was significantly higher ($p<0.05$) at Site 2 for the sub-soil (20-30 cm; Table 5). No significant difference was observed with the topsoil (0-10 cm). A wide range for soil Bd was observed at Site 1 (min – 1.16 $g \cdot cm^{-3}$ and max – 1.81 $g \cdot cm^{-3}$), compared to Site 2 (min – 1.34 $g \cdot cm^{-3}$ and max – 1.83 $g \cdot cm^{-3}$) at a depth of 0-10 cm. In contrast, at a depth of 20-30 cm, smaller ranges between min and max variables were observed. Overall, average Bd at both sites was 1.47 $g \cdot cm^{-3}$ (0-10 cm) and 1.60 $g \cdot cm^{-3}$ (20-30 cm). Based on the samples collected, 40 and 81% were above the root limiting levels for Bd (limit 1.49 $g \cdot cm^{-3}$) and 15 and 56% were above the root restriction level (>1.58 $g \cdot cm^{-3}$) for the 0-10 and 20-30 cm depth respectively. Soils collected for Bd were analyzed for coarse debris (rocks, roots, etc.), which has the potential to drastically influence soil density. Overall, the majority of soil samples collected contained no coarse debris.

Table 5. Minimum, maximum and average bulk density for Sites 1 and 2 soil at two depths (0-10 and 20-30 cm).

| Site | Depth | Bulk density | | |
|---|---|---|---|---|
| | | Minimum | Maximum | Average |
| 1 | 0-10 | 1.16 | 1.81 | 1.45 |
| 1 | 20-30 | 1.30 | 1.77 | 1.55 |
| 2 | 0-10 | 1.34 | 1.83 | 1.49 |
| 2 | 20-30 | 1.49 | 1.94 | 1.67 |

**Soil Moisture and Tension**

Two snap-shot methods to assess soil moisture were used; soil collection with oven drying and using a soil tensiometer. A significant negative relationship was determined between soil percent moisture (g [water]/g [dry soil]) and Bd (Fig. 1). Similar significant relationships were observed with LOI and porosity. In contrast no relationship was observed between clay content and moisture. Based on visual inspection of the data, soils that contained a Bd less than 1.49 $g \cdot cm^{-3}$ were more likely to have higher but more variable percent moisture. Soils with a Bd of 1.49 $g \cdot cm^{-3}$ or greater had a steady decrease in percent moisture. Soil tension measurements were taken monthly (from June to September). Values from the tensiometer were typically over the tension capabilities for the meter (> 80 centibars of soil suction), which made it impossible to determine if a relationship existed between the soil characteristics and moisture tension.

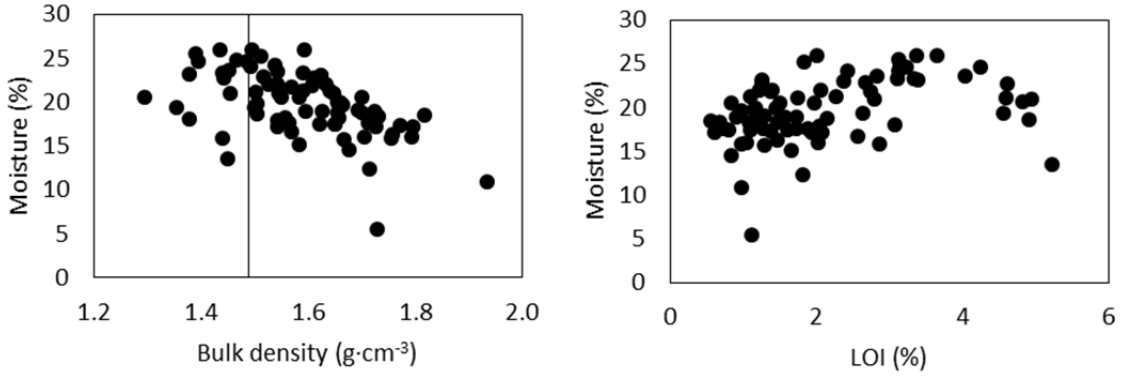


Fig. 1. Response of soil moisture to bulk density (left; g·cm$^{-3}$) and organic matter content (loss on ignition %; right). The solid vertical line (left) indicate soil bulk density at 1.49 g·cm$^{-3.}$

**Stomatal Conductance and Total Chlorophyll Content of Leaves**

Although no regression analysis was performed patterns based on monthly observations emerged in the dataset. In July, all of the tested species were considered the most stressed which was observed with the low stomatal conductance (Table 5). The highest values for stomatal conductance (least stressed) were observed in September. Peak chlorophyll content for each tree species was determined in the month of July (Table 6). Overall, a gradual decrease in chlorophyll content was observed in August and then again in September (data not shown).

Table 5. Average stomatal conductance (mmol·m$^{-2}$·s$^{-1}$) for each tree species for July, August and September.

| Species | July | August | September |
|---|---|---|---|
| *Acer × freemanii* | 70.66 | 171.50 | 199.14 |
| *Celtis occidentalis* | 65.20 | 165.53 | 257.27 |
| *Gleditsia triacanthos* | 76.38 | 195.95 | 197.35 |

Table 6. Minimum, maximum and average chlorophyll (SPAD) content for each tree species in July.

| Species | Min | Max | Average |
|---|---|---|---|
| *Acer × freemanii* | 24.41 | 29.05 | 26.73 |
| *Celtis occidentalis* | 21.13 | 26.74 | 23.36 |
| *Gleditsia triacanthos* | 25.65 | 39.87 | 35.05 |

**DISCUSSION**

The bulk density samples that were collected across both sites were above root limiting ranges for the soil type (40% [0-10 cm] and 81% [20-30 cm] were above 1.49 g·cm$^{-3}$ for silty clay soils) if not above root restricting values (15% [0-10 cm] and 56% [20-30 cm] were above 1.58 g·cm$^{-3}$) (Watson and Himmelick, 2013). Even after ~45 years for potential recovery, compaction impacts were still observed at levels that influence tree roots and survival.

Day et al. (2009) argues that when trees leave the nursery and have developed deep structural roots and roots that are not radially oriented, establishment in the landscape is more difficult. This is particularly a problem when weak or deep primary roots encounter

the compacted or poorly drained soils close to the surface in urban environments. When the conditions in the lower soil profile are less favourable than those near the surface structural roots, and as a result tree establishment, can be inhibited. Arnold et al. (2007) found that planting small [9.3 L (3 gal)] container-grown trees as little as 7.5 cm below grade decreased survival and growth of all but one of five taxa, as the trees were planted into a sandy-loam soil (15-30 cm) over a hard-pan clay.

Tree roots respond to the stress that results from being transplanted into compacted soils and low $O_2$ by concentration of root growth closer to the soil surface. Gilman et al. (1987) found that roots that are lower than 12 cm below the soil line at planting grew toward the soil surface and were most prevalent in the topmost centimeters of the soil volume. Managing root growth during production, especially of root distribution and depth in the nursery is vital for woody species that will be transplanted into compact soils in the urban environment. Gilman et al. (1987) found that *G. triacanathos* var. *inermis* seedlings had significantly shallower roots in compacted soils with more of the roots distributed into the upper soil layers. Additionally, many of the roots were directed up towards the soil surface from the deeper soil layers. Our findings regarding the influence on tree growth corroborate the findings from other tree studies that have investigated urban tree survival in compacted soils (e.g., Gilman et al., 1987; Arnold et al., 2007; Day et al., 2009). The growth of primary roots slows when it encounters denser, less aerated conditions of deeper soil conditions, which according to our findings can actually occur in the 0-10 cm range of compacted soils.

Dirr (1998) classifies woody vegetation as slow (less than 30 cm growth annually) medium (30-60 cm), and fast growing (more than 60 cm annually). *Cercis canadensis* is considered to have a medium growth rate (Dirr, 1998) but average growth was 0.04 cm at Site 1 and -0.09 cm at Site 2 (the negative value is an artefact of tissue dieback during the season). The average vertical growth of *G. triacanthos* planted in the USA was 49 cm per year during the first 7 years and when well established the annual diameter growth is 8 to 13 mm (Blair, 1990). *Celtis occidentalis* growth can be as much as 8 mm in diameter annually on alluvial soils (Krajicek and Williams, 1990) and slow growth and dwarfing is an indicator of poor soil conditions. *Acer* × *freemanii* performed the best in terms of growth for the first season after transplant. Fair et al. (2012) found *A.* × *freemanii* 'Celzam', Celebration® maple was not affected by soil compaction and put on significantly more caliper than all other cultivars despite compaction. Different cultivars responded differently to soil compaction; some cultivars of *A.* × *freemanii* are more capable of increasing caliper growth in high bulk density soils. Even for *A.* × *freemanii* cultivars however, high density soils have been reported to result in significantly smaller aboveground biomass, than those growing in non-compacted plots (Fair et al., 2012). For instance, for some cultivars growing in non-compacted plots increased caliper on average 83% more than trees growing in the compacted plots. Commonly, the effects of soil compaction on root growth of woody species precede the effects on shoot and diameter growth (Tardieu et al., 1991; Kozlowski, 1999). Our hypothesis that the suboptimal vegetative growth recorded during this study is a result of the consistently high bulk density is corroborated by Arnold et al. (2007); they found that planting below-grade into hard-pan clay significantly reduced the height growth and trunk cross-sectional area of four of five taxa. Additionally, Amoroso et al. (2010) reported that container-produced trees with root deformations from production exhibit higher levels of stress and reduced growth when compared to trees without root deformations. Height, caliper, and shoot growth in Year 2 could be decreased as vegetation growth outstrips root mass accumulation.

Héroult et al. (2013) found that stomatal conductance for *Eucalyptus* spp. was distinctly lower during a drought event compared with later in the season. Zwack et al. (1998) reported measurements of 43 $mmol \cdot m^{-2} \cdot s^{-1}$ during the fourth drought cycle for *A.* × *freemanii* cultivars which is consistent with the low average stomatal conductance values we observed in July for all species (65.20, 76.38, and 70.66 $mmol \cdot m^{-2} \cdot s^{-1}$ for *C. occidentalis*, *G. triacanthos*, and *A.* × *freemanii*, respectively). Precipitation for July

(2013) was ~110 mm (climate normal ~100 mm [1981-2010]; Table 1). July precipitation was inflated with a one-day heavy rainfall event (~65 mm fell). With the elimination of that extreme event, July was a warm, dry month with ~45 mm of rain. The values for stomatal conductance are high (values for species increased in August and again in September). Additionally, Zwack et al. (1998) reported stomatal conductance as 255 $mmol \cdot m^{-2} \cdot s^{-1}$ at container capacity for *A.* × *freemanii* cultivars. The averages for September for *A.* × *freemanii*, *C. occidentalis*, and *G. triancanthos* (199.14, 257.27 and 197.35 $mmol \cdot m^{-2} \cdot s^{-1}$, respectively) therefore appear high. However, a more in depth, multi-year study that includes various treatments for soil Bd levels would help to better explain this relationship for the species tested.

The values from the tensiometer were typically over the tension capabilities for the meter (>80 centibars of soil suction), making it impossible to determine if a relationship existed between the soil characteristics and moisture tension. However, Fair et al. (2012) found that compacted soils held water more tightly at the higher tension and less water is available for trees. Day et al. (2000) found *Acer saccharinum*'s (L.) roots were capable of penetrating compacted soils at saturation but *Cornus florida* (L.) was not. During heavy inundation of precipitation the voids in the soil may completely be occupied by water and air would be absent (Jim, 1998; Watson and Himmelick, 2013). This may explain why bottomland species like *A. saccharinum* and *C. occidentalis* are more adaptable in compacted urban soils. In the clay-based soils in the study by Fair et al. (2012) the authors report that hydraulic conductivity was significantly reduced due to compaction, and the higher density soils led to a reduction in above ground biomass for the majority of the samples that were tested.

Although survival after Year 1 was high, after the second winter, survival was reduced for all species. Miller and Miller (1991) found that much of the mortality associated with newly planted street trees (4-5 cm caliper) occurs 1 to 2 years after installation. The generally poor survival rate of *C. canadensis* may be attributed to the source of the propagative material. For instance, *C. canadensis* plants of southern origin were slower to enter dormancy under shorter days (Donselman et al., 1982). We can also attribute the low survival of *C. canadensis* to the fact it does not grow well on flooded sites and cannot survive in poorly aerated soils (Dickson, 1990).

We conclude that high bulk density is a limiting factor for tree establishment in highway roadside plantings. It is particularly of concern because of the high bulk density observed at all of the soil sampling locations tested. Although this paper avoids discussion of specific root management practices in the nursery and instead focuses on root ecological interactions with the environment it is important for the nursery industry to understand the types of environments into which their products will be planted in order to better understand how to produce plants that are better equipped to deal with the conditions of urban soils. In particular, based on the soil conditions we have encountered practices that ensure shallow structural roots that are radially oriented around the trunk are better situated to make contact with the least compact volume of soil and begin accruing resources post-transplant and would increase survival.

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# Reducing Drought Stress in Transplanted Trees Using Mycorrhizae©[1]

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**High mortality rates among most species of nursery trees after transplanting is generally attributed to water stress imposed by a range of soil and other environmental conditions. This study examined the efficacy of a consortium of mycorrhizae (Root Rescue Landscape Powder), comprised of 20 species of both endo- and ecto-mycorrhizae, in mitigating water stress when inoculated into the root zone of recently transplanted trees [*Thuja occidentalis* 'Smaragd' (emerald pyramidal cedar) and *Acer rubrum* 'Brandywine' (Brandywine red maple)]. The water status of the trees was monitored with automated stem psychrometers measuring stem water potential (Ψ) at 30-min intervals for at least 2 weeks after transplanting. Treated trees exhibited a significant reduction in mid-day water stress and enhancement of overnight rehydration, relative to control trees, when inoculated with the consortium of mycorrhizae, as shown by diurnal patterns of water stress and recovery.**

## INTRODUCTION

Irrigation of nursery plants in Canada consumes approximately 180 million $m^3$ of water annually. This represents a significant portion of the water, not allowing for the recycled portion, used by the ornamental horticulture sector (Deloitte and Touche, 2009). The majority of this nursery irrigation water is applied using overhead sprayers, which remains one of the least efficient forms of irrigation for above ground [containerized] crops (Howell, 2003). With ever increasing pressure on water resources the nursery industry is an obvious candidate for continued development of more efficient water management practices.

There are few technologies that can reliably measure the effects of water management practices on nursery crops (Jones, 2004). This technology vacuum represents a significant challenge to environmental stewardship in the perennial nursery industry. Conventional agronomic measurements such as caliper, foliage density, plant height, and qualitative assessments of plant vigour are insufficient in providing data appropriate for interpreting water management strategies in a timely manner (Jones, 2008). Other factors which must be accounted for in the water management strategy include contributions from precipitation events; leaching fraction for container grown plants; applications of pesticides, herbicides, and nutrient fertilizers; and control of run-off.

It has long been understood that the plant is the most reliable "sensor" of its environment. Plants routinely and continuously integrate the effects of all the environmental variables to which they are exposed. Significant changes in any of these variables (e.g., temperature, humidity, light, $CO_2$, nutrients, and water) are ultimately reflected in the water status of plants. Reliable plant water status data, in addition to other currently used metrics, could offer significant improvements in water use efficiency through improved irrigation scheduling (Howell, 2007).

The study of plant water relations has produced a number of techniques to measure total

[1] The presented data is a subset of a larger data set presented elsewhere.

plant water potential (Ψ) or the value of the suction forces in the water conducting tissues of a plant in response to evaporative and osmotic forces. The least invasive and most reliable technique in measuring Ψ is arguably the thermocouple psychrometer (Dixon and Tyree, 1984). Many psychometric-based systems have been developed and evaluated in the literature (Boyer, 1972; Brown and Tanner, 1981; Campbell and Campbell, 1974; Dixon and Tyree, 1984; McBurney and Costigan, 1982; Millar, 1974; Neumann and Thurtle, 1972); however, the instrument described by Dixon and Tyree (1984) has emerged as the most successful and reliable technique in the field (Dixon et al., 1988; Lee et al., 1989; Edwards and Dixon, 1995a, b; Coffey et al., 1997; Chamberlain et al., 2003). The most recent version of this device (ICT International Pty. Ltd., Armidale, NSW, Australia) was used in the current study to evaluate mycorrhizae inoculation efficacy in the mitigation of drought effects on ornamental tree species.

Root Rescue Landscape Powder (RRLP) is a proprietary compound comprised of 20 species of both endo- and ectomycorrhizae, which can be applied as a water-based root zone inoculum. There is ample evidence in the literature that supports the benefits of mycorrhizal inoculation in a number of applications, such as tree nursery and horticultural production (Marx et al., 1989; Davies et al., 1996), as well as field crops and turf grass management (Fini et al., 2011; Lehto and Zwiazek, 2011; Balakrishna et al., 2006; Auge, 2001). Numerous studies have attempted to quantify the beneficial effects of associating mycorrhizal fungi with the root zones of various plants, especially in relation to drought stress conditions (Al-Karaki, 1998; Abdel-Fatah et al., 2002), but all have lacked suitable evaluation of water potential in response to a fluctuating environment. This underscores the inherent technical difficulty and interpretation problems associated with many attempts to measure water potential in the field. As the dominant physiological variable in assessing plant-environment interactions, it is clear that better temporal resolution and more reliable measurement techniques are required if these interactions are to be reliably and correctly interpreted.

The objective of this study was to evaluate the efficacy of a custom mycorrhizae inoculum for the amelioration of drought stress in commercially significant nursery tree species following transplanting. The course of stem water potential responses was monitored for at least one extended drought period (4-7 days) for each species during the season to determine if there were differences in average plant water status responses between the mycorrhizae treated trees and untreated control trees. The study further served to evaluate the field performance of a fully automated in situ stem psychrometer equipped with wireless data telemetry.

## MATERIALS AND METHODS

### Site Description

The field trials took place between June and September, 2012 at Connon Nurseries NVK Holdings Ltd., located in Dundas, Ontario (43°21’07.90”N, 79°54’36.86”W). Six species of ornamental trees were planted in a recently constructed berm that comprised of a mix of soil and subsoil from a recently excavated holding pond. It was reasoned that this substrate would be a reasonable facsimile for housing development sites in urban areas and roadside plantings where the majority of these species would typically be planted. Trees were planted approximately 3 m apart and grouped by species. Treatments were randomly assigned within each species block within the field plot. Tree planting was conducted by Connon Nursery staff and was split up into two plantings, one occurring on 14 June 2012 and the other on 7 Aug. 2012.

### Plant Material and Mycorrhizae Inoculation

In the spring and summer of 2012, potted trees ready for transplanting were selected and planted in a specially prepared site at Connon Nurseries NVK Holdings Ltd. (Dundas, Ontario, Canada). Although eight species were planted this report will focus on two of them representing both an evergreen and deciduous species [*Thuja occidentalis*

'Smaragd' (emerald pyramidal cedar) and *Acer rubrum* 'Brandywine' (Brandywine red maple)]. The trees varied in height from 2-3 m and from 0.2-0.3 m in stem caliper at the site of installation of the stem psychrometers. There were 16 trees of each species, which were divided into two groups ($n$=8). One treatment comprised a one-time drench inoculation of the rootball during transplant at the field site. The inoculum consisted of 6 g of Root Rescue Landscape Powder (RRLP) suspended in 10 L of water (Root Rescue Environmental Products Inc., Waterdown, Ontario, Canada). The control group was untreated and both treatment and control trees were provided with the same volume and frequency of manual irrigation and natural rain events throughout the season.

For the purposes of this presentation the results of one representative deciduous species (*A. rubrum*) and one conifer (*T. occidentalis*) will be used to illustrate the water status responses of the transplanted trees to the mycorrhizal innoculations.

**Water Potential Measurements**

To assess the response to repeat cycles of drought and recovery of the trees in this field setting, each tree was fitted with an in situ stem psychrometer (Dixon and Tyree, 1984) and wireless datalogger system provided by ICT International Pty. Ltd., (Armidale, NSW, Australia). The instruments were installed as shown in Figure 1 and each of two species (32 trees) were monitored simultaneously for periods of up to 2 weeks during the summer. The psychrometer installation procedure is also outlined in detail at: <http://www.ces.uoguelph.ca/psychrometer_media.shtml>.

**Design and Statistical Analyses**

The experiment was laid out as a completely randomized design. Water potential data was analyzed using SAS PROCMixed with repeated measures (SAS Institute Inc., Cary, North Carolina, USA). Stress events were defined as the period immediately after a rain or irrigation event through to the next watering event, provided that the interim period was sufficiently dry to induce water stress as directly measured by the in situ stem psychrometer. Periods that exhibited, or were subjected to, the most stress were designated as "stress phases" and ran from 00:00 HR of the first stress day to 23:59 HR of the last stress day. A diurnal, negative peak in water potential, typically plateauing between 13:00 and 17:00 HR, characterized the maximum stress phase. Conversely, between 01:00 and 05:00 HR the trees typically displayed a recovery phase characterized by an increase in water potential, reaching a plateau sometime within this time frame. These peak stress and recovery periods (4 h) were used as the base data for the repeated measures analysis; mean peak separation was evaluated for each daily stress and recovery plateau. The 4 h stress and recovery means were based on a minimum of five instruments (one instrument per tree) collecting a water potential measurement every 30 min. No comparisons between species were made.

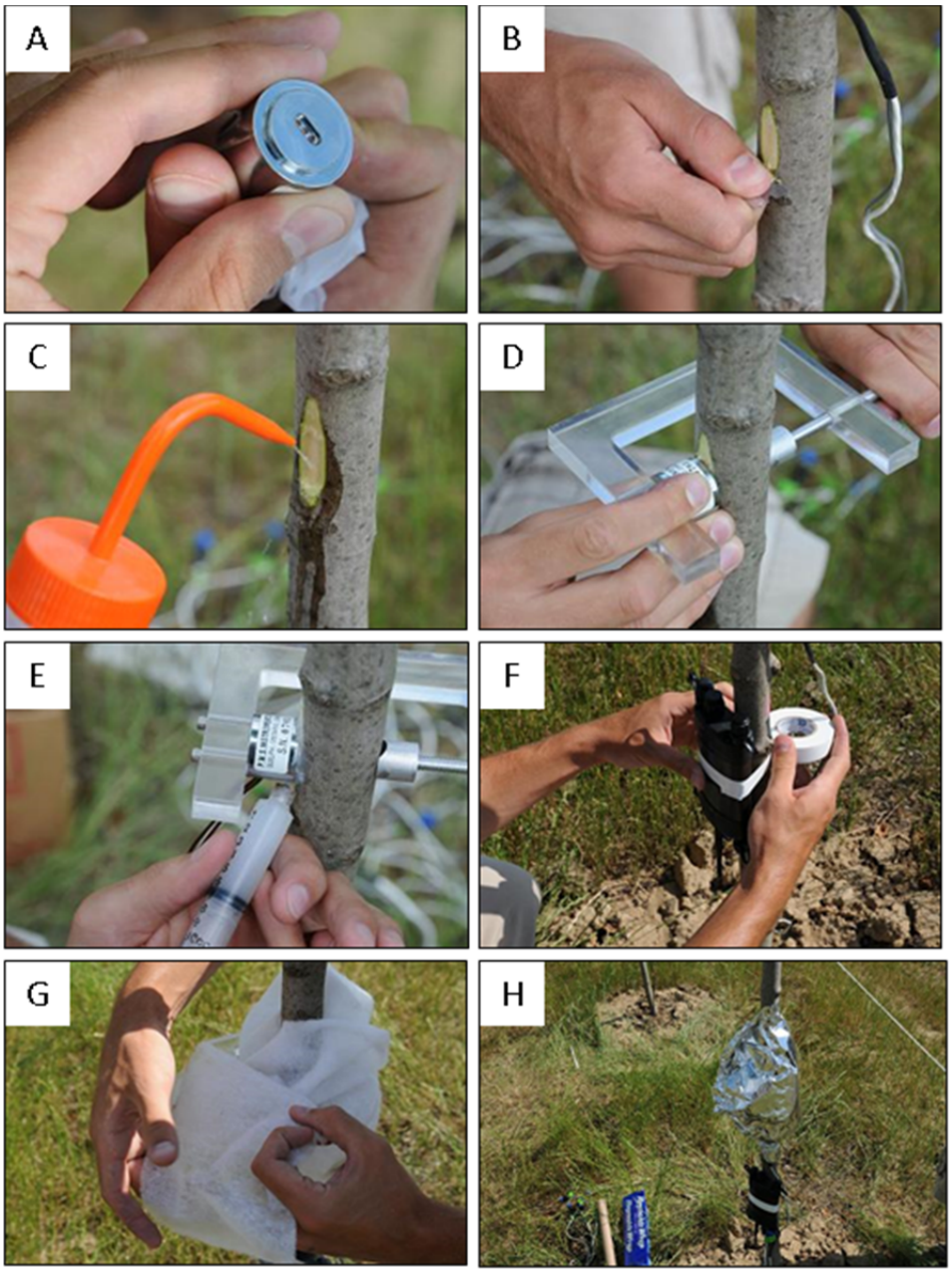


Fig. 1. Typical installation of an automated stem psychrometer for the evaluation of water stress in transplanted ornamental nursery trees: (A) Make sure sensor is clean and thermocouples are intact; (B) Expose plant sapwood tissue; (C) Use deionized water to wash away residual plant tissue; (D) Secure sensor flush against plant using clamp; (E) Apply silicone grease for a gas-tight seal around instrument; (F) Attach automated PSY data logger to plant; (G) Insulate instrument; (H) Wrap installation in aluminum foil.

## RESULTS

### *Acer rubrum* 'Brandywine'

Figure 2 shows the season long results of the RRLP treatment for *A. rubrum* following a particularly dry summer during which the treated tree exhibited a much healthier and

robust appearance than the untreated tree. The water relations data in Figure 3 showed a clear separation between control and treated tree groups. After an initial rain event just prior to the period shown in Figure 3, the mean peak separation increased each day, culminating in another watering event that brought the water potential back to a similar level in both groups during the following night recovery phase (not shown in Fig. 3). The treated trees maintained a higher (less negative) water status both in the daily stress phases and in overnight recovery phases. The cumulative effects of this water status differential between the control and treated plants are again clearly demonstrated in Figure 2.

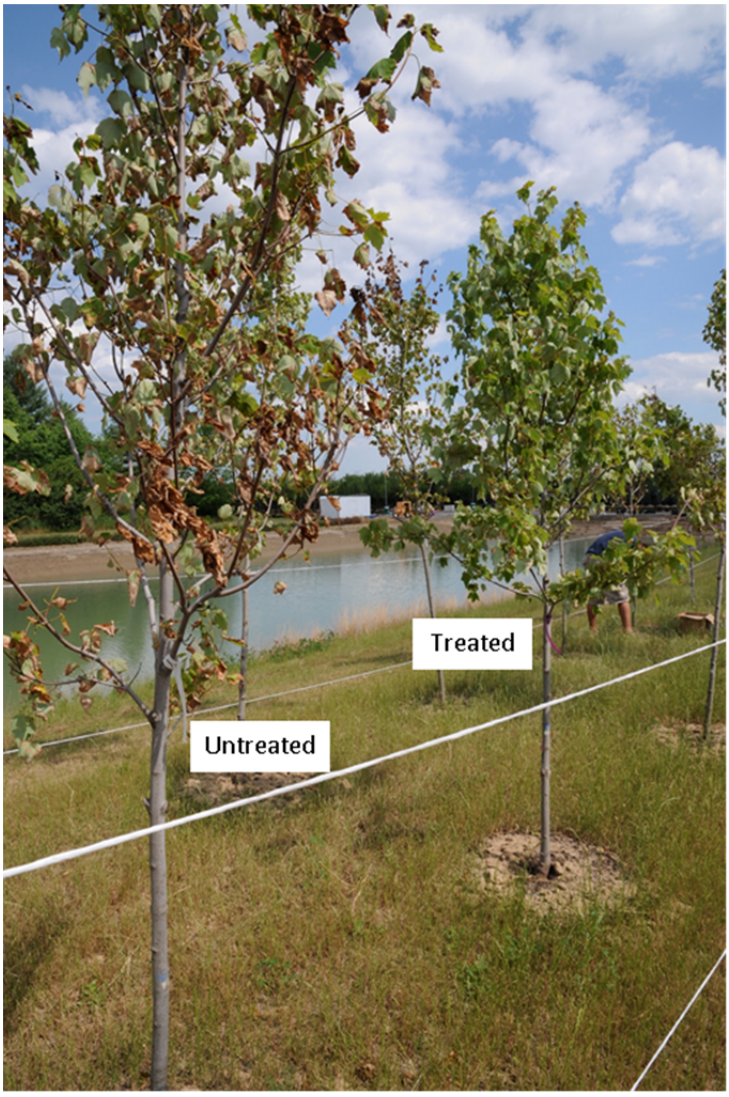


Fig. 2. Comparison of treated (background) and untreated (foreground) transplanted *Acer rubrum* trees in the experimental plot at Connon Nurseries NVK Holdings Ltd.

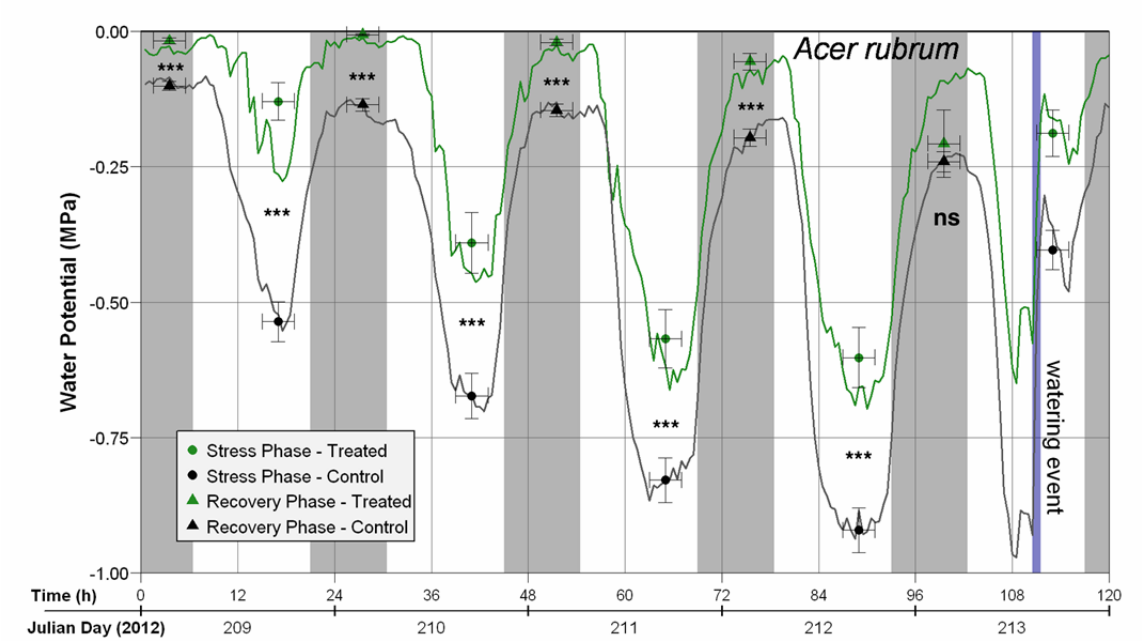


Fig. 3. Five-day drought time course of water potential (MPa) measurements comparing groups of *Acer rubrum* transplanted trees treated with a mychorrhizae inoculum and untreated controls. Lines are a local regression smoothing (loess) of all the data collected at 30 min intervals for each treatment over the 5-day drought-monitoring period. Grey shaded vertical bars represent sunset to sunrise periods. Specific stress (circles) and recovery (triangles) data points are the means of eight consecutive readings during the stress and recovery plateau periods. Vertical error bars are ±SEM; horizontal bars are the time range from which means were calculated. Daily stress and recovery mean difference significance levels are represented by: *, **, ***, ns, corresponding to P≤0.05, 0.01, 0.001 and P≥0.05, respectively.

***Thuja occidentalis* 'Smaragd'**

Figure 4 outlines the clear differences in stem water potential between treatment groups, with consistently higher water potential readings for the treated group in both the stress and recovery phases; differences between the recovery and the stress phases become more pronounced over time. According to Dixon et al. (1984), the critical threshold for stomatal closure for *T. occidentalis* is approximately -2.0 MPa. At that point, plants were found to close their stomata and decrease transpiration in order to conserve water until more favourable conditions returned. Figure 4 shows that the control group consistently fell below the threshold for stomatal closure while the treated group remained above it, suggesting that treated trees were able to remain photosynthetically active for greater periods of the day than the control trees.

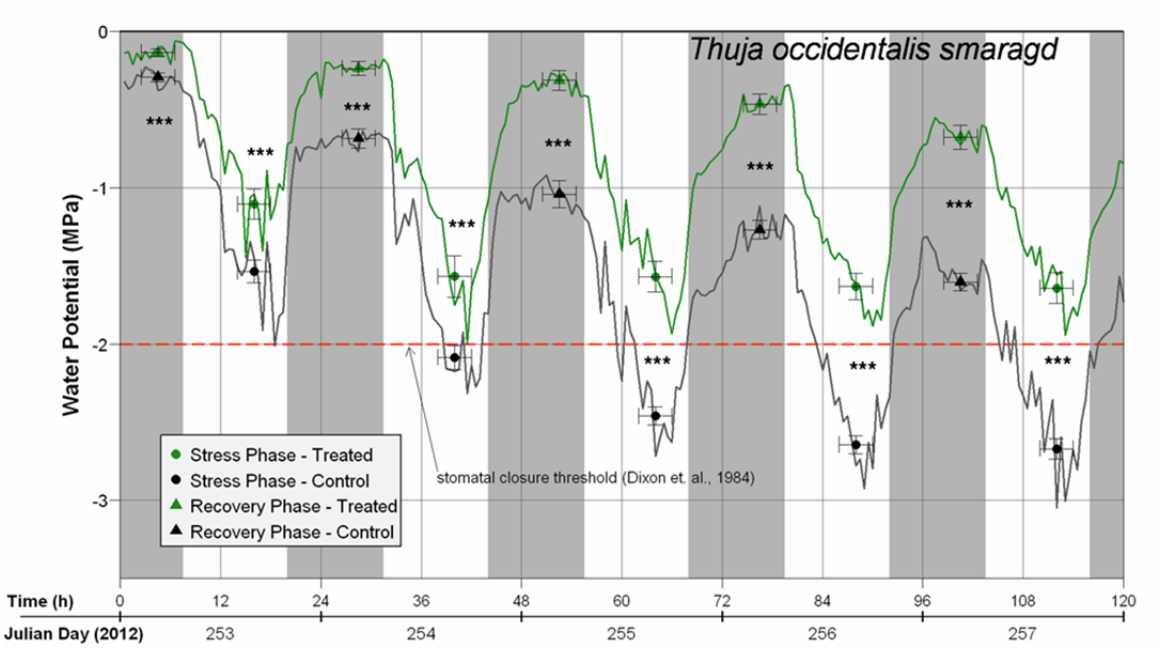


Fig. 4. Five-day drought time course of water potential (MPa) measurements comparing groups of *Thuja occidentalis* 'Smaragd' transplanted trees treated with a mychorrhizae inoculum and untreated controls. Lines are a local regression smoothing (loess) of all the data collected at 30 min intervals for each treatment over the 5-day drought-monitoring period. Grey shaded vertical bars represent sunset to sunrise periods. Specific stress (circles) and recovery (triangles) data points are the means of eight consecutive readings during the stress and recovery plateau periods. Vertical error bars are ±SEM; horizontal bars are the time range from which means were calculated. Daily stress and recovery mean difference significance levels are represented by: *, **, ***, ns, corresponding to $P \leq 0.05$, 0.01, 0.001 and $P \geq 0.05$, respectively.

## CONCLUSIONS

The time courses of detailed water potential measurements from the 2012 field trials demonstrated that RRLP was generally effective in mitigating the effects of drought stress on ornamental transplanted trees. The generally higher (less negative) water potential exhibited by the treated plants suggested that, in this case, the mycorrhizae had a direct positive effect on water uptake. The water potential trends in both the control and treated samples were negative (progressively more negative daily peak water potentials) over the course of a drying event, which was expected. Although the trend was negative, the treated plants maintained higher, more favourable overall water potentials over the drought stress period relative to the controls.

In conclusion, RRLP mycorrhizae inoculations improved overall drought tolerance in *A. rubrum* and *T. occidentalis*. The use of in situ stem psychrometers, in numbers that gave statistically reliable data, allowed for a unique look at water relations in nursery woody perennial species. The combination of in situ water potential monitoring and drought mitigating mycorrhizae inoculation, as demonstrated, may provide new mechanisms for managing irrigation water use in the nursery sector.

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Ltd. provided the mycorrhizal inoculum and extensive support of field operations.

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# Improving Irrigation Scheduling Protocols for Nursery Trees by Relating Cumulative Water Potential to Concurrent Vapour Pressure Deficit©

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**Conventional irrigation practices are based on physical factors and observations, however this fails to include plant water status measurements. This study examined the relationship between cumulative water potential with concurrent cumulative vapour pressure deficit (VPD) for the common nursery species *Thuja occidentalis* 'Smaragd' (emerald pyramidal cedar). Establishing the relationship for these plant-environment interactions will provide nursery growers with a rational irrigation scheduling tool that indicates a more effective and efficient use of scarce water resources. Plant water status and environmental conditions were monitored throughout a growing season taking measurements every 15 min between irrigation events. The overall relationship between cumulative water potential and cumulative VPD exhibited a slope response of -2.2 MPa·h/kPa·h. This coefficient provides growers with an objective tool for irrigation management for this species and leads the way to exploit this approach across the spectrum of nursery commodities.**

## INTRODUCTION

Irrigation scheduling is the balance between frequency and amount of water applied to a crop and is a fundamental concept in irrigation management (Linacre and Till, 1969). Nursery growers tend to base their scheduling on factors such as observed leaf wilt, soil dryness, and general weather forecasts. These decisions are largely subjective and can lead to inefficient or ineffective use of water resources, namely over-irrigation or under-irrigation. Ultimately, poor irrigation scheduling can reduce plant growth and directly affect product quality (Wilson et al., 1998).

Several techniques have been developed to assist nursery growers in determining the most appropriate time to irrigate; these techniques are described by Howell et al. (2007) and Jones (2004). A common procedure used for irrigation scheduling is the pan evaporation method. This technique measures the evaporation rate of an open water surface as a surrogate measure of evapotranspiration or the total water lost by the plant system. The method is a baseline attempt to integrate conventional environmental variables such as solar radiation, vapour pressure, and precipitation that influence the overall water status of the crop. It is due to the simplicity and economy of the pan evaporation technique and the robust relationship with plant water use (Eliades et al., 1988) that it is widely used. Eliades et al. (1988) and Ertek et al. (2006) have both demonstrated effective irrigation scheduling for cucumber production based on pan evaporation measurements. Although quality in irrigation scheduling is improved by using pan evaporation measurements in comparison to irrigation by observation (Howell et al., 2007), the method does not quantify the *actual* plant water status responses between irrigation events. To assess plant water status under any water management strategy, measurements of plant water potential (status) are required.

The study of water relations has developed numerous techniques to measure plant water potential, which is essentially an integrated response to all environmental variables

influencing the plant. The temperature corrected stem psychrometer (Dixon and Tyree, 1984) has emerged as the most field applicable and temporally responsive method for monitoring plant water status. Further, the method is non-destructive and, with current advancements (ICT International Pty. Ltd., Armidale, NSW, Australia), plant water status of representative plants in the field can be remotely monitored. Studies conducted by Edwards and Dixon (1995), Offenthaler et al. (2001), and Stöhr and Lösch (2004) have demonstrated the effectiveness of the stem psychrometer as a plant water status monitoring tool.

Water stress is a cumulative process that impacts a plant's overall performance between irrigation events. Quantifying the cumulative plant water status between irrigation events can lead to a deeper understanding of plant-water requirements. Smart and Barrs (1973) established that between 74-96% of diurnal variation of water potential can be explained by temperature, radiation, and vapour pressure deficit (VPD). Combining modern instrumentation to collect water potential data and concurrent measurement of standard environmental variables (e.g., temperature, relative humidity, light, etc.) can lead to improved irrigation practices, particularly if the relationship between vapour pressure deficit and plant water potential can be resolved at the whole plant level.

The relationship between cumulative water potential and environmental demand (i.e., VPD) for a common nursery species was used to develop a modified (relative to current nursery irrigation scheduling) irrigation schedule. A detailed assessment of the modified schedule was conducted to analyze and correlate cumulative water status with environmental demand (i.e., VPD) with the objective of predicting plant water status from VPD, an easily calculated environmental variable.

## MATERIALS AND METHODS

The presented study was conducted over two consecutive growing seasons (summers 2013 and 2014) and consisted of two distinct phases: (1) assessment of nursery tree water status under conventional irrigation management (season one), and (2) assessment of nursery tree water status under modified irrigation schedules designed to reduce water use (season two). Although the overall study involved two phases, only the modified irrigation scheduling results from season two are presented herein. However to summarize the first phase, baseline water status responses were collected, analyzed, and fully characterized to develop a modified irrigation strategy which was applied the following year. In the second phase, water status responses were monitored under the modified irrigation strategy and was correlated with concurrent environmental measurements of VPD to determine the relationship between these variables.

### Site Description

The study was conducted at a tree nursery located in Waterdown, Ontario, Canada (N 43° 21'24.231", W 79°54'34.568"). *Thuja occidentalis* 'Smaragd' (emerald pyramidal cedar) was selected as a representative ornamental evergreen. Each tree was grown in a pot-in-pot production system with manually scheduled/triggered drip irrigation. The trees were evaluated on the basis of the modified irrigation protocols developed from data collected in phase one (data not shown). The trees were grown in 38 L (10 gal.) pots using a potting media comprised of: peat moss (PM), composted pine bark (CPB), and leaf and yard waste compost (WC) Gro-Bark (Milton, Ontario, Canada).

### Irrigation Management

Trees were irrigated using a drip irrigation system. Drippers were calibrated gravimetrically to ensure homogeneous distribution of water during irrigation events. The average output of a dripper head was 0.19±0.01 L/min. Irrigation events were 30 min in duration, which provided a sufficient volume of water to generate a small amount of run-off, ensuring near field capacity in the pots.

Watering events were defined as either a rain event or irrigation. The modified irrigation scheduling (described below) was imposed as part of the experimental protocol, a

threshold of 10 mm or more of rain was deemed equivalent to a normal irrigation event.

**Assessing Modified Irrigation Protocols — 2014 Field Season**
Trees were arranged linearly with 30 trees, however only 21 trees were randomly selected for experimentation due to limited instrumentation. Edge effects were controlled by two additional buffer rows surrounding the row of trees. There were three irrigation treatments with seven randomly selected trees ($n$=7) in each treatment level. Previous field trials with this species (Dixon et al., 2015) had identified the range of water potentials expected under conditions designed to induce severe water stress. The first phase of the present study found that the trees never approached the levels of water stress they had exhibited (and tolerated) in that study. Therefore the routine practice of the nursery was subjectively labeled as the mild stress treatment (control). Treatments were determined as multiples of the average cumulative water potential integrals previously measured under conventional nursery practices. These were identified as: mild (1$x$), moderate (2$x$), and high (3$x$) levels of water stress. For the purposes of this report only mild and moderate stress levels will be examined.

**Water Potential Measurements**
Water potential responses were measured every 15 min using a PSY1 Stem Psychrometer sensor package from ICT International Pty. Ltd. (Armidale, NSW, Australia). The assembly and installation process is demonstrated in detail at: <http://www.ces.uoguelph.ca/psychrometer_media.shtml>.

**Cumulative Water Potential Threshold Determination**
Cumulative water potential integrals were the sums of average water potential measurements (MPa) by time (hours) accumulated during daylight hours between watering events. Each stress threshold treatment was derived as a multiple of the water stress values from the conventional irrigation protocol study in phase one. Accumulated water potential integral between irrigation events was approximately -50 MPa·h in the first phase. Based on these stress ranges, three different thresholds were selected between the lowest and highest cumulative water potential integral to cover: mild (-50 MPa·h) and moderate (-100 MPa·h) levels of water stress conditions. For each threshold, after a watering event, the cumulative threshold was reset to zero to indicate adequate soil moisture and the process was repeated throughout the season.

**Meteorological Measurements**
Meteorological data was collected using a Vantage Pro 2 wireless weather station (Davis Instruments Corp., California, USA). Measurements were collected every 15 min. which provided the same measurement frequency as stem water potentials. The main environmental variables that were monitored consisted of: solar radiation ($W/m^2$), air temperature (°C), wind speed (km/h), precipitation (mm), and relative humidity (%). Using these variables, VPD was calculated by vapour pressure equations found in Allen et al. (1998). Cumulative VPD integrals were then accumulated during daylight hours between watering events when solar radiation values ($W/m^2$) were greater than zero. These were correlated and analyzed with the cumulative water potential integrals.

**Statistical Analysis**
Statistical analyses were conducted with SAS 9.4 (SAS Institute Inc., Cary, North Carolina, USA) on water potential measurements. All treatments were compared using a repeated measures test following the mixed model procedure (PROCMIXED) to indicate significant differences between water stress treatments.

## RESULTS

### *Thuja occidentalis* Water Status

Figure 1 illustrates a sample of stem water potential data exhibiting mild and moderate stress treatments. Throughout this period, water stress levels for each treatment exhibited a distinct separation that persisted until a significant watering event occurred to rehydrate the trees in both treatments. Separation of treatment levels was based on stress thresholds that were assigned to each treatment. Under the moderate stress treatment, the trees temporarily exceeded the approximate threshold for stomatal closure of -2.0 MPa reported by Dixon et al. (1984). At that threshold, stomata begin to close in response to the experienced water stress in an attempt to decrease transpiration rates. This isohydric response is a mechanism used by plants to conserve internal water supplies and prevent water stress.

### *Thuja occidentalis* Cumulative Water Stress and VPD

In Figure 2, the relationship between VPD and water potential integrals exhibited a slope response of -2.2 MPa·h/kPa·h with a strong coefficient of correlation ($r^2$=0.83). A relationship with this degree of reliability implies that growers can simply accumulate environmental vapour pressure measurements and trigger irrigation at an appropriate corresponding level of plant water status as predicted by this relationship. Additional field trials will be used to confirm this relationship that will include multiple nursery species, which will allow for the development of a catalogue of water status responses based on environmental conditions.

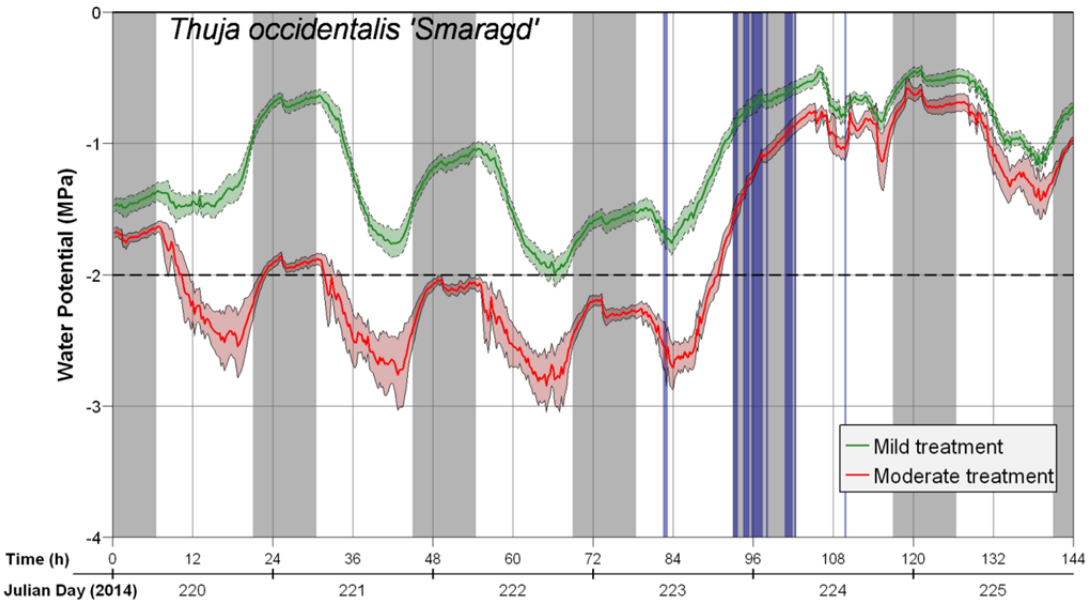


Fig. 1. A 6-day diurnal time course of water potential (MPa) measurements for *Thuja occidentalis* 'Smaragd' that illustrates water stress treatments: mild (upper line) and moderate (lower line). Lines follow a local regression smoothing algorithm (loess) for the data collected at 15 min intervals for each stress treatment. Transparent bands surrounding the water potential measurements are error bars of ± SEM. Grey shaded vertical bars indicate sunset to sunrise periods and blue vertical bars indicate a watering event. The dashed lines at -2 MPa represents the threshold of stomatal closure observed by Dixon and Tyree (1984). Using repeated measures integrated analysis, mild treatment and moderate treatments were significantly different with a $P<0.01$.

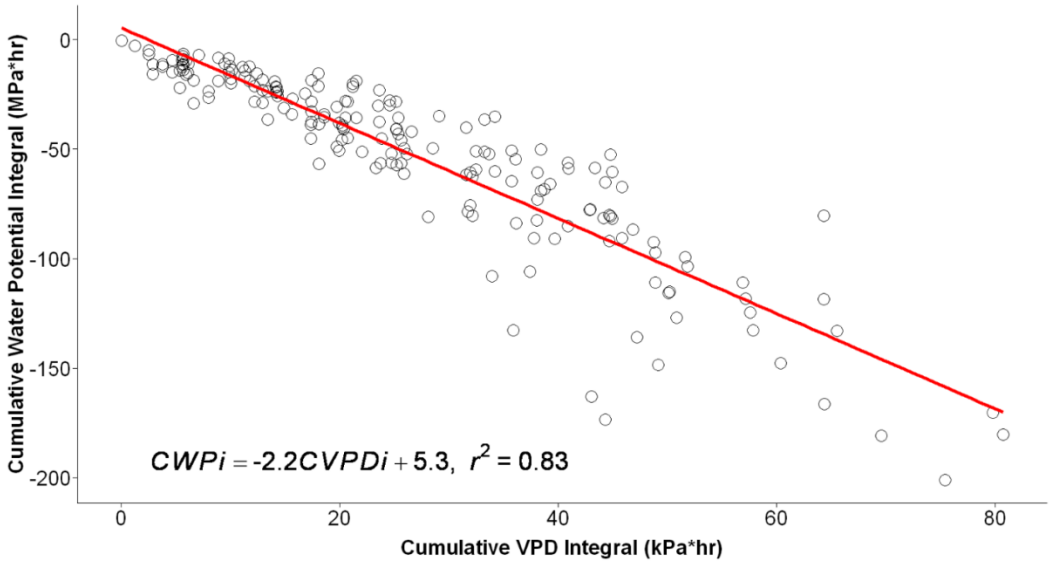


Fig. 2. Relationship between cumulative vapour pressure deficit integrals (CVPDi) vs cumulative water potential integrals (CWPi) between watering events from sunrise to sunset for *Thuja occidentalis* 'Smaragd'. Data shown contains mild and moderate treatments during the experimental period. The red line represents a fitted regression line that illustrates a slope response of -2.2 MPa·h/kPa·h with a strong $r^2$ of 0.83.

## CONCLUSION

The ultimate goal of this study was to develop and demonstrate a rational approach to irrigation management that is less subjective and more efficient than conventional methods. An irrigation management strategy that requires nothing more than a conventional weather station will provide nursery growers with a tool to indicate the exact time to initiate an irrigation event based on predicted plant water requirements.

This research represents the penultimate step towards developing an irrigation-scheduling tool that will use standard meteorological measurements to accurately predict plant water status in the field. This in turn can be used to trigger irrigation events based on actual plant needs rather than making often subjective assumptions of plant needs. The presented data clearly established the reliability of the relationship between plant water potential and VPD for this species. This relationship will now be used to form irrigation schedules based solely on calculated VPDs, with plant water potential measurements used to validate the efficacy of the scheduling in ongoing research in this field.

## ACKNOWLEDGEMENTS

The authors would like to acknowledge and thank ICT International Pty. Ltd for their kind contributions of instrumentation and technical support. Connon Nurseries C.B. Vanderkruk Holdings Ltd. for providing all plant material, irrigation supplies, and personnel support in the field. As well as Root Rescue Environmental Ltd. for contributing and supporting all of our field operations.

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# New Generation of Precision Sprayers©

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In August 2013, OMAF and MRA invited representatives from the USDA's Agricultural Research Service and Ohio State University to demonstrate a new way to spray. The "Intelligent Sprayer", developed by a team led by Dr. Heping Zhu, was trialed for 40 nurserymen and industry reps during a day-long workshop at J.C. Bakker and Sons Nursery in St. Catharines, where attendees learned about the sprayer and about how they can improve coverage in their own operations.

Given the range of crops nurserymen grow; it is very difficult to achieve effective and efficient spray coverage with only one or two sprayers. The volume of spray, ground speed of the sprayer, and the orientation and volume of air required is significantly different when spraying whips, flowers, shrubs, or container crops. Therefore, to get efficient coverage every time they spray, the operator must re-calibrate the sprayer every time they move into a new crop. This is difficult, time consuming and in most cases, not feasible.

Fig. 1. The Intelligent Sprayer.

Dr. Zhu's variable-rate, air-assisted sprayer (Fig. 1) meets the challenge by automatically adjusting the spray volume in real time based on the plant height, distance from the sprayer and the density of the crop canopy. This is not like an airblast sprayer with electronic "eyes" that turn sections of the boom on or off. The Intelligent sprayer employs a single laser sensor and onboard computer to determine exactly how much pesticide is needed from each of 40 independently-controlled nozzles. The nozzles use solenoids to switch rapidly between on and off positions. This "pulse width modulation" allows the sprayer to apply just enough spray without recalibrating the sprayer. Five Intelligent Sprayers are operating in the USA right now. To date, they have reduced spray loss beyond tree canopies by 40-87%, airborne spray drift by up to 87%, spray loss on the ground by 68-93%, and spray volume by 47-73% in a growing season.

To demonstrate the intelligent sprayer, water-sensitive paper targets were placed deep inside the canopy of trees and shrubs as far as 20 ft from the alley (Fig. 2). These yellow

targets turn blue when sprayed. The Intelligent sprayer was pitted against the nursery's overhead boom sprayer and airblast sprayer. Papers were retrieved and replaced after each sprayer finished its pass. In almost every case, the Intelligent Sprayer achieved better coverage and less off-target waste with less spray, compared to the conventional sprayers (Fig. 3).

Fig. 2. Papers placed deep in canopy.

Unfortunately, the Intelligent Sprayer is not for sale at this time. The prototype cost more than $21,000.00 in parts, alone. However, there are things operators can do to improve the efficacy and efficiency of their current sprayers.

Ontario Ministry of Agriculture, Food (OMAF) and MRA have been testing crop-adapted spraying, which is a new method of optimizing airblast applications in orchards. This method is a series of sprayer adjustments to match the sprayer calibration to the size, shape, and density of the crop. Growers have reported pesticide savings of 20% or even 50% in apple orchards, with no significant difference in pest control compared to control blocks sprayed with conventional methods. Here are a few key points on how a spray operator can make their sprayers more "intelligent":

1) Use water sensitive paper as a cheap and easy way to assess spray coverage. Place papers in hard-to-reach areas to give a true assessment of what you are hitting and what you are missing. Papers can also be placed beneath and beyond the crop to assess wasted spray.
2) Tie a 25 cm length of flagging tape to the far side of the target canopy. As the sprayer passes, have a partner assess how the flagging tape behaves. The goal is to only just move the ribbon. If it stands our straight, you are using too much air. If it does not move, spray is likely not penetrating the canopy. You can then modify your practices

according, such as: changing your ground speed, changing your fan gear, or if you are using a positive displacement pump you can change your tractor gear (gear-up, throttle-down) to change fan speed.

3) To ensure each nozzle is operating correctly, perform a timed output test (i.e., collect spray for 1 min to determine the rate). Use in tandem with the water-sensitive paper, you may have to switch to a nozzle with a different rate.

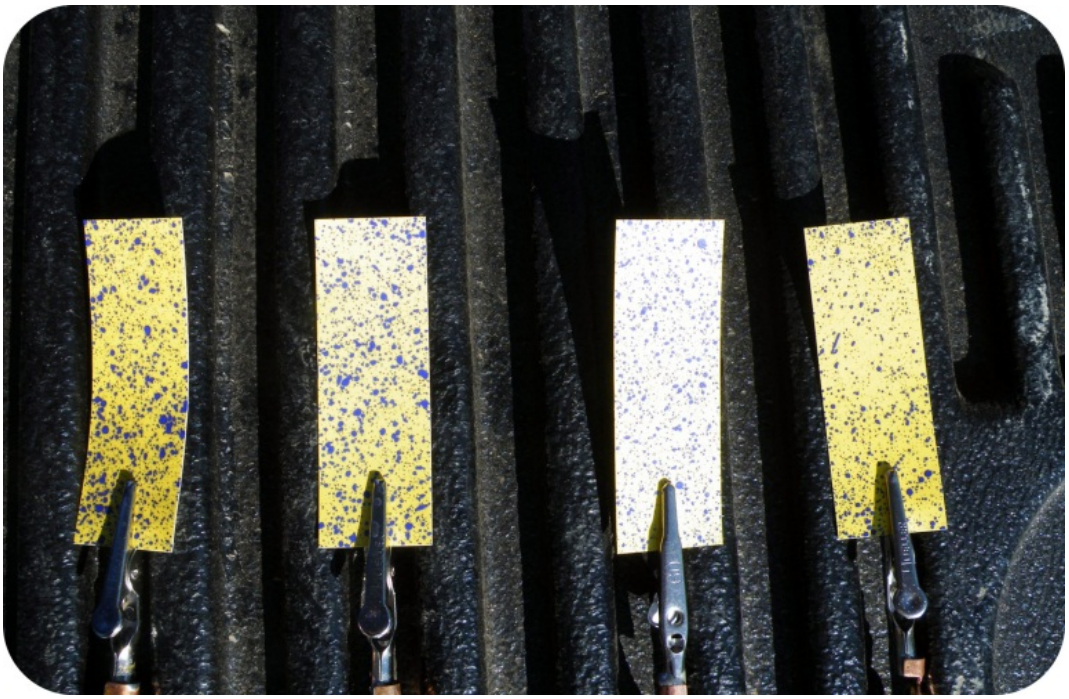

Fig. 3. Excellent coverage from Intelligent Sprayer.

Minimally-acceptable coverage on water-sensitive paper is 85 discreet drops per square centimetre and at least 10% of the paper covered with spray. If you are getting more than that, you should consider keeping your tank mix the same, but spraying less per hectare. If you are not achieving that coverage, spray more per hectare, but never exceed the label rate. The Intelligent Sprayer clearly showed that a sprayer calibrated to achieve the "right" amount of coverage reduces spray waste and improves coverage. Until it is commercially available, spray operators will have to make changes to their existing sprayers, and how they use them, to get similar results.

We are developing an app for operators to try it themselves. That information, a description of the steps for making any sprayer more effective, and so much more can be found at: www.sprayers101.com.

# Hardiness Zones and Bioclimatic Modelling of Plant Species Distributions in North America©

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## INTRODUCTION

The subject of potential species distributions has long been of interest to ecologists (e.g., Elton, 1927; Scott et al., 2002), but the subject is also important to agriculturalists, horticulturalists, and gardeners as it relates to plant hardiness. Plant hardiness is often thought of as the mortality or dieback of plants caused by temperature stress (mostly cold but also heat). In practical terms, hardiness zones are intended to help define the potential distribution of perennial plant species. The United States Department of Agriculture (USDA) extreme minimum temperature model (and related map) has been a useful surrogate for plant hardiness and is widely used throughout North America (<http://planthardiness.ars.usda.gov/PHZMWeb/>; see also <http://www.ars.usda.gov/Main/docs.htm?docid=15616> for a heat stress model).

In Canada, a plant hardiness map has also been developed (Oulette and Sherk, 1967a, b, c), and has become a standard and familiar source for Canadians. This model employed seven climatic parameters, and was thought to better represent the plant hardiness situation in Canada, where long winters and snow cover can dramatically affect plant survival and performance. McKenney et al. (2001, 2014) updated Canada's hardiness zone maps using recent climate data and modern, mathematically sophisticated climate interpolation techniques. The advent of intensive computer processing techniques and the digitization of plant observation data have opened the door to a shift away from traditional hardiness zones in favour of species-specific potential distribution models. Indeed, there has been a proliferation of species distribution models globally in recent decades (Booth et al., 2014). Any climate-based plant distribution model can be interpreted as a customized hardiness map for that species — a connection that has not been widely recognized. Here we briefly summarize some of the major changes in hardiness zones that have occurred in Canada as the climate has evolved over the last 50 years. We also briefly describe a plant hardiness project for North America that involves the collation and bioclimatic analysis of plant observation data (McKenney et al., 2007a). We illustrate the relationship between the most recent hardiness zones and species distribution models using two representative woody species and show examples of projecting species' range shifts under a changing climate.

## CANADA'S HARDINESS ZONES

Hardiness zones are widely known and used around the world to help identify what plants can grow where (Widrlechner et al., 2012). In Canada there are two hardiness zone systems, a made-in-Canada approach based on seven climate variables and the USDA extreme minimum temperature model. The Canadian plant hardiness system was originally developed by Agriculture Canada in the early 1960s using 1930-1960 climate data and involved field-based assessments of woody plant species responses to Canadian climate (Oulette and Sherk, 1967a, b, c). In the original work, survival data for 174 woody plant and shrub species and cultivars were gathered at 108 test stations across the country. A hardiness index was generated at each test location according to performance and survival rates of the various species under study. The hardiness index was ultimately

modeled as a function of seven climate variables that influence plant survival and growth in temperate regions:

- Mean minimum temperature of the coldest month
- Frost free period in days
- Rainfall June through November
- Mean maximum temperature of the warmest month
- Rainfall in January
- Mean maximum snow depth
- Maximum wind gust in 30 years.

The original plant hardiness zone map was produced by calculating the hardiness index at 640 climate stations and then hand-interpolating these values onto separate maps of eastern and western Canada (Ouellet and Sherk, 1967c). Raw hardiness values (which ranged from 0 to 92) were classified into 10, 10-unit zones (labelled 0 to 9), and each zone was further divided into two, 5-unit subzones (indicated by the letters a and b). It is these zones that are commonly known to gardeners and other users.

As noted, the USDA hardiness zone map, which is based solely on annual extreme minimum temperature, is also used to guide planting decisions in Canada. The original version of this map was produced in the 1960s (Skinner, 1962) using annual extreme minimum temperature values over the 1899-1952 time period. Ten zones were defined (1-10) based on 5.6°C temperature intervals. This model was recently updated and is available at an 800 m resolution for the United States (including Alaska and Hawaii) and Puerto Rico for the 1976-2005 period (Daly et al., 2012). This updated map has eleven 5.6°C zones (1-11) within the continental United States which are further subdivided into 2.8°C half zones (e.g., 1a, 1b, 2a, etc).

Both the Canadian (Fig. 1) and USDA (Fig. 2) plant hardiness maps have been updated for the Canadian land base using recent and improved climate data and modern climate interpolation methods (McKenney et al., 2001, 2014). High resolution versions of these maps are available at: <http://planthardiness.gc.ca>, which include fine-scaled insets for several regions of the country. Note that the Canadian and USDA zones do not overlap in a simple fashion (McKenney et al., 2006 for a detailed comparison of the two systems); this is to be expected given the very different approaches used to generate the two products.

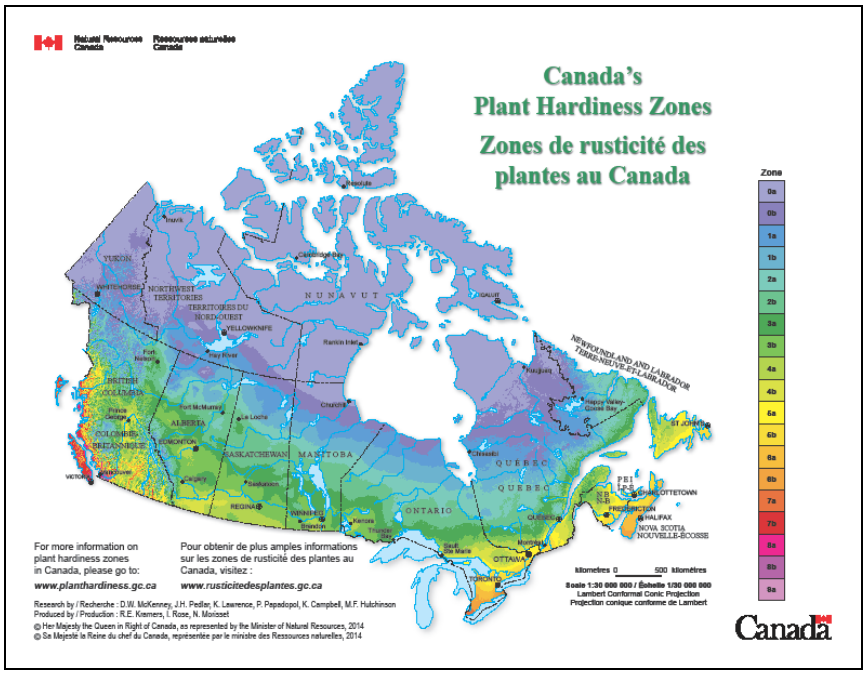


Fig. 1. Canadian plant hardiness zone map for 1981-2010 .

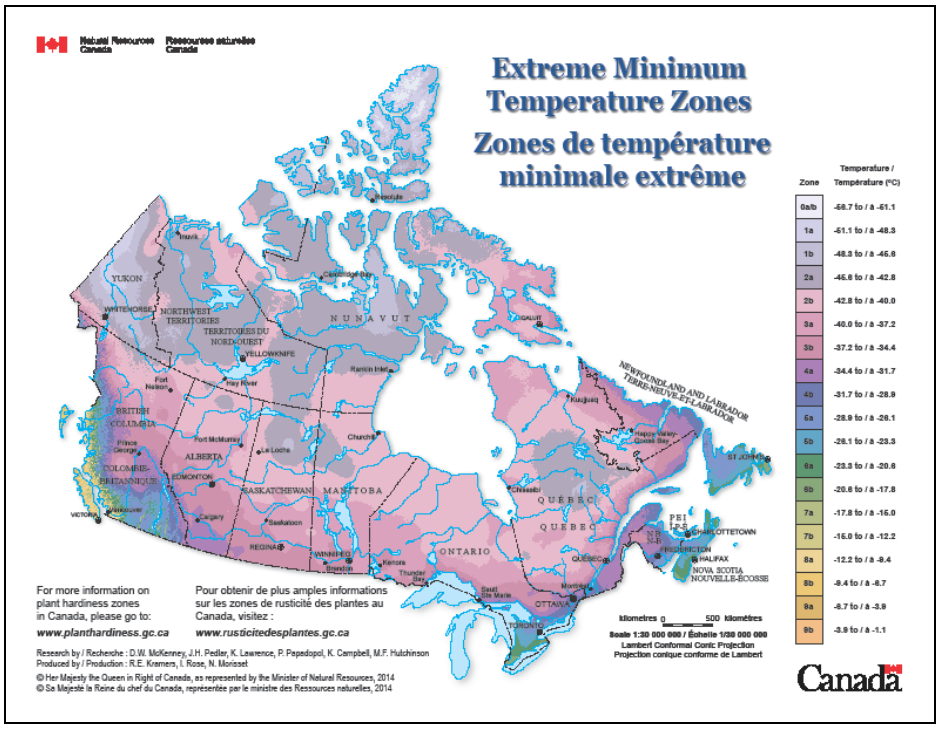


Fig. 2. Extreme minimum temperature plant hardiness zone map for 1981-2010 (follows United States Department of Agriculture approach for hardiness zones).

## CLIMATE ENVELOPE MODELS AS HARDINESS MAPS FOR INDIVIDUAL SPECIES

The Canadian and USDA hardiness zone maps summarize gradients in climate variables that, in a general and intuitive way, influence the survival and growth of woody and other perennial plants. Plants are generally assigned to hardiness zones given the experience and expectations of growers and not through exhaustive survival and performance tests (but see <http://prairietrees.ca/prairie.htm> for an example involving shade trees being tested at four nursery locations in the Canadian Prairies). As noted, an emerging alternative is the use of individual species distribution models (also known as climate envelope models), which offer a robust approach for mapping the range limits (or hardiness zone) of a plant species. For this approach, all that is needed are spatial climate models (e.g., McKenney et al., 2013) and longitude and latitude coordinates where the species is known to occur in an enduring manner; experience suggests that as few as 30 reasonably well distributed observations can produce robust models. Importantly, the approach lends itself to rapid updates as new data become available.

In support of this approach, plant distribution data from across North America have been gathered through ongoing citizen science and data sharing agreements with government and non-government organizations (see McKenney et al., 2007a for details). These data, which comprise approximately 3 million plant occurrence observations, have been used to generate climate profiles for nearly 3000 North American plant species that can be downloaded at Canada's Plant Hardiness Website <http://planthardiness.gc.ca/>. These climate profiles, generated using the software ANUCLIM (Xu and Hutchinson, 2013), provide simple statistics (min, max, mean, and various percentiles) that summarize a wide range of climate variables at the occurrence locations of each species. When mapped, a "full" climate range identifies all pixels with climatic conditions that fall between the minimum and maximum values occupied by the species for one or more climate variables of interest (Figs. 3 and 4). These full climate ranges invariably extend outside the typical range limits of the species and are probably best interpreted as an approximation of the fundamental climate niche — the potential environmental space

occupied by a species in the absence of biotic constraints such as predation and competition (Hutchinson, 1957). Alternatively, users can select percentile cut-offs to eliminate outlying data points and identify a core range that more closely resembles the species' realized niche (Figs. 3 and 4).

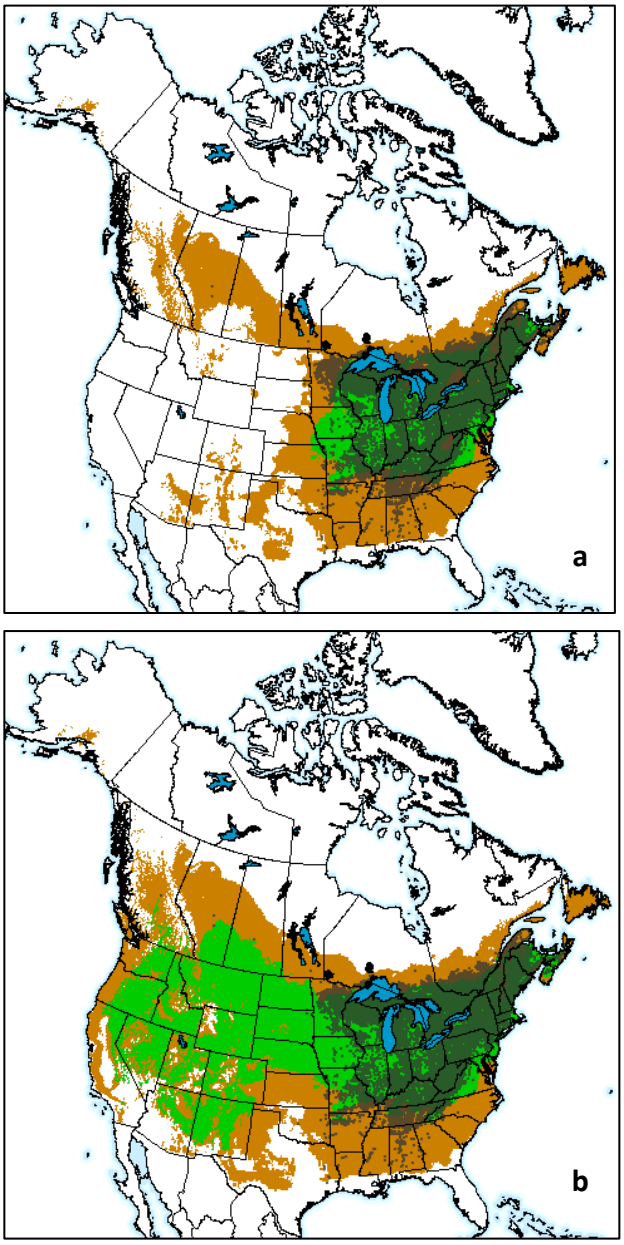


Fig. 3. Sugar maple climate envelope maps showing 41,764 occurrence observations (gray dots), full climatic range (orange), and core climatic range (green) for models based on (a) precipitation and temperature, and (b) temperature only.

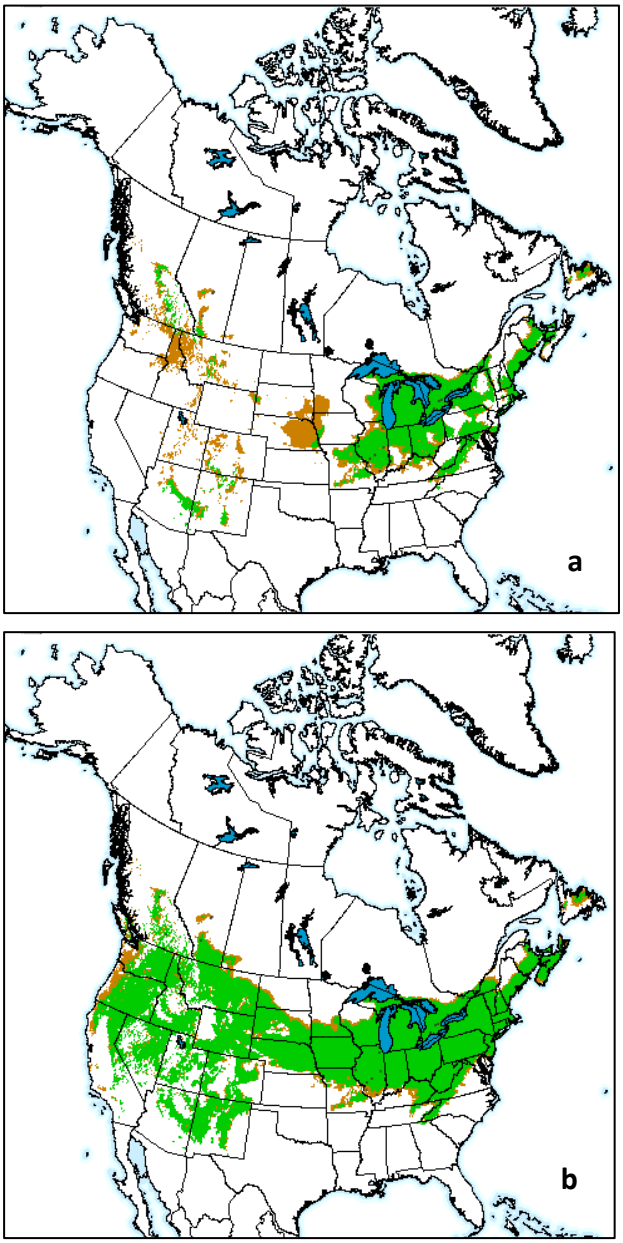


Fig. 4. Horse chestnut climate envelope maps showing 39 occurrence observations (gray dots), full climatic range (orange), and core climatic range (green) for models based on (a) precipitation and temperature, and (b) temperature only.

Several types of climate envelope models have been produced and are available for viewing at the plant hardiness web site. These include models that are based on both temperature and precipitation variables as would be experienced in natural settings (Figs. 3a and 4a), as well as temperature-only models which are aimed at horticultural situations where water can be added by the grower/gardener (Figs. 3b and 4b). A recent addition to the website is a set of distribution models generated using a machine learning method called Maxent (Phillips et al., 2006). This approach, which provides a sophisticated estimate of site suitability by comparing occurrence locations against a random selection of background points, has performed well in comparison to other distribution modelling techniques (Elith et al., 2006).

## COMPARING CLIMATE ENVELOPES AND HARDINESS ZONES

Figures 5a and b show climate envelope models for two tree species (sugar maple — *Acer saccharum* and horse chestnut — *Aesculus hippocastanum*) overlaid on the Canadian plant hardiness map. These species were selected because they were part of the original indicator species used by Ouellet and Sherk (1967a) and they illustrate other attributes associated with the species modelling approach. The sugar maple model has over 40,000 georeferenced locations in our plant hardiness database, including places well outside its known natural range (Little, 1971). In contrast, the horse chestnut model is based on only 39 observations. Sugar maple is an indicator species for Canadian plant hardiness Zone 4a, while horse chestnut is an indicator species for Zone 5a. The climate envelope models (and actual observations used in the models) suggest that the species are in fact hardy to areas outside these zone designations in certain regions. The horse chestnut model is clearly a work in progress — as new observation data are obtained the models are updated. The preliminary nature of models with very few observations is intended to help spur contributions.

## PLANT HARDINESS ZONES UNDER A CHANGING CLIMATE

McKenney et al. (2014) demonstrated that climate changes over the past century have resulted in significant changes in plant hardiness zones. Specifically, both systems exhibited: increases of 1 to 3 hardiness zone designations across western Canada; relatively small increases of up to 1 zone across eastern Canada (with some areas even showing slight declines); and the appearance of new zones (8b and 9a) on Vancouver Island that had not previously been found in Canada. The prospects for climate change in the coming century (IPCC, 2013) suggest ongoing changes to plant hardiness zones, however, future plant hardiness zone maps have not been generated due to difficulties in obtaining reliable future estimates of certain climate variables required to calculate the plant hardiness indices (e.g., maximum snow depth, maximum wind gust, and extreme minimum temperature).

Climate envelope models are well suited to climate change analysis; models based on current climate can be projected onto grids of future climate to visualize where suitable climate is expected to migrate during the course of this century. Numerous studies have applied this approach to examine changes in potential distributions of plant species. For example, McKenney et al. (2007b) undertook an analysis of 130 North American tree species; based on climate projections that assume continued high levels of greenhouse gas emissions, the average northerly shift in the climate habitat for all species by the latter part of the current century was approximately 700 km. This is not to say the species will migrate these distances, but it does suggest that a remarkable degree of migration pressure will be placed on species over the coming century. Projecting how species will actually shift in response to climate change is incredibly challenging, and involves considerations such as species' migration rates, biotic interactions, disturbance regimes, and human interventions.

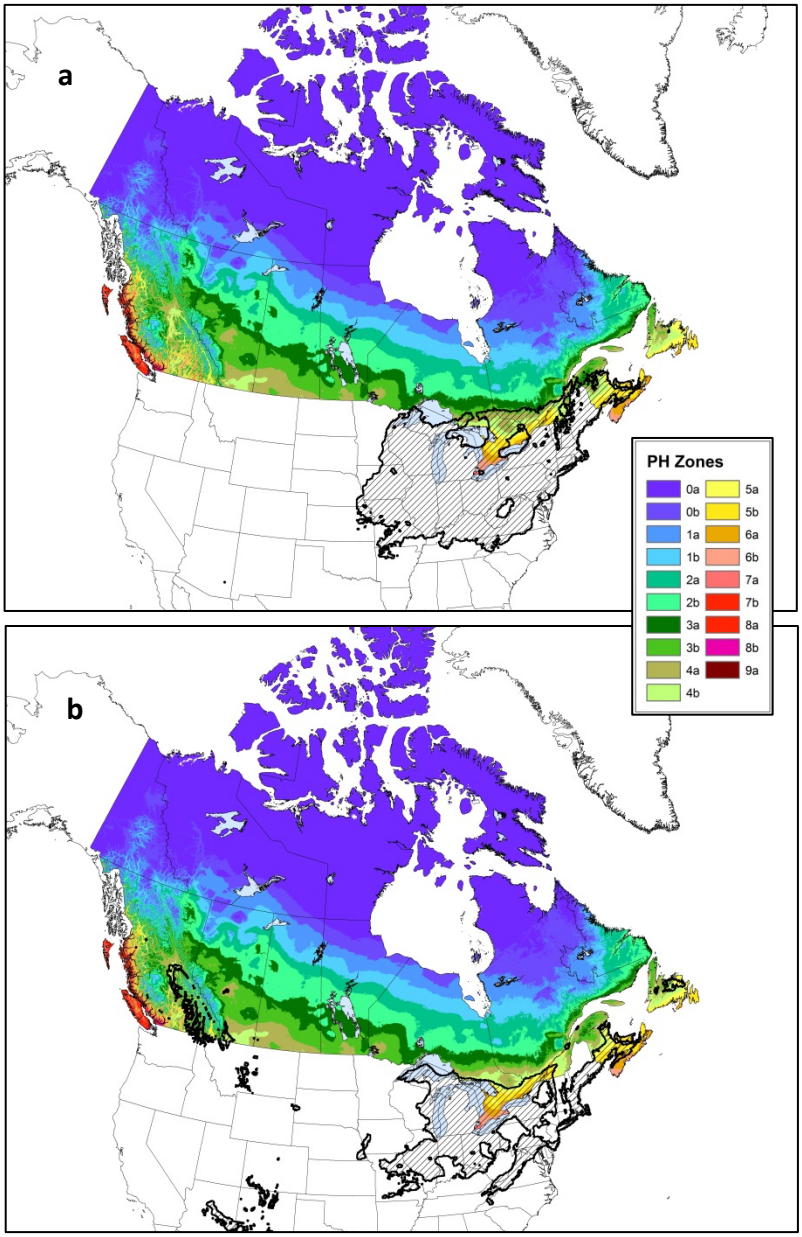


Fig. 5. Current climate envelope of (a) sugar maple, and (b) horse chestnut overlaid on the 1981-2010 Canadian plant hardiness zone map.

Figures 6a and b show the projected climate envelopes for sugar maple and horse chestnut by mid-century, overlaid on the current hardiness zones. Both species show significant northward shifts, such that locations currently designated as Zone 1 may become suitable for sugar maple, while locations currently designated as Zone 2 appear to become suitable for horse chestnut. If climate change progresses as projected, there will clearly be significant changes in planting opportunities throughout Canada. These planting opportunities may already be occurring but trends in factors such as late spring frosts may also limit success (McKenney et al., 2014). The spatial complexity of the future climate envelopes, as shown in the example here for sugar maple, indicates that temperature and precipitation are not simply projected to shift northward in synchrony under climate change; rather, certain climate combinations are expected to be lost, while novel climate combinations may also be formed (Williams and Jackson, 2007).

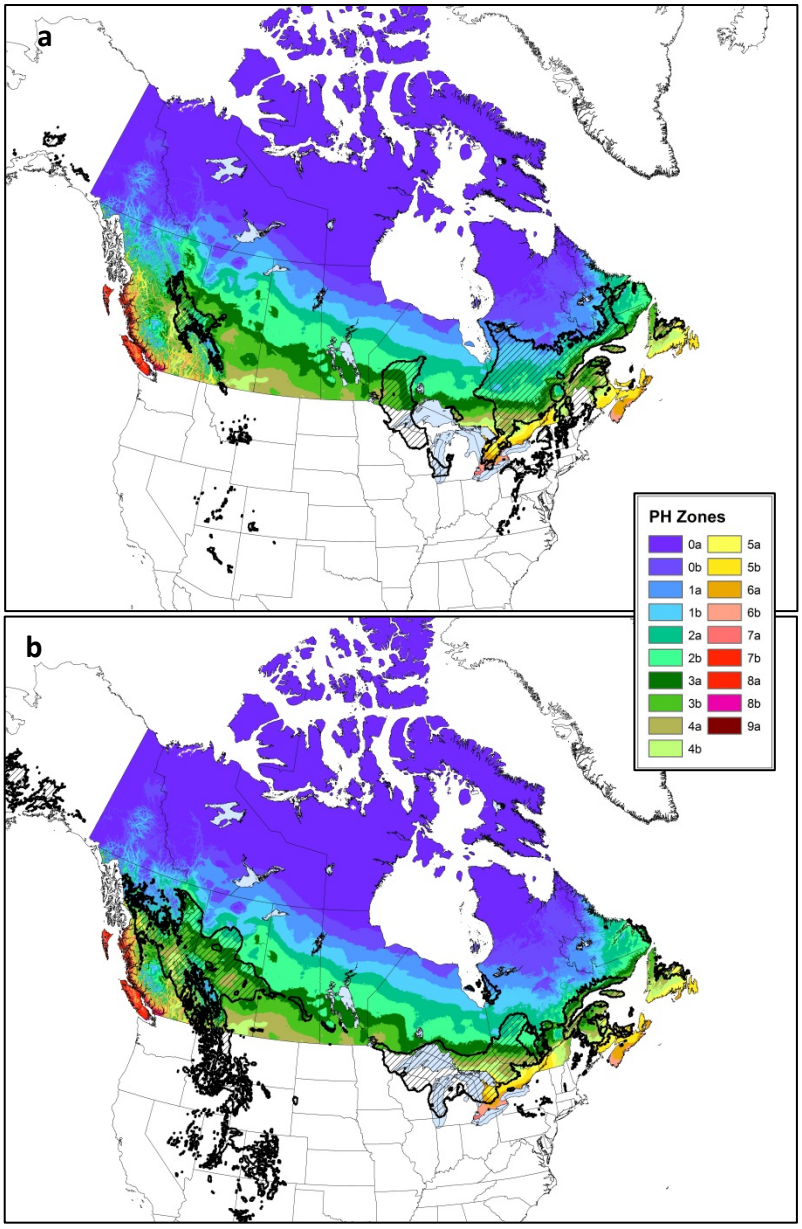


Fig. 6. Future (2041-2070) climate envelope of (a) sugar maple, and (b) horse chestnut overlaid on the 1981-2010 Canadian plant hardiness zone map.

## CONCLUSIONS

Although the hardiness map of Oulette and Sherk (1967c) was seminal for its time and represented a robust approach to hardiness modelling and mapping for Canada, there are important limitations to general hardiness zones. First, the map applied a single formula for the entire country, ignoring possible interactions in bioclimatic variables that may vary spatially, temporally, and by individual plant species. For example, as the climate evolves, warmer temperatures may be useful for plant survival in western coastal areas but could decrease snow cover in other parts of the country exposing plants to lethal minimum temperatures and damaging winter rains. Furthermore, the hardiness zone designation for a particular plant is often not based on extensive testing in the field, which limits the overall effectiveness of the system.

Given that plant species respond to climate in individualistic ways, species-specific

distribution models are increasingly practical and offer a flexible and rapid approach to mapping potential distributions. Through data gathered as part of our plant hardiness project <http://planthardiness.gc.ca>, we have developed climate envelope models for nearly 3000 species to date that cover both the USA and Canada. This work is ongoing as time and resources allow. A much larger set of plant species models could be developed with fairly minimal coordination between nursery growers and citizens and models such as those described here. Indeed it would appear that some form of citizen science would be the most effective way to build, maintain and modify plant hardiness zones in the future. Collaborations are invited.

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# Propagate Plants from Cuttings Using Foliar-Applied Aqueous (Water-Based) IBA Rooting Solutions: Tips — Do's and Don'ts©

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Today growers worldwide successfully propagate plants from cuttings using foliar applied aqueous (water-based) IBA rooting solutions. They use the Spray Drip Down and Total Immerse Methods. Leafy cuttings are taken from annual, perennial, and woody plants in the growing season. Compared with other propagation methods, foliar application has significant labor and material cost savings. Cuttings are treated in bulk at low rates.

## A BRIEF HISTORY OF FOLIAR APPLIED IBA ROOTING SOLUTIONS

More than 25 years ago growers who wanted to propagate plants from cuttings by using rooting hormones were limited to basal application. Scientists had known plants produce growth substances (rooting hormones) in leaves. Charles Darwin, in his book *The Power of Movement in Plants* (1880), described his study of the production and flow of these substances from the leaves to the lower portions of the plant. Scientists later identified the substances produced by plants. Called auxins, indole-3-acetic acid (IAA) and later indole-3-butyric acid (IBA) have been identified as natural rooting hormones. Commercial rooting hormones became available. As scientists and growers advanced procedures to propagate plants from cuttings they only focused on basal application of rooting hormones. They did not consider that foliar application of rooting hormones would naturally translocate to the basal end of cuttings where it can induce root formation.

Dr. Frederick Davies did histological and physiological studies on the foliar application of aqueous IBA rooting solutions (1978). Indole-3-butyric acid is a well used root promoting substance. The studies were concurrent with his propagation work comparing root formation in juvenile and mature cuttings.

In 1985 Kees Eigenraam, the technical advisor at Rhizopon, introduced to Dutch growers the foliar application of IBA rooting solutions to propagate plants from cuttings. At the time, Kees did not know the research by Dr. Davies. Kees and Joel Kroin began to formalize the foliar techniques later named the Spray Drip Down and Total Immerse Methods. By the early 1990s they introduced these techniques to USA growers. Initially growers of annual plants adopted the methods. Soon after, growers at Yoder (now Aris), Green Leaf Plants, and Keepsake Plants began using the Spray Drip Down Method on their many perennial plant taxa. They also developed a foliar program on their Yoder brand chrysanthemums. After 2000, Sam Drahn's studies at Bailey Nurseries led to their extensive use of the Spray Drip Down Method on woody ornamental plant cuttings (Fig. 1).

## METHODS TO PROPAGATE PLANTS FROM CUTTINGS

Currently five methods are used to propagate plants from cuttings. No one method is best for all plant taxa under all situations. Use the optimum foliar and/or basal methods as needed for the plants and operation of the facility.

### Basal Methods

Three methods are used to apply rooting hormones to the basal end of cuttings. The methods are used all year depending upon the condition of the cuttings.

Using dry powder rooting hormones ready for use:

- Basal dry dip method.

Using rooting solutions:

- Basal quick dip method.

• Basal long soak method.

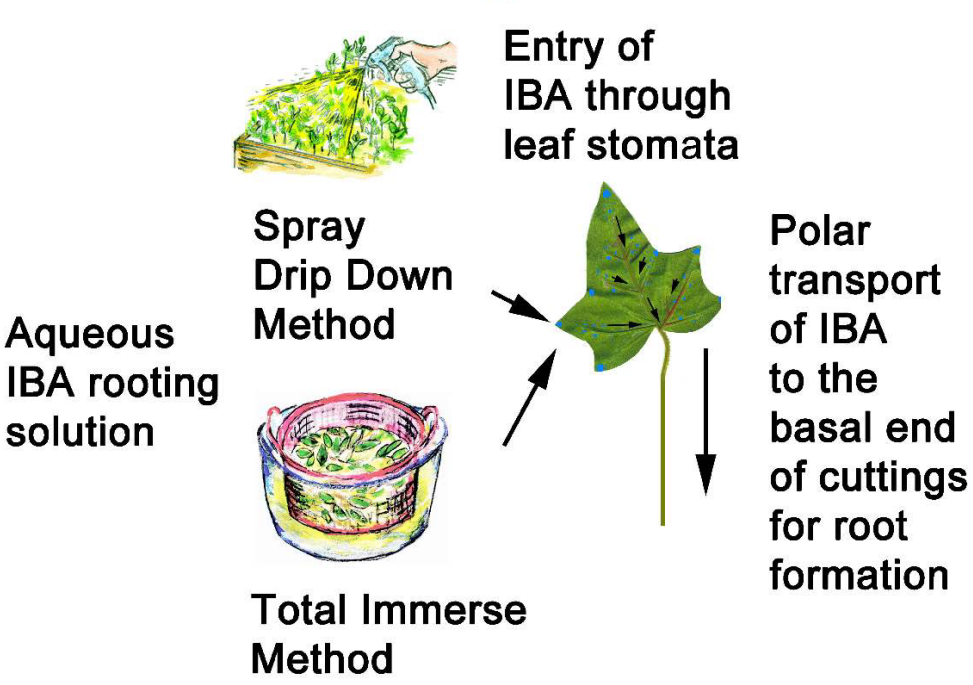


Fig. 1. Plant propagation by cuttings using foliar applied aqueous rooting solutions.

**Foliar Methods**

Two methods are used to apply rooting solutions to the leaves of cuttings. The methods are used on leafy cuttings taken during the growing season. They are not used on leafless or dormant cuttings. Using aqueous (water-based) IBA rooting solutions:

- Spray drip down method
- Total immerse method

How does foliar application work? Leafy cuttings are taken from stock plants in the growing season. The leaves of plant cuttings are treated with aqueous (water-based) IBA solutions. Indole-3-butyric acid can enter the vascular system through open pores in the stomata. Stomata are open in a temperature range from about 60-90°F (15-33°C) and when cuttings are well hydrated before treatment.

- A large number of IBA particles are deposited on the leaves. The amount is in excess of the amount that the plant needs for growth regulation (Fig. 2).
- The IBA translocates through the plant's vascular system, by polar (one way) transport, to the basal end of the cuttings (Fig. 2).
- At some time in the flow, apparently the plant is able to identify it's need for the newly arrived IBA. Somehow some of the surplus IBA is sent away from the basal end.
- Though the rooting hormones have been known and studied since the 1930s, scientists are still uncertain how they are transported, induce root cell division and root formation.
- At the basal end IBA interacts with IAA, another natural rooting hormone, to induce root formation.

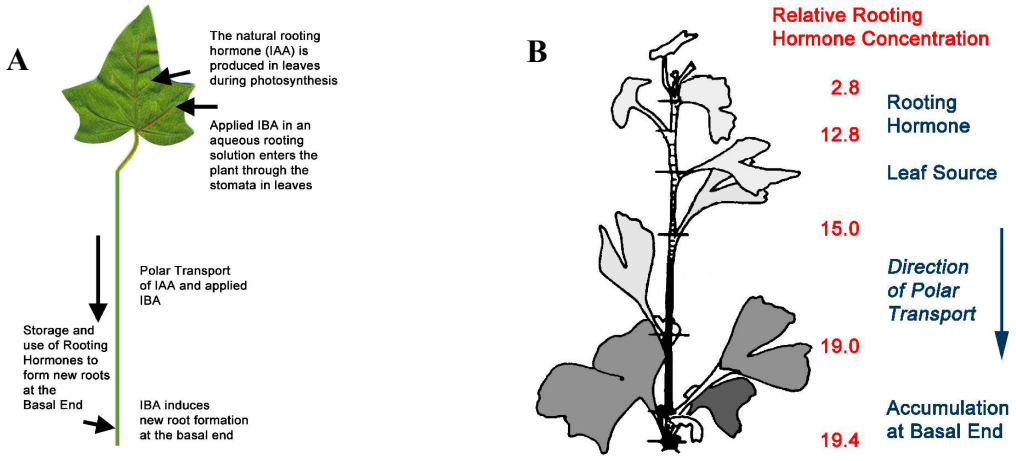


Fig. 2. A: Polar transport in cuttings of applied IBA and IAA rooting hormones. B: Relative concentration gradient of rooting hormones in a cutting based on Thimann (1977).

We can look at the IBA flow like a ferryboat (carrier) model:
The ferry boat:

- Boats pickup an increasing number of passengers on the departure side.
- Passengers are transported across the river to a small arrival loading dock.
- The loading dock fills to capacity.
- If overload, some passengers are carried back.

We can make a carrier model for the foliar applied IBA (Fig. 3):

- A large number of IBA particles in a rooting solution is applied to the broad area of leaves.
- IBA enters the plant's system vascular system through pores in open stomata. It is polar transported through in the phloem to the basal end.
- The amount of IBA needed by the plant is accumulated at the small basal site. There the IBA, in coordination with the other natural rooting hormone IAA, initiates roots.
- For the un-needed amount, the excess IBA is returned to the leaves in a non-polar route. The returned IBA may cause tender leaf deformities on existing leaves.
- New leaves and roots form normally.

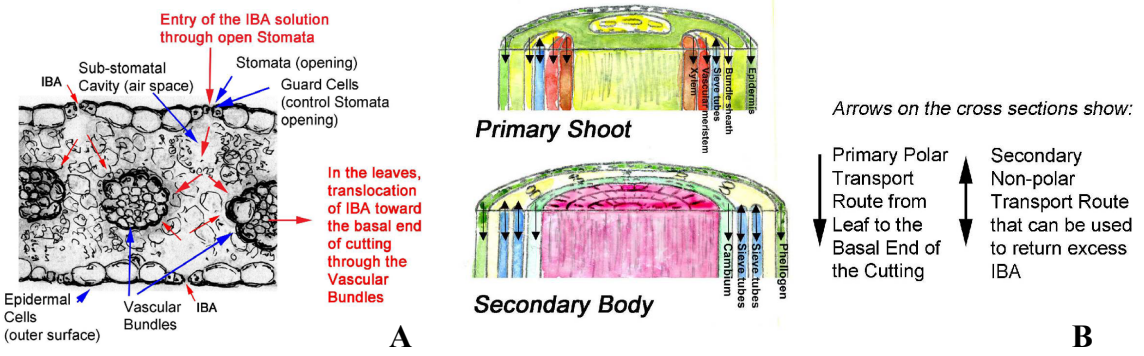


Fig. 3. A: Leaf cross section showing entry of IBA through stomata. B: Free IBA transport from leaves to the basal end of cuttings through primary shoots and secondary stem.

**1. Low Labor Cost.** Foliar methods require less labor than basal methods. It is faster to stick cuttings when they are batch treated as compared with individual basal treatment, and low foliar rates means low material cost.
**2. Temperature When Treating.** For foliar methods do not apply when the cuttings and solutions are at low or high ambient temperatures. Use foliar application when the temperature of both the solution and cuttings are at about 60-90°F (15-33°C).

**Total Immerse Method**
- Use a tub and strainer basket (Fig. 4).
- Dip the cuttings in the solution until the leaves are completely covered with liquid, about 5 sec.
- Drain.
- Stick the cuttings into media.

Some benefits:
- Simple equipment is used.
- The total immerse method can be used for large homogeneous plant lots that are clean and free of diseases.
- The method requires little setup and it can be used on small lots.
- Can be used to treat large leaves that may be difficult to spray uniformly.

Fig. 4. Total immerse method.

**Spray Drip Down Method**
- Stick the cuttings into media.
- Use the selected sprayer.
- Spray the solution onto the leaves of the cuttings until there is a drip down. The drips are visual indicator that an adequate amount of solution has been applied. The top and bottom of cuttings should be treated.
- Excess application is best.
- The solution gets sucked by capillary action into the plant. Wait about 30-45 min or until the solution dries on the leaves, then turn on misters.
- Typical solution use is about 200 sf/gallon (10 $m^{-2} \cdot L^{-1}$).

Some benefits:
- No personal protective equipment is required for sticking untreated cuttings.
- The spray drip down method can be used on many small production lots at one time.

- The solutions are used one time. There can be no cross contamination between production lots due to biological matter going into the solution.

A

B

Fig. 5. A: spraying cuttings after sticking. B: spraying cuttings until solution drips down.

**1. Sticking and Treatment Timing.**
- Apply by the Spray Drip Down Method within the day of sticking.
- For cuttings kept in a hot climate, such as southern Florida, cuttings are stuck during the day and treated early the following morning.

**2. Cutting Hydration and Misting.** Well hydrate cuttings before foliar treatment:
- Hydrate cuttings before treating to assure the stomata are open. This will allow the IBA solution to enter the vascular system.
- Wilted cuttings have closed stomata. The cuttings must be fully hydrated before treatment.

Well hydrate cuttings after foliar treatment:
- When using the Total Immerse Method, misters can be turned on any time after sticking. There is always a lag time between treatment and sticking.
- When using the Spray Drip Down Method, wait to turn on misters about 30-45 min or until the solution dries on the leaves.
- Some growers of chrysanthemum find they get better rooting when they let the cuttings lose turgor before turning on misters.

**Rooting Solutions for Foliar Methods**

Foliar methods use aqueous (water-based) IBA solutions (Table 1). Water is the natural fluid in plants that is used to translocate natural rooting substances.

The US EPA requires registration of IBA rooting products. There are only two registered products used to make water-based IBA rooting solutions and labeled for foliar application. These products are: Hortus IBA Water Soluble Salts. (Distributed by Phytotronics, phytotronics.com, <sales@phytotronics.com>) and Rhizopon AA Water Soluble Tablets (Distributed by Phytotronics, (URL: <phytotronics.com>).

Only use water-based solutions do not use alcohol-base IBA rooting solutions when using foliar application. Alcohol dehydrates plant tissue and causes cutting fatality called "alcohol burn." When using foliar methods do not use wetting agents in solutions made with Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets.

**1. Make Concentrate Rooting Solutions.** It is sometimes easier to measure and mix solutions rather than dry measure the salts or tablets for many production tanks. In those cases make up a solution concentrate at the required number of grams or tablets, then, decant the solution into the production tank. Add water to bring the tank to the required volume. Do not use dry powder rooting hormones. Dry powder rooting hormone products, like Rhizopon AA #1, #2, and #3, are not used by foliar application. These products are insoluble in water.

**2. Foliar Rates.**

*Annual Cuttings.* Annual cuttings require low rates. Some tender plant taxa and juvenile cuttings are treated at rates 80-100 ppm IBA. If rates are slightly too high there may be

some leaf distortion; the roots may form well and new leaves will be normal. Leaf distortion many not be evident on mature cuttings.
*Perennial and Woody Ornamental Plant Cuttings.* Perennial and woody plant cuttings have a similar range of rates. The selected trial rates are: 500, 1000, and 1500 ppm IBA. Rates above 1500 ppm IBA are rarely needed except for some mature cuttings. Rates below 500 ppm IBA are sometimes needed for juvenile tender perennial cuttings.
*Tissue Culture Plantlets.* Use the total immerse method on tissue culture plantlets when transplanting at the third to fifth stages. Blueberry example: use two Rhizopon AA Water Soluble Tablets per liter water.

Table 1. Trial foliar application rates using Hortus IBA Water Soluble Salts and Rhizopon AA water soluble tablets.

| Cutting type | Hortus IBA Water Soluble Salts as ppm IBA | Rhizopon AA Water Soluble Tablets in tablets per liter water |
|---|---|---|
| Annuals and tender perennials | 80-250 | 1-5 |
| Perennials | 250-1500 | 5-30 |
| Woody ornamental | 300-1500 | 6-30 |
| Tissue culture plantlets at 3rd to 5th stage transplants | | 1-3 |

- Juvenile cuttings require lower rates than mature cuttings.
- Growers generally know which of their cuttings are seasonally easy or hard to root. Based upon that knowledge it is best to select trial rates on the appropriate part of the range.
- Do not use the same rates for foliar application as used by the basal quick dip method, they are usually too high.

**Use The Proper Equipment and Cutting Material**
**1. Spray Drip Down Method.** Use appropriate spray equipment for the job for labor saving and effectiveness.
**2. Total Immerse Method.** Use a basket for dipping into the solution tank (Fig. 7A).
- Do not overload the baskets to avoid cutting breakage.
- Do not use a basket or tank made from materials that can corrode.

Figure 7A shows a simple tank and strainer at a *Hedera* (ivy) greenhouse in Europe. Notice the sticking personnel in the background. Figure 7B shows use on tissue culture plants. Few cuttings are in the basket to prevent damage.
**3. The Cuttings.** Cutting types:
- Use leafy cuttings in the growing season.
- Do not take dormant or leafless cuttings. For those cuttings use basal methods like the dry dip, basal long soak, or basal quick dip methods.

**4. Cutting Maturity.**
- Do not use hard woody or old mature cuttings.
- Juvenile cuttings are easier to propagate from cuttings compared to those which are mature. When possible, take cuttings from cuttings. Juvenile cuttings require lower IBA rooting solution rates than mature cuttings.
- Bad cuttings cannot be revived.

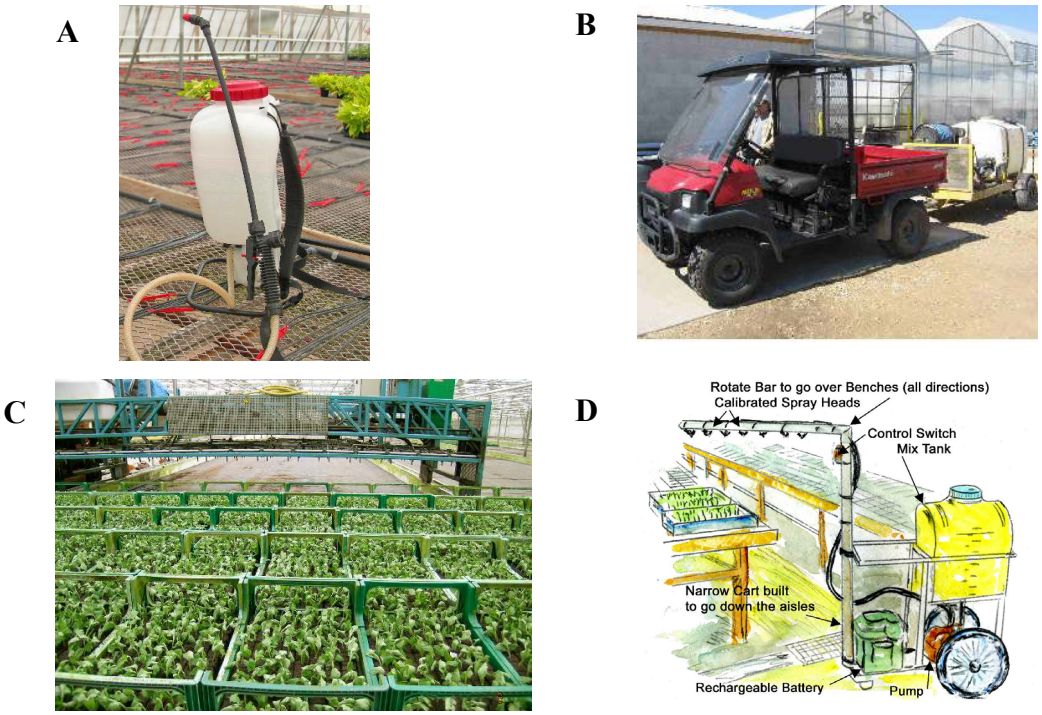


Fig. 6. Typical sprayers: A: Backpack sprayer; B: Hydraulic sprayer (Bailey Nurseries); C: Robotic sprayer on chrysanthemums in Holland; D: Sketch showing a custom spray cart used at Aris Green Leaf Plants in Lancaster Pennsylvania.

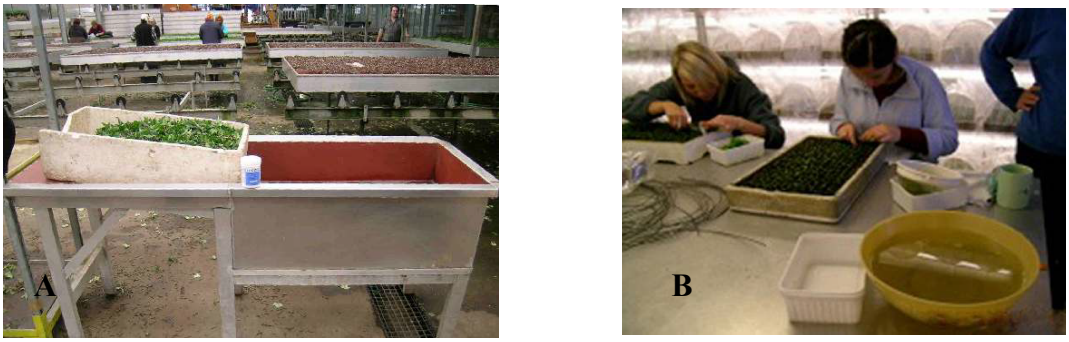


Fig. 7. A: Simple tank and strainer at a *Hedera* (ivy) greenhouse in Europe. B: Use on tissue culture plants.

**5. Cutting Nodes and Leaf Tip Cutting.** Use cuttings that do not have nodes or buds at the basal end (Fig. 8A). Do not cut leaf tips (Fig. 8B). In "old-school" for propagation by other methods, some growers cut the tips of large leaf cuttings to obtain more cuttings in a propagation tray.

There are reasons NOT to cut the tips:

- The cut causes a wound that is open to infection.
- The cuttings have reduced natural rooting substance IAA formed at a usual place, the tips of leaves. The natural IAA works with the applied IBA to induce roots. With the tips cut, there is less IAA available.
- With a wound present, the cuttings use valuable resources to heal, rather than induce root formation.

- Growing compact stock plants allows taking cuttings from an earlier stage where the preferred leaves are smaller.

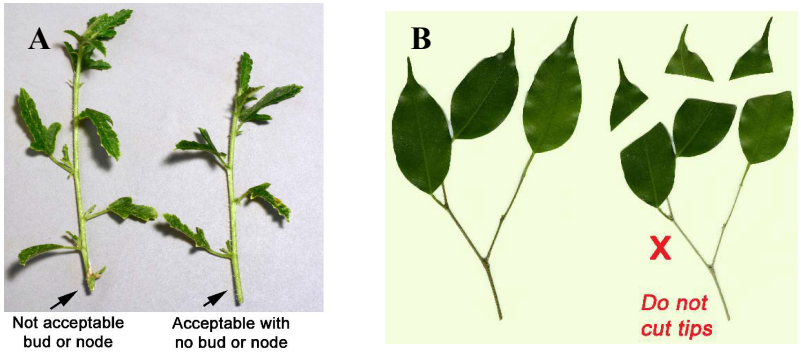


Fig. 8. A: Photo shows without node or bud at basal end; B: Photo shows cutting without tips cut.

**IMPORTANCE OF THE STOMATA**

Stomata are located on outside surfaces of plants. When stomata pores open they allow fluid, vapor and gas exchanges between the plant and it's environment. Stomata on some plant taxa are more numerous, larger, and on the underside of leaves. In some taxa there are more stomata on the underside.

Stomata functions:

- Open when cuttings are well hydrated.
- Open when temperatures and other factors are suitable for translocation of fluids and air.
- Close when cuttings are wilted.
- Close when protecting the plant from exchanges under harsh environmental conditions.
- Close in the dark and open in the light.

Sometimes identifying the primary stomata side is easy. Leaf curl means the plant is under stress leading to closed stomata interior to the curl.

**SECONDARY APPLICATION**

For leafy cuttings in the growing state that were first treated by any method, secondary spray drip down method applications are used. The application levels crops and helps to improve slow-to-root cuttings. Secondary applications are done weekly as required at the standard rates for that type of cutting.

**HYBRID PROPAGATION SYSTEMS AND SOLUTION PRODUCT INVENTORY**

- Many growers use a hybrid system of both basal and foliar applications in the same facility. By season, foliar methods may be used with some crops, dry powder rooting hormones or basal quick dip for others.
- When using aqueous IBA rooting solutions you can use the same product for both basal and foliar application solution needs. There is no need to stock more than one product.

**USE APPROPRIATE PERSONAL PROTECTIVE EQUIPMENT**

- Use the most effective personal protective equipment that complies with the product label. Unless otherwise specified, thin waterproof gloves are adequate for handling aqueous (water-based) IBA rooting solutions.

- No chemicals are handled by sticking personal when using the Spray Drip Down Method, therefore no gloves or other PPE are needed. Thin gloves may be used solely for sanitary purposes.

**AQUEOUS IBA ROOTING SOLUTION DISPOSAL**

Do not keep unused solutions for more than several weeks. Biological materials in the make-up water, such as untreated water, pond water, or well water, may cause the active ingredient to degrade. Based upon unknown biological factors, the keeping life of the aqueous solutions cannot be defined. It depends upon the quality of the water.

**ADVICE FOR METHODS**

- The total immerse method drags biological substances into the use tank. Avoid cross contamination in the solutions. Dispose the solution after each production lot or the end of the production day.
- The spray drip down method uses the solution one time. The solutions can be kept until used up. Don't keep the solutions a very long time.

**OVERCOMING PROBLEMS**

**Trials Are Essential**

Before doing full production using foliar methods, always do trials on small lots. Select appropriate leafy plants in the growing season.

- Evaluate a range of rates and methods.
- Consider the time of the year that propagation is being done.
- Review the quality of roots produced on the cuttings.
- Study the facility advantages, and labor and setup cost.

**Typical Deformities on Tender Plant Cuttings**

Leaf curl and spotting are sometimes due to too high an IBA rate, but reversible (Fig. 9).

- When IBA is applied to the leaves of cuttings, it is absorbed into the vascular system then translocated to the basal end by polar transport. At the basal end the IBA is accumulated. If there is an IBA excess, it will move back to the leaves causing leaf deformities such curl or spotting.
- Despite initial leaf irregularities, the cuttings will usually form normal roots and normal new leaves.

**A**  **B** 

Fig. 9. A: Leaf curling; B: Leaf spotting.

**Study Plant Variations**

For any successful method of propagation there sometimes may be unexpected results. The method or rate may be considered the culprit even though there was not knowingly change to the rate, method, timing, product, or other factors.

Common problems when using foliar application of rooting solutions is selection of juvenile vs mature cuttings. With excessive rates, juvenile cutting may exhibit distortions in leaves. Juvenile cuttings require lower rates than mature cuttings.

Some of many things to consider:
- Genetic variations of the cuttings: different stock plants.
- Quality of the cuttings.
- Deviations in the growing area such as changes in the environmental control systems and facility.
- Cuttings taken from a different part of the stock area, location, or plantation.
- Timing of taking cuttings from previous.
- Seasonal variations from the norm.

When other reasons are not found, somebody "forgot" to do something!

**Hybrid System**

To produce an optimum crop it may be beneficial to use several methods concurrently. Foliar methods may be used on a crop at one time of the year and basal methods at another time.
- By season, foliar methods may be used with some crops, dry powder rooting hormones or basal quick dip for others.

**CONCLUSIONS**

Growers worldwide successfully propagate annual, perennial, and woody plants using:
- Leafy cuttings.
- In the growing season.

Two foliar methods are used:
1) Spray drip down method: cuttings are stuck then sprayed until the solution drips down. Misters are turned on after 30-45 min or when the solution dries.
2) Total immerse method: cuttings are totally immersed in the solution then stuck.

Key factors for foliar method success:
- Make IBA rooting solutions using Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets.
- Cuttings are to be well hydrated before treatment.
- Temperatures at time of application should be from about 60-90°F.

All cuttings get uniformly treated: Since all the cuttings are treated in bulk, there is a reduced possibility that some cuttings don't get (basal) treatment by "misses."

Significant labor savings:
- Compared with other propagation methods, foliar application has about one-third the amount of labor used by individual treatment/sticking
- Reduced material cost due to low rates: typical rates for annual cuttings are 80-250 ppm IBA, and perennial and woody plant cuttings rates are typically in the range from 500-1500 ppm IBA. Foliar rates are usually lower than those by the basal quick dip method.

Foliar methods are useful to propagate many plants from cuttings when taken in the growing season. While foliar can be useful, basal methods may be more effective for some cuttings.

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# Optimizing Profit Improvement Potential©

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As business owners, you are constantly faced with challenges in your business that affects your profitability. The main factors affecting your profitability consist of the following:

1) The price you charge
2) The quantity that you sell or volume
3) The direct costs you incur to produce your product (i.e., direct costs)
4) The costs you incur regardless of whether you make any sales (i.e., fixed or indirect costs)

Profitability is impacted by a change in any one of these factors. Due to the dynamic business environment that we operate in today, it is likely that there is a change to multiple factors at any given time. Although you may have a positive impact in one factor such as an increase in sales volume, the effect of the profitability impact is only realized if there isn't an offsetting increase or decrease in one of the other factors. Also, some of the factors you have control over such as price whereas other factors are not in your control such as fixed costs like property taxes.

When conducting a review of your profitability factors and your strategy, some key questions to ask are:

1) Can I increase my price and what would be the effect to my sales volume?
2) How can I get my customers to buy more often?
3) How can I get more customers?
4) How can I reduce my costs?

If we look closer at price and volume, it is important to realize that for any increase in price, sales volume would have to remain either constant or any decline in volume would have to be less than the offset created by increasing the price. Likewise, for a decrease in price, the sales volume would have to increase sufficiently to offset the decline in price. Let's look at an example in Table 1 of a plant grower who currently sells 10,000 plants at a price of $100 per plant and each plant costs $60 to produce resulting in a gross margin of $40 per plant. At current levels, the grower is realizing sales of $1,000,000 per year with a gross margin of $400,000 before fixed costs.

Table 1. Price and volume effect.

| Volume: | 10,000 | plants | Current | Price Increase by 5% | Price Decrease by 5% |
|---|---|---|---|---|---|
| Price: | $ 100 | | | | |
| Cost: | 60 | | | | |
| Gross margin | $ 40 | | | | |
| | | Revenue | $1,000,000 | $1,050,000 | $ 950,000 |
| | | Direct cost | 600,000 | 600,000 | 600,000 |
| | | Gross margin | $ 400,000 | $ 450,000 | $ 350,000 |
| | | Change | | $ 50,000 | -$ 50,000 |
| | | Volume adjustment required | 1,250 | | 1,429 |
| | | | | 179 | |

If we increase the price per plant by 5% to $105, the increase in price results in increasing the gross margin by $50,000 to $450,000. Likewise, if we decrease the price by 5% to $95 per plant, the gross margin is reduced by $50,000 to $350,000. What is interesting is the effect on volume to deal with these changes. For example, if we didn't increase the price by 5%, the grower would need to sell an additional 1,250 plants in the base scenario for a total of 11,250 plants to achieve an increase in gross margin to $450,000 equal to the 5% price increase. Alternatively, as a result of the price decrease of 5%, the grower would need to sell an additional 1,429 plants just to retain the gross margin of $400,000. Many growers don't realize the effect of discounting their price and the additional volume requirements necessary to keep their gross margins or to increase their margins.

Next let's look at costs in the operations. There are two initial questions to ask:

1) Do you understand your costs?
2) Are you allocating your costs properly?

Many growers do not have a full grasp of the actual costs involved to grow their crops. Although the total expenditures are recorded, the allocation of direct costs to inventory is not necessary done correctly and there should also be an allocation of fixed or overhead costs charged to inventory to determine the actual production cost of a crop. Without a good understanding of your cost structure, it is difficult or even impossible to correctly price your crops.

Overall there are two types of costs:

1) Direct (or also called variable): these are costs that are directly incurred in the production of your crops. An example would be seeds or fertilizer.
2) Fixed (also called indirect or overhead): these relate to costs which do not fluctuate with volume levels. An example would be advertising or property taxes.

A decrease in variable costs indicates a greater efficiency in the operations and has a similar effect to the price increase in that the gross margin increases. A decrease in your fixed costs will result in improving net income but it doesn't have the same multiplier effect since it isn't linked to volume.

Table 2 below shows four different scenarios and provides some examples of the effect of price, volume, and cost adjustments. The base scenario is the same as Table 1 with 10,000 plants sold for $100 each with a direct cost of production of $60 resulting in a gross margin of 40% or $400,000. In addition, we have added a fixed cost component of $300,000 resulting in net income of $100,000.

Scenario 1 shows the effect of a 5% price increase matched with a 3% volume increase and a $3 per plant decrease in direct costs and a reduction of fixed costs by $20,000. This results in an increase to revenue of $81,500 and an increase in gross margin of 5.7% or $94,400. When you match this with a fixed cost savings of $20,000, the result is net income of $214,400 for an increase of $114,400 or 114% over the base scenario.

Scenario 2 shows the effect of a price increase of 5% per unit matched with a 10% reduction in volume, a $3 per plant decrease in cost and a $20,000 decrease in fixed costs. This results in revenue of $945,000 which is lower than our base scenario by $55,000 but is producing gross margin of $432,000 less direct costs of $280,000 for net income of $152,000. This scenario is still an improvement over the base scenario by $52,000 even though there has been a significant decrease in volume.

Scenario 3 includes an increase in volume by 10% to 11,000 plants with a 5% decrease in the unit price and direct cost per unit remaining at $60 per plant which is the same as our base scenario. Fixed costs have remained at $280,000. This results in revenue of $1,045,000, a gross margin of $385,000 and net income of $105,000.

Scenario 4 is almost identical to Scenario 3 except it shows a $3 decrease in the per unit direct cost. This results, in revenue of $1,045,000 with a gross margin of $418,000 and net income of $138,000.

Table 2. Price, volume and cost scenarios.

| | | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|---|
| Volume | 10,000 | 10,300 | 9,000 | 11,000 | 11,000 |
| Price | $ 100 | $ 105 | $ 105 | $ 95 | $ 95 |
| Direct cost | $ 60 | $ 57 | $ 57 | $ 60 | $ 57 |
| Fixed costs | $ 300,000 | $ 280,000 | $ 280,000 | $ 280,000 | $ 280,000 |
| Revenue | $ 1,000,000 | $ 1,081,500 | $ 945,000 | $ 1,045,000 | $ 1,045,000 |
| Cost of goods sold | 600,000 | 587,100 | 513,000 | 660,000 | 627,000 |
| Gross margin | 400,000 | 494,400 | 432,000 | 385,000 | 418,000 |
| % | 40.0% | 45.7% | 45.7% | 36.8% | 40.0% |
| Fixed costs | 300,000 | 280,000 | 280,000 | 280,000 | 280,000 |
| Net income before tax | $ 100,000 | $ 214,400 | $ 152,000 | $ 105,000 | $ 138,000 |
| $ improvement over base | | $ 114,400 | $ 52,000 | $ 5,000 | $ 38,000 |
| % improvement over base | | 114% | 52% | 2% | 25% |

As a result, one can see the powerful effect that price adjustment and volume adjustments can have in the profitability of your business.

The next two tables show some information regarding the amount of volume adjustments that are necessary to compensate for changes in your inputs. Table 3 shows the amount of volume increases necessary to produce the same profit. For example, if your margin is 35% and you have a price decrease of 6%, then you would need to increase your sales volume by 21% to keep the same gross margin. Table 4 shows the amount your sales can reduce when you increase your price in order to produce the same profit. If you have a price increase of 4% with a 35% gross margin, your sales can decrease by 10%.

In conclusion, it is important first to correctly understand your cost of production. Once you have the correct cost bases, then you can review your pricing decisions and effect on cost and volume to fully maximize your returns.

Table 3. Compensating for price discounting.

| | If your price margin is: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 20% | 25% | 30% | 35% | 40% | 45% | 50% | 55% | 60% |
| And you reduce price by | To produce the same exact profit, sales volume must increase by: | | | | | | | | |
| 2% | 11% | 9% | 7% | 6% | 5% | 5% | 4% | 4% | 3% |
| 4% | 25% | 19% | 15% | 13% | 11% | 10% | 9% | 8% | 7% |
| 6% | 43% | 32% | 25% | 21% | 18% | 15% | 14% | 12% | 11% |
| 8% | 67% | 47% | 36% | 30% | 25% | 22% | 19% | 17% | 15% |
| 10% | 100% | 67% | 50% | 40% | 33% | 29% | 25% | 22% | 20% |
| 12% | 150% | 92% | 67% | 52% | 43% | 36% | 32% | 28% | 25% |
| 14% | 233% | 127% | 88% | 67% | 54% | 45% | 39% | 34% | 30% |
| 16% | 400% | 178% | 114% | 84% | 67% | 55% | 47% | 41% | 36% |
| 18% | 900% | 257% | 150% | 106% | 82% | 67% | 56% | 49% | 43% |
| 20% | - | 400% | 200% | 133% | 100% | 80% | 67% | 57% | 50% |
| 25% | - | - | 500% | 250% | 167% | 125% | 100% | 83% | 71% |
| 30% | - | - | - | 600% | 300% | 200% | 150 | 120% | 100% |

Table 4. Sales decline following a price increase.

| | If your price margin is: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 20% | 25% | 30% | 35% | 40% | 45% | 50% | 55% | 60% |
| And you increase price by | To produce the same exact profit, sales volume must reduce by: | | | | | | | | |
| 2% | 9% | 7% | 6% | 5% | 5% | 4% | 4% | 4% | 3% |
| 4% | 17% | 14% | 12% | 10% | 9% | 8% | 7% | 7% | 6% |
| 6% | 23% | 19% | 17% | 15% | 13% | 12% | 11% | 10% | 9% |
| 8% | 29% | 24% | 21% | 19% | 17% | 15% | 14% | 13% | 12% |
| 10% | 33% | 29% | 25% | 22% | 20% | 18% | 17% | 15% | 14% |
| 12% | 38% | 32% | 29% | 26% | 23% | 21% | 19% | 18% | 17% |
| 14% | 41% | 36% | 32% | 29% | 26% | 24% | 22% | 20% | 19% |
| 16% | 44% | 39% | 35% | 31% | 29% | 26% | 24% | 23% | 21% |
| 18% | 47% | 42% | 38% | 34% | 31% | 29% | 26% | 25% | 23% |
| 20% | 50% | 44% | 40% | 36% | 33% | 31% | 29% | 27% | 25% |
| 25% | 56% | 50% | 45% | 42% | 38% | 36% | 33% | 31% | 29% |
| 30% | 60% | 55% | 50% | 46% | 43% | 40% | 38% | 35% | 33% |

# Did You Say the "V" Word?©

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Nursery growers and other landscape horticulture professionals never cease to amaze me by their extensive knowledge of plant botanical names. Most of us learned botanical names from an early age, perhaps hearing them from our parents, in an educational setting or, in the workplace. Both botanical and common names are a requirement for us to be fluent in our profession. Who among us has not had the temptation to rattle off a long, tongue-twisting name for someone not so well versed in botanical Latin? I have used *Ampelopsis brevipedunculata* var. *maximowiczii*. Apparently the currently accepted name of that plant is *Ampelopsis glandulosa* var. *heterophylla*. Perhaps botanical taxonomists just try to increase our vocabulary.

Plant names come easily for us as we work with plants every day. Thousands of botanical names, many with unusual sounds like *Trachelospermum*, *Eleutherococcus*, and *glyptostroboides*, roll off our tongues like water over Niagara Falls. However, there is one word that should rarely roll off our tongues. That is the word "variety". What we mean and should say is "cultivar".

Nursery catalogues and trade magazines are filled with plant names correctly enclosed in single quotes. Those marks denote a cultivar. However, when speaking, many professionals say variety for those names. Many respected gardening personalities on radio and television incorrectly say variety when they mean cultivar. Even some nursery catalogues, trade magazines, and promotional materials use variety when they mean cultivar.

The *International Code of Nomenclature for Cultivated Plants* (ICNCP, 2009) indicates that: (1) "the botanical categories *varietas* (var.) and *forma* (f.) are not equivalent to cultivar and these terms must not be automatically treated as equivalent terms for cultivar", and (2) "the English words "variety," "form," and "strain," or their equivalent in other languages must not be used for the word "cultivar" ….". Perhaps confusion arises from the fact that some national and international legislation uses variety as a legal term "to denominate a proven variant that is distinct, uniform, and stable, and is exactly equivalent to the word "cultivar" …" (ICNCP, 2009).

Dirr (2009) describes the word variety (or subspecies) as "… individuals displaying rather marked differences in nature. The differences are inheritable and reproduce true-to-type in succeeding generations". An example is *Cornus florida* var. *rubra*. A seedling population from a single, individual variety may have some seedlings without the parent's unique trait. A closely related term is form (*forma*) that Dirr (2009) describes as "plant variation that occurs sporadically and randomly throughout the population of a native plant species. The trait is usually unstable (unreproducible) through sexual reproduction (seed) and must be reproduced vegetatively …". His example is *Lindera benzoin* f. *rubra*.

Dirr's (2009) description of a cultivar is "an assemblage of cultivated plants which is clearly distinguished by any characters (morphological, physiological, cytological, chemical, or others) and which when reproduced (sexually or asexually) retain its distinguishing characteristic(s)". His example is *Cercis canadensis* 'Forest Pansy'. Cultivar names begin with a capital letter and are written within single quotes.

Varieties have their origin and exist in nature. Cultivars are variants that originate and are perpetuated in cultivation. Another way to think of the difference between a variety and a cultivar is that if the word in written within single quotes, call it a cultivar not a variety.

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# Using Ultraviolet-C Light as a Plant Growth Regulator©

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## INTRODUCTION

Plants use sunlight for photosynthesis and are exposed to the ultraviolet (UV) radiation that is present in sunlight. Ultraviolet radiation is divided into three classes: UV-C, UV-B, and UV-A. The ultraviolet-C (UV-C) region of the UV spectrum includes wavelengths from 200-280 nm; these highly energetic wavelengths are absorbed by ozone and are not present in the sunlight at the earth's surface. Under normal growing conditions, effects of UV-C light are not seen on plants.

At 254 nm wavelength, UV-C irradiation is germicidal. As a result, UV-C irradiation has been successfully used in the food industry as an environmentally-friendly and safe defense-inducible biological elicitor for meats and horticultural products such as juices, fruits, and vegetables (Gonzalez-Aguilar et al., 2007; Vicente et al., 2005; Wilson et al., 1997). Very recent research from Europe has demonstrated very promising uses of UV-C to suppress diseases in ornamental plants, to extend postharvest life of cut flowers, and as a pre-harvest treatment, to make plants flower quicker and grow with increased fresh mass and lateral branching (Darras et al., 2012, 2013). Other potential uses of UV-C irradiation have also been identified in the plant sciences, especially with plant tissue culture (Aros and Bridgen, 2013).

A new research project has begun this year using UV-C irradiation thanks to a grant from the American Floral Endowment. The objective of this project is to determine the effects of ultraviolet-C irradiation (UV-C) on commercially-valuable greenhouse ornamental plants with specific interest in disease suppression, growth regulation (height/branching/fresh weight), and postharvest longevity. The use of UV-C irradiation is a low-cost technique that is easy to apply to plants. It has already been shown to be a defense-inducible biological elicitor in horticultural products that can extend the postharvest vase life of cut flowers, suppress attack from natural diseases such as *Botrytis cinerea*, *Penicillium expansum*, and other plant pathogens, and act as a natural growth regulator (Darras, 2013; Darras et al., 2010).

## MATERIALS AND METHODS

Germicidal low-pressure vapor UV lamps were assembled on a moveable frame in the Cornell University greenhouses for treatment applications. A plywood box measuring 4×4×8 ft. was constructed on the greenhouse bench and surrounded the lights to exclude outside light. Each lamp has a nominal power output of 30 W and peak wavelength emission of 254 nm. The dosage rate was measured at room temperature (~25°C) using a Zenith Ultraviolet Meter. Ultraviolet-C doses of 0, 0.5, 1.0, 2.5, 5.0 or 10.0 $kJ \cdot m^{-2}$ were applied to the test plants depending on the experimental design and exposure times in seconds.

Seedlings of *Pelargonium* × *hortorum* (geranium), *Impatiens wallerana* (impatiens), *Salvia splendens* (scarlet sage), *Catharanthus roseus* (vinca), *Portulaca grandiflora* (moss-rose), *Viola* × *wittrockiana* (pansy) and others were treated for different times (weekly treatments) and UV-C intensities. The light intensities were accomplished by varying the closeness of the lamps to the plants and the duration of treatments. The duration of treatments varied on the day of application (for example: 15, 30, 90 min) and the number of treatments (weekly for multiple weeks). After treatment, the seedlings were transplanted into larger pots and grown until anthesis. The plants received normal watering and fertilizer regimes and were arranged in the greenhouses in a randomized complete block design. Three to six replications per species were used per crop cycle with replicate trials; non-irradiated plants were used as controls.

Growth and flowering responses were evaluated from phenotypic observations during the cultivation period. The number of days to first inflorescence, number of inflorescences, and plant height (cm) were recorded every week or at the termination of the treatment and experiment. The number of lateral stems were recorded when the plant reached anthesis. Fresh and dry weights of the upper parts of the plants (i.e., stems, leaves and inflorescences) were recorded with a digital balance.

## RESULTS

This research recently began this year and the results that have been seen so far are very exciting. The first thing that was determined was the range of dosages of UV-C light that were damaging to the plants. The dosage of light that a plant receives is a combination of the distance from the plant that the light is and the amount of time that a plant is exposed to the light. If the dosage is too high, plants show damage within 24 h of treatment. Extreme damage symptoms include crispy and off-color leaves.

When young plants receive certain levels of UV-C irradiation, they will have shorter growth habits when they reach flowering than plants that received no UV-C irradiation. Plants that showed this response included African marigold (*Tagetes erecta*), French marigold (*T. patula*), pansy (*V. tricolor*), scarlet sage (*S. coccinea*), vinca (*C. roseus*), and zinnia (*Zinnia elegans*). Some plants showed increased branching when they received UV-C irradiation as seedlings. These included pansy (*V. tricolor*), scarlet sage (*S. coccinea*), and to some degree, geraniums (*P. × hortorum*). There is evidence that UV-C light treatments affect the time to flower of some plants. With pansy plants that received UV-C light, it was noticed that flowering began 1 to 3 days earlier than control plants. With other plants, such as scarlet sage (*S. coccinea*) and geranium (*P. × hortorum*), flowering was slightly delayed due to the UV-C light treatments. These results were dosage-dependent.

## SUMMARY

There are several positive and significant impacts of applying UV-C irradiation to greenhouse seedlings. This research has shown that UV-C light treatments can be used as a plant growth regulator; proper application of UV-C light to seedlings of annual plants can reduce plant height, increase branching, and delay or promote flowering depending on species.

This technique has worked successfully on a number of annual plant species including African marigold (*T. erecta*), French marigold (*T. patula*), pansy (*V. tricolor*), scarlet sage (*S. coccinea*), vinca (*C. roseus*), zinnia (*Z. elegans*), and geraniums (*P. × hortorum*). This research has just begun and will continue to fine-tune the dosage rates and amount of time that seedlings need to be treated.

The use of UV-C irradiation has several advantages as a plant growth regulator. This novel technology is a low-cost technique that is easy to apply to plants. By using simple light fixtures with special light bulbs, the UV-C can be administered. It has the potential to save time and money for greenhouse growers by decreasing, or possibly eliminating, the need for plant growth regulators (PGR). If implemented as a PGR, it can have tremendous benefits for the environment by reducing pesticide applications to plants.

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# The Effects of Potting Container Size and Irrigation Frequency on Medium Temperature©

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**This report focuses on the effects that potting container size and irrigation frequency has on the medium temperature and overall appearance of *Senecio cineraria* (dusty miller). A 7-week trial was conducted in which 20 four replicates of *S. cineraria* were potted into 1-, 2-, and 3-gal containers and evenly divided into two irrigation treatments: as needed (Treatment A), and on a daily basis (Treatment B). Their medium temperatures, as well as ambient and ground temperatures, were recorded throughout the trial.**

**Quantitative results showed that plants in Treatment A tended to exhibit higher medium temperatures, usually surpassing ambient temperatures. Results also showed that the medium temperatures of plants in 1-gal container were usually the highest ones and tended to fluctuate more than those of plants in 2- and 3-gal containers, and they also tended to exceed ambient temperatures. Finally, difference in temperature between container size was less evident for plants in Treatment B. Qualitative results showed that plants in Treatment B were bigger, more abundant, and had less dry leaves than plants in Treatment A; and that plants in 1 gal containers were the smallest and exhibited more dry leaves.**

**It was concluded that daily watering of *S. cineraria* helps to maintain their medium temperatures close to their preferred range more effectively, that *S. cineraria* grow faster and healthier when potted into 2-gal and 3-gal containers, and that medium temperature is ultimately dependant upon their surroundings. Recommendations include watering *S. cineraria* every day, potting them into containers bigger than 2 gal, and conducting further research and enhanced trials on this area.**

## INTRODUCTION

Over the past years, container-grown plants have emerged as the most popular method of growing plants for sale in the horticulture industry (Evans, 2013). With its many benefits, such as better establishment of plants after transplanting, decreased labour, and increased product availability, growers have started to shift from traditional in-ground production to the container one (Mathers et al., 2007). Nevertheless, growing plants in containers alters root growth and function, and it may change root morphology (Mathers et al., 2007). In fact, roots of container-grown plants are especially susceptible to temperature and moisture extremes that are not normally found in field production (Henley et al., 2006). *Senecio cineraria* (Dusty Miller), in particular, prefers a medium temperature of 18 to 23°C (Cornell University, 2006) and is especially water hungry when grown in containers (Wishhart, 2014). Two important factors that affect medium temperature of container-grown plants are the size of the potting container and water regimes. According to Martin and Ingram (1993), different potting container dimensions might either alleviate or intensify optimal rooting medium temperatures, which in turn have an effect on the well-being of the plant. Irrigation water also plays an important role in affecting the medium temperature of plants as it may help disperse heat energy and maintain plant media at an optimal temperature (Martin and Ingram, 1991). Even though it is well known in the horticulture industry that these two factors affect the medium temperature of plants, many growers have issues determining the optimal container size and water regimes for their crops. Therefore, the purpose of this report is to analyze the effect that potting container size and water regimes have on the medium temperature of *S. cineraria*, and to clarify the role of container size and irrigation as a useful management tool for heat dispersal. The report will examine the results of a seven-week temperature trial, reach a conclusion, and propose appropriate recommendations.

## CONTAINER-GROWN PLANT PRODUCTION

Container-grown plant production is the practice of growing plants exclusively in containers as opposed to planting them in the ground (Mills, 2012). Due to its flexibility, portability, and compaction, container-grown plant production has become extremely popular nowadays, with more and more growers adapting this method and seeing it as more appropriate (Missouri Botanical Garden, 2014). Some benefits of container-grown plant production include control of growing conditions, such as soil, water, sunlight, and nutrients; low requirements of money, human capital, and tools; maximization of growing space; and many more (Mills, 2012).The growth of plants will ultimately depend on providing the basic needs of each species, an adequate growing medium, sufficient light, proper temperature, and necessary moisture and nutrients (Missouri Botanical Garden, 2014).

Even though container-grown plants are extremely popular, it is important to keep in mind that growing in a closed system unfortunately increases the susceptibility of plants to health issues and causes the root zone to be very fragile (Million et al., 2011). This is because containers are an artificial environment and thus lack the healthy soil ecosystem usually found in raised beds and in-ground gardens (Williams, 2014). Containers also do not retain water for long periods of time and they tend to heat up a lot faster, depending on their size (Martin and Ingram, 1991). These factors ultimately affect the medium temperature of the plant and, in turn, the success of its growth (Martin and Ingram, 1991). Since physical support is the only feature sustained after the initial planting, appropriate container size, and levels of irrigation are essential for the cultivation of premium quality plants (Bailey et al., 2001).

## SIGNIFICANCE OF MEDIUM TEMPERATURE IN PLANT HEALTH AND IMPORTANCE OF STUDY

Maintaining an adequate medium temperature is extremely important for the well development of plants (Mathers, 2001). High medium temperatures are a major limiting factor in the distribution, adaptability, and productivity of wild and cultivated plants and may result in inhibition of growth or plant decline (Mathers, 2001). Net photosynthesis, in particular, is one of the most heat-sensitive processes that govern plant growth (Hamerlynck and Knapp, 1995). Heat stress has been shown to be a major limiting factor for plant production and adaptability in containers since the roots of container plants are exposed to more rapid fluctuations and greater extremes in temperatures than plants grown in the ground (Henley et al., 2006). With the increased use of containers as a culturing method, determining the appropriate temperature for the optimal growth of specific species has become of high importance (Bunt, 1988). In fact, growers could encounter a cost of more than $200 per cubic yard of container plants through losses in plants or reduced plant quality due to a poor container medium (Henley et al., 2006). Since the size of the potting container and the watering regimes are important factors that affect medium temperatures, choosing the right container and developing an adequate irrigation regime is an investment that will pay great dividends in terms of plant growth and quality (Martin and Ingram, 1991). In hopes of improving the horticultural industry and the container stock production, Mr. Keith Osborne has proposed to do a study about the effects of potting container size and irrigation on the medium temperature of *S. cineraria.* This study will ultimately help determine the effects container size and irrigation frequency have on medium temperature of plants, as well as provide insight for prospective investigations.

## MATERIALS AND METHODS

### Methodology

The study began on 17 June 2014, and lasted for 6 weeks until 25 July 2014. The entire trial took place at Gro-Bark's Milton site located on 12300 Britannia Road East, Milton, Ontario, Canada, where 30 replicates of *S. cineraria* in 1-gal, 2-gal, and 3-gal potting

containers were placed on the west field next to the front parking lot. The following section explains the materials used, the experimental set-up, the watering regimes, and the data collection for this study.

**Materials**

- 10 1-gal black potting containers
- 10 2-gal black potting containers
- 10 3-gal black potting containers
- 30 plugs of *S. cineraria*
- 8 HOBO® meter
- Hanna® pH and conductivity metre
- Temperature metre
- 60 gal of bark mix of Sheridan 2014 #3
- Distilled water
- Plant rack and collecting tray
- White oil-based pen
- 40-cm identifying flag
- 50-ml testing cup
- 550-ml measuring cup
- 250-ml graduated cylinder
- Hose
- Data collection sheet

**Experimental Set-Up**

Set-up for the study began on the first day during the afternoon when ten replicates of *S. cineraria* were potted in a 1-gal, 2-gal, and 3-gal potting containers for a total of 30 replicates. Plants were located on the west field next to the front parking lot and separated into two different sections based on their watering regimes, as shown in Figure 1. Plants in section A were irrigated as needed (Treatment A), and plants in section B were irrigated once a day during the early morning (Treatment B). A buffer zone of approximately 2.65 m was left between the two sections. Within Treatment A and Treatment B, plants were separated into three different subsections depending on their potting container size. For example, plants in Treatment A that were potted into the 1-gal potting containers were in one group called TA-1; those that were potted into the 2-gal potting containers were in another group called TA-2; and those potted into the 3-gal potting containers were in group TA-3. All plants were potted in a soilless mix called Sheridan 2014 #3, which was supplied by Gro-Bark. This mix contains 40% of composted pine bark, 35% of aged bark – Blend A, 15% of compost, 10% of peat moss, and fertilizer Osmocote© 21-4-8 at a rate of 3.18 kg per yard$^3$.

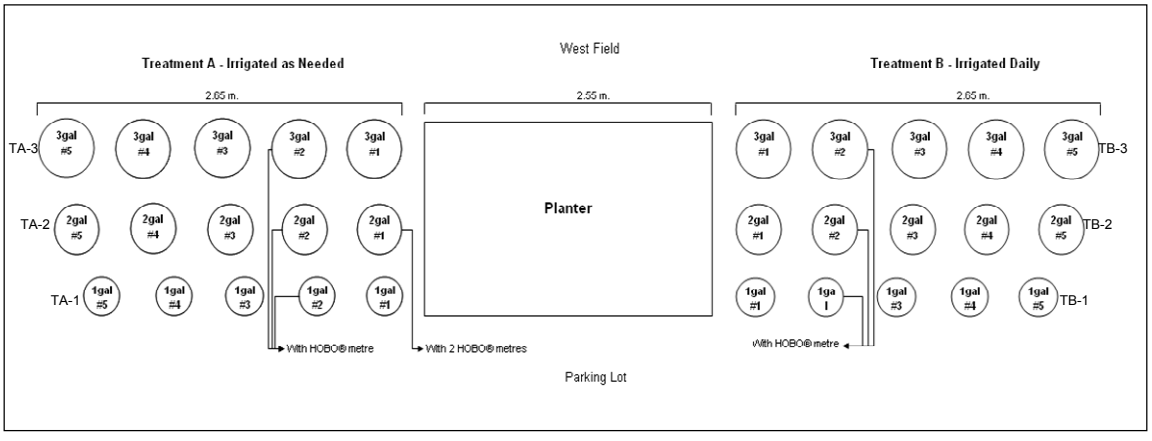


Fig. 1. Experimental set-up for the temperature trial.

**Potting**

Plugs were obtained from Sheridan Nurseries and were transferred to Gro-Bark Milton's location. Potting began on the first day of the trial on 17 June 2014 and took place at the west field. All plugs were potted by one Gro-Bark employee in order to reduce the variability in potting techniques. The plant species, mix, and fertilizer rate combination were repeated five times per potting container size and per water treatment to decrease

variability of experimental results and increase the chance of statistical significance. The potting procedure is explained below.

1) Fill a 1-gal container three quarters of the way with Sheridan 2014 #3 mix.
2) Compact the mix by lifting the pot approximately 3 in. off the floor and then let it fall. Repeat this two more times.
3) Insert the plug into the container.
4) Backfill the container with the mix.
5) Firm mix by repeatedly applying light pressure with your fingertips to top surface of the mix.
6) Add or subtract soil as necessary to ensure there is 1.5 cm between the medium and the pot lip.
7) Label the pot with the correct container size, sample number, and watering treatment name and code.
8) Place the species in its corresponding section as shown in Figure 1 and ensuring equal spacing between each pot.
9) Repeat steps 1-8 nine more times to achieve a total of 10 identical replicates.
10) Repeat steps 1-9 for the 2-gal and 3-gal potting containers.
11) Insert one HOBO meter into the core of Sample #2 of the 1-gal, 2-gal, and 3-gal potting containers for both watering treatments. Position it in the centre of the pot and right below the plant.
12) Place one HOBO meter on top of Sample #1 of the 2-gal container of Treatment A as shown in Figure 2.
13) Tie another HOBO meter to the top of the 40-cm identifying flag and stick the flag onto Sample #1 of the 2-gal container of Treatment A as shown in Figure 2.


Fig. 2. HOBO® metres placed in Sample #1 of the 2-gal container of Treatment A.

**Irrigation**

Plants were irrigated by placing a hose on top of the soil and watering it until a bed of water of approximately 1 cm was visible. The first irrigation took place right after potting on 17 June 2014 at around 4:30 PM. After that, plants in Treatment A were irrigated once or twice a week, depending on precipitation levels and dryness of the plants. Hot and dry weeks usually resulted in plants being watered twice a week, whereas mild and wet weeks resulted in only one irrigation treatment per week. Plants in Treatment B were irrigated

every day during the early morning around 8:30 AM. Due to lack of personnel, plants were not irrigated during the weekends and holidays.

**Data Collection**

The data that the temperature trial looked at was ambient temperature, soil temperature, precipitation levels, pH, and electrical conductivity (EC), as well as overall appearance of the plants. Ambient temperature was obtained with the two HOBO meters placed in Sample #1 of Treatment A, and soil temperature was obtained with the other six HOBO meters that were inserted into the core of Sample #2 for the 1-gal, 2-gal, and 3-gal potting containers for both watering treatments. All eight probes were programmed to collect data at 15 min intervals from 17 July 2014 at 4:00 PM until 25 July 2014 at 4 PM. Precipitation data was obtained every morning using a standard rain gauge that was placed on top of one the planters by the west field. A week after activating the probes, weekly pour through tests for all Samples #3 were performed every Friday around 8 AM to measure pH and EC levels for the medium. Pour through tests were conducted in accordance with the procedure below.

1) Place Sample #3 of the 1-gal container size of Treatment A upon a rack with collecting tray.
2) Measure 250 ml of distilled water and pour this into the pot. It is important to pour the water in the center of the pot and to pour slowly to avoid water running down the inside wall of the pot without being filtered through the soil.
3) Check to see if the collecting tray contains any leachate. If there is no leachate, slowly continue to pour water onto the soil in 100-ml increments until at least 30 ml of leachate is obtained.
4) Record the amount of water poured into the pot in the data collection sheet.
5) Pour the leachate into a small 50-ml testing cup.
6) Obtain the pH/EC probe and rinse with distilled water.
7) Turn on the probe and set it to the pH function.
8) Insert the probe into the testing cup and wait for the pH to stabilize.
9) Once the pH has stabilized enter the EC mode by pressing the EC button located on the meter, wait for the EC to stabilize and record this number on the data collection sheet.
10) Enter the pH mode once more and record this number on the data collection sheet.
11) Record the amount of leachate by pouring the remaining liquid left in the collecting tray in the 250-ml graduated cylinder and then adding this amount to the 30 ml of leachate that was poured into the testing cup.
12) Rinse all equipment with distilled water.
13) Place plant back into its corresponding section.
14) Repeat steps 1-13 for Sample #3 of the 2-gal and 3-gal potting containers in Treatment A.
15) Repeat steps 1-14 for Treatment B.

**RESULTS**

Results were divided into quantitative and qualitative ones. A total of 18 graphs were constructed to depict the data obtained for the entire duration of the trial and were divided according to their specific purpose. The week of 8 July to 14 July 2014 shows the typical outcome, with ambient temperatures peaking at noon and declining as the day progresses, and it will be the focus of this section.

**Quantitative Results**

The data showed that the temperature recorded with the HOBO meter placed on top of the soil and the one placed 1½ m above it was significantly different, with the ground temperature being generally 10°C higher. The maximum ground temperature was 56.6°C and the maximum ambient temperature was 40.2°C. They both occurred on 28 June 2014 at 14:15. Out of all the plants with HOBO meters, the plant in the 1-gal container in Treatment A (irrigated as needed) showed the highest maximum medium temperature of

43.8°C, while the plants in the 3-gal container in Treatment B (irrigated daily) showed the lowest maximum medium temperature of 38.8°C. The plant in the 1-gal container for Treatment A also showed the lowest minimum medium temperature of 9.3°C, while the plant in the 3-gal container for Treatment A showed the highest minimum temperature of 13.1°C. The plant in the 3-gal container for both Treatment A and B showed the highest average medium temperature of 25.2°C for the one in Treatment A, and 24.5°C for the one in Treatment B. Statistics are depicted in Table 1.

Table 1. Maximum, minimum, range, and average ambient and medium temperatures.

| | Temperature (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ambient ground | Ambient 1½ m | Treatment A | | | Treatment B | | |
| | | | 1 gal as needed | 2 gal as needed | 3 gal as needed | 1 gal daily | 2 gal daily | 3 gal daily |
| Max | 55.6 | 40.2 | 43.8 | 41.9 | 40.5 | 41.6 | 40.3 | 38.8 |
| Min | 6.5 | 7.5 | 9.3 | 11.4 | 13.1 | 9.6 | 10.9 | 12.1 |
| Range | 49.1 | 32.7 | 34.6 | 30.5 | 27.5 | 32.0 | 29.4 | 26.7 |
| Average | 24.6 | 22.9 | 24.5 | 25.1 | 25.2 | 23.6 | 24.3 | 24.5 |

During the afternoon, plants in Treatment A tended to exhibit higher medium temperatures, while during the night and early morning plants in both treatments shared similar medium temperatures, as shown in Figures 3, 4, and 5. Medium temperatures of plants in both treatments generally exceeded ambient temperatures, although plants in treatment A had a tendency to do so more often. They only exceeded ground temperatures during the night and early morning. After that, ground temperatures tended to be significantly higher than medium temperatures.

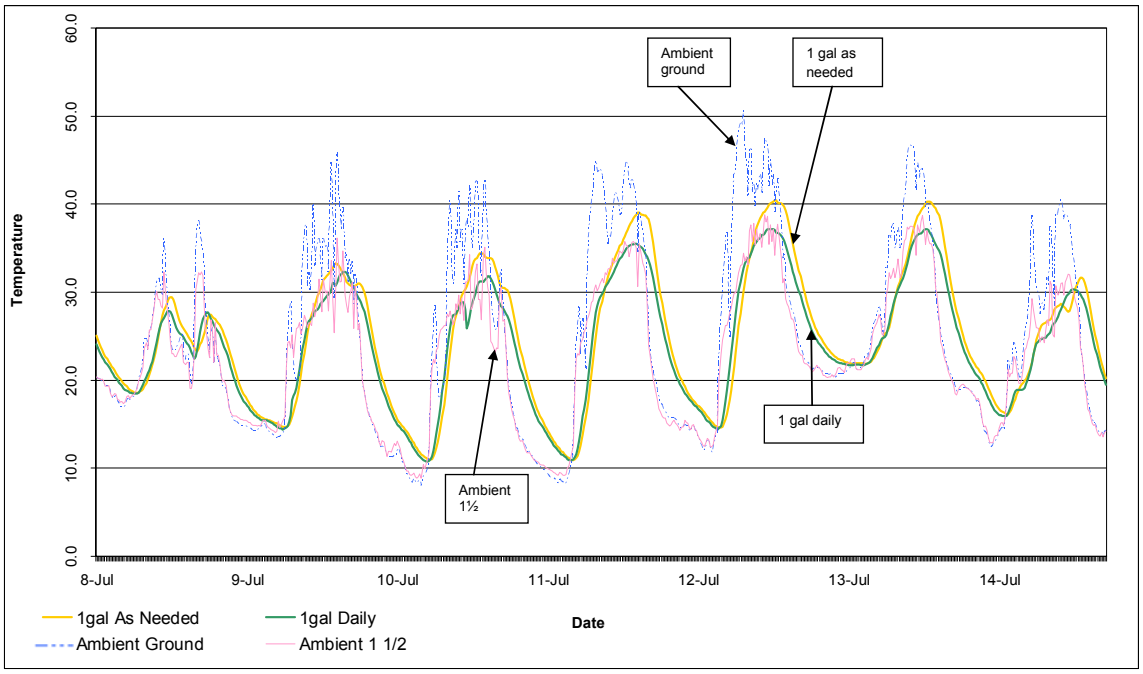


Fig. 3. Comparison of the medium temperature between Treatment A and B for 1-gal containers (8-14 July 2014).

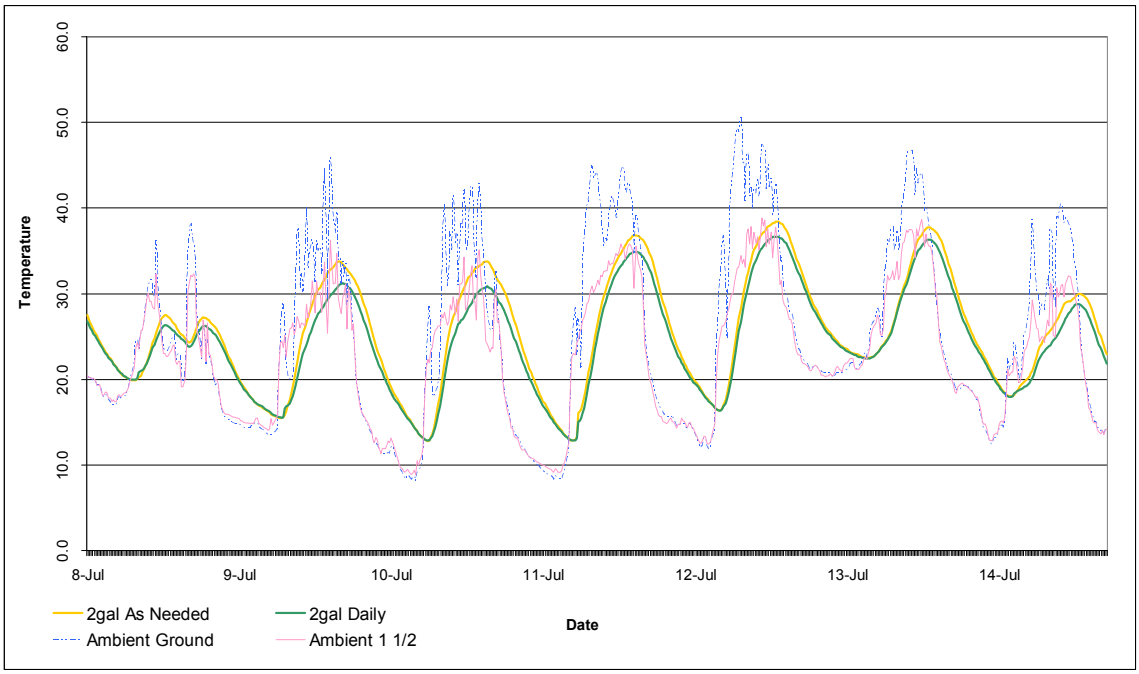


Fig. 4. Comparison of the medium temperature between Treatment A and B for 2-gal containers (8-14 July 2014).

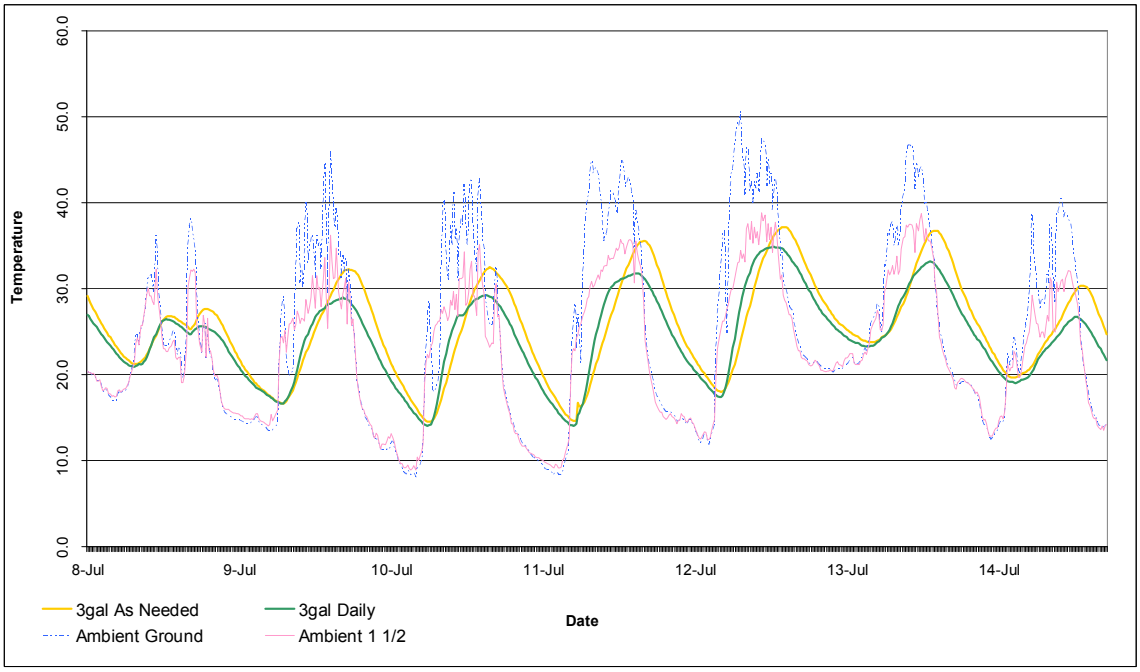


Fig. 5. Comparison of the medium temperature between Treatment A and B for 3-gal containers (8-14 July 2014).

Results also showed that the medium temperature of plants in 1-gal containers of both treatments fluctuated more than medium temperatures of plants in 2-gal and 3-gal containers, exhibiting the highest range of all containers of 34.6°C for Treatment A and 32.0°C for Treatment B. Medium temperatures of plants in 1-gal containers were usually

the highest ones, especially during the late morning and afternoon, and they tended to exceed the ambient temperature with more frequency. All plants exceeded the ambient and ground temperature during the night and early morning, where plants in 3-gal containers had the highest medium temperature. Finally, differences in temperature between containers size was less evident for plants in Treatment B.

As for pH and EC results, plants in both treatments shared the same average pH of 6.7 and very similar average EC results of 1.62 $mS \cdot cm^{-1}$ for Treatment A and 1.58 $mS \cdot cm^{-1}$ for Treatment B. Plants in Treatment A yielded a lower leachate percentage of 31.09% as compared to plants in Treatment B with a leachate percentage of 33.89%, as shown in Table 2. Both pH and EC tended to increase as container size increases, although this is more evident with pH.

Table 2. Field test result averages for Treatment A and B.

| Treatment | Pot size (gal) | $H_2O$ added (ml) | Leachate (ml) | Leachate (%) | pH | EC ($mS \cdot cm^{-1}$) |
|---|---|---|---|---|---|---|
| A: As needed | 1 | 208.33 | 79.83 | 38.32 | 6.5 | 1.24 |
| | 2 | 333.33 | 119.17 | 35.75 | 6.7 | 1.84 |
| | 3 | 533.33 | 102.33 | 19.19 | 6.8 | 1.78 |
| | Average | 358.33 | 100.44 | 31.09 | 6.7 | 1.62 |
| B: Daily | 1 | 225.00 | 97.50 | 43.33 | 6.5 | 1.45 |
| | 2 | 333.33 | 86.67 | 26.00 | 6.8 | 1.65 |
| | 3 | 533.33 | 172.50 | 32.34 | 6.8 | 1.65 |
| | Average | 363.9 | 118.9 | 33.89 | 6.7 | 1.58 |

**Qualitative Results**

At the end of the trial, plants in Treatment A exhibited more dry leaves and looked less abundant than plants in Treatment B, as shown in Figure 6. Plant size and abundance increased as potting container size increased, making the plants in 1-gal containers the smallest for both treatments, also shown in Figure 6. The biggest plants were found in the 3-gal containers. Plants in 1-gal containers in both Treatments also tended to exhibit some dry and yellow leaves at the bottom, as shown in Figure 7. When it comes to plants in 2-gal and 3-gal pots, plants in Treatment B did not exhibit any dry leaves but those in Treatment A seemed to have a few dry leaves at the bottom.

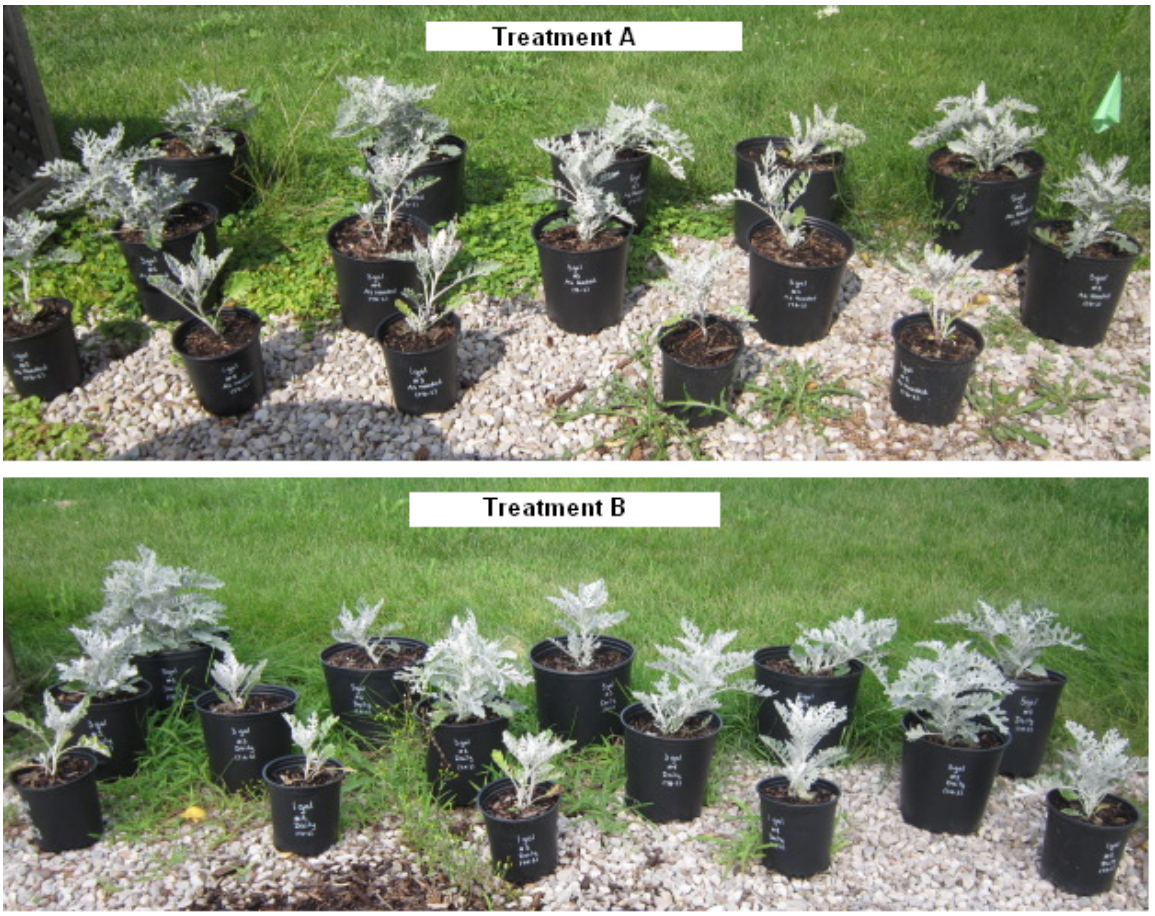


Fig. 6. Comparison of size and abundance of plants in Treatment A and B.

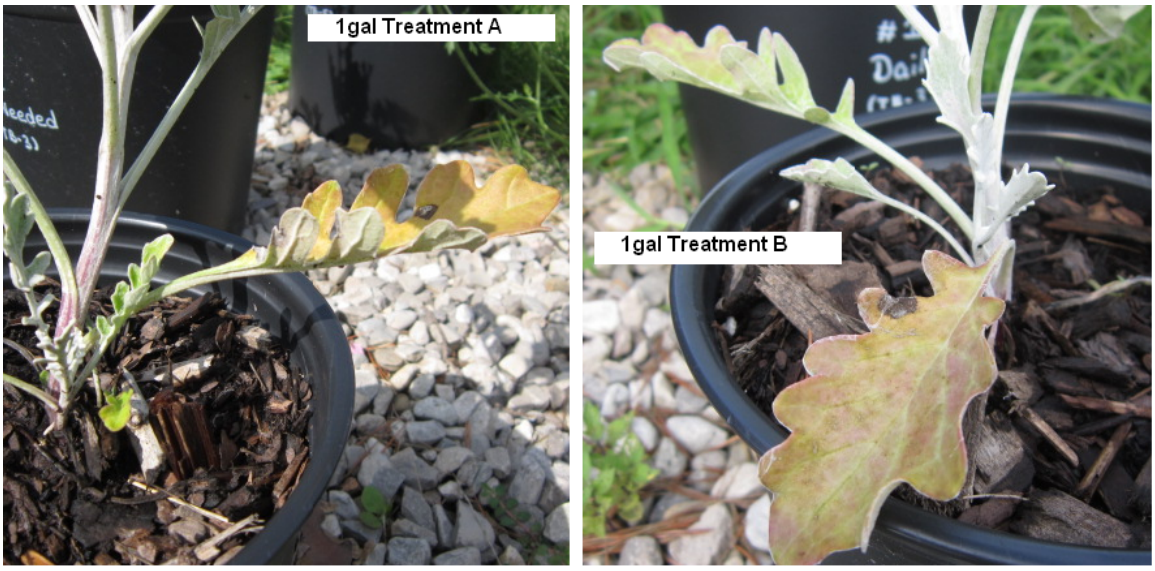


Fig. 7. Plants in 1-gal pots exhibiting yellow leaves in Treatments A and B.

## DISCUSSION AND INTERPRETATION

Once all the data was organized, theories could then be revised. Throughout the trial, ambient and ground temperatures showed extremes changes unlike the medium of all plants which generally followed the same curvy pattern. However, medium temperatures of all plants usually tended to correlate with the ambient and ground temperatures. As seen in Figure 4, the peak medium and ground temperature occurred around noon when there is more direct sunlight. After that, temperatures decreased as the sun started to set. Medium temperatures revealed a similar tendency, with temperatures increasing and decreasing around the same time as ambient and ground temperatures do so and strongly suggesting that the warmth of the medium of all plants is dependent upon its surroundings. It is interesting to note that medium temperatures of all plants generally tended to exceed ambient temperatures, suggesting that the medium was usually warmer than its exterior. In comparison to temperature data obtained by previous Gro-Bark trials, medium temperatures for this study were significantly higher. In fact, medium temperatures in previous studies were well below the ambient temperature. This raises the question of why medium temperature for this trial was significantly higher and provides opportunities for future research. Possible reasons could include the proximity of the plants, the level of shade received, the colour of the pots, and the solar radiation. Another interesting observation is that ground temperatures were generally higher than ambient temperature. This could be because the HOBO meter recording ground temperature was placed directly on top of the soil, and thus it was receiving some of the heat that the soil itself was releasing and it was barely receiving any currents of air.

There were also many interesting findings when comparing medium temperatures and the appearance of plants between both irrigation treatments. In general, plants in Treatment A had higher medium temperatures and tended to exceed ambient temperatures more often than plants in Treatment B. Additionally, plants in Treatment A exhibited more dry leaves and were less abundant than plants in Treatment B. These findings are consistent with the theory that irrigation usually lowers the medium temperature of container-grown plants and, in turn, allows for a healthier plant growth. In fact, a study performed by Keever and Cobb (1985) showed that overhead irrigations reduced container medium temperatures and increased the root growth of *Rhododendron* 'Hershey's Red' compared to irrigations applied as needed. This is because the temperature differential between the irrigation water and container medium "creates a gradient for the flow of heat energy by the thermal processes of conduction and convection until temperature equilibrium is established" (Martin and Ingram, 1991). However, Keever and Cob (1985) discuss that this is only true if the temperature of the irrigation water is lower than the medium temperature and a sufficient volume of water is applied to physically disperse the thermal energy, which was indeed the case for this trial. Furthermore, the results showed that the difference in medium temperature between container sizes is less evident for plants in Treatment B. This could be because water mitigates temperature fluctuations by allowing plants to release more energy, making in this way medium temperatures less variable in Treatment B. Temperature results and overall appearance of plants in Treatment A when compared to those in Treatment B strongly suggest that irrigation water, when cold and applied in sufficient volumes, may be a successful method for lowering container medium temperatures, dispersing heat energy, and optimizing root development and the well-being of plants.

The trial also provided interesting findings when comparing medium temperatures and the appearance of plants between different container sizes. In general, medium temperatures of plants in 1-gal containers were usually higher. This is also consistent with previous studies and theories that discuss that smaller containers tend to heat up faster as heat has a more limited space to disperse and thus it is concentrated more intensely (Martin and Ingram, 1993). Plants in smaller containers also do not retain water as well as those in bigger containers, and thus the medium temperature is usually higher (Martin and Ingram, 1993). High medium temperatures could be the cause of why plants in 1-gal containers showed browner leaves than those in 2 and 3-gal containers, especially at the

bottom. However, another cause could also be that when the plants in the 1-gal containers were irrigated the water coming out of the hose usually made contact with the leaves at the bottom due to limited space, and this ultimately might have caused some ornamental damage (Wishhart, 2014). Further research is necessary to determine the main cause of this. Plants in 1-gal containers also showed a more variable medium temperature than that of plants in 2 and 3-gal containers. Reasons for this include the fact that the HOBO meter inserted into the 1-gal containers had less insulation, less soil volume, and less water present, and thus ambient temperature had a bigger impact in the temperature readings. Another reason could be that the plants in the 1-gal containers were smaller, and thus the soil was not receiving as much shade. The results also showed that plant size and abundance increased as potting container size increased. This could be due to the fact that 1-gal containers had a more limited space for roots to growth. In fact, a similar study performed by Navindra and others (2011) showed that plants in 3-gal pots produced the highest number of leaves and roots per seedling, and greater stem height and diameter than the ones in 1-gal pots. Bar-Tal and others (1995) affirmed that plant height, number of leaves as well as shoot and root dry weight increases with increasing container size, and Keever and others (1985) reported that root confinement within a limited volume results in reduced root growth. These theories correspond to the findings in this study with regard to the increase of container size and plant size and abundance, whereby plants in 1-gal containers in both treatments were the smallest.

It is important to note that all of these findings should be taken in the strictest manner. As the experiment was conducted on *S. cineraria* using a custom soil substrate supplied by Gro-Bark, the estimate is only valid under the same conditions. The trial also had some limitations and sources of error. For example, plants were not always watered at the same time or in the exact same manner since they were irrigated by hand. This might have caused some deviation in the data, although exact effects are unknown. Additionally, the medium temperature of only one plant per container size was recorded and this prevents the results to be generalized to a larger scale. Finally, numerous factors that could have affected the results were not measured, such as the amount of solar radiation, exact levels of precipitation, proximity of the plants, amount of shade received, currents of winds, etc.

## CONCLUSIONS

After an analysis and interpretation of both quantitative and qualitative result, it is concluded that a water regime that consists of daily irrigation helps to maintain the medium temperature of *S. cineraria* close to its preferred range more effectively than irrigating the plant on a once or twice a week basis. This will ultimately help the plant to achieve a more rapid growth and greater leave abundance, as well as to prevent the generation of dry and yellow leaves.

Another conclusion is that potting *S. cineraria* in 2-gal and 3-gal containers also helps the plant to maintain a medium temperature that is close to its preferred temperature range, more stable throughout the day, and more resistant to extreme weather conditions than when they are potted in 1-gal containers. *Senecio cineraria* also tend to achieve a bigger size, greater abundance, and an overall healthier appearance when they are potted in 2- or 3-gal containers since roots have more space to spread out.

One final conclusion is that, even though the medium temperature of *S. cineraria* may be controlled by their container size and watering regime, medium temperatures are ultimately dependant upon their surroundings, and thus choosing an optimal container size and irrigation regime are not enough to ensure that the medium temperature of *S. cineraria* is within the plant's preferred range. Other factors such as the proximity of the plant, the colour of the pot, the amount of solar radiation, and the overall weather conditions could also play a big role and more research on this area is necessary.

## RECOMMENDATIONS

Based on the analysis and previous conclusions, it is recommended that *S. cineraria* are thoroughly watered everyday in order to maintain optimum medium temperatures,

achieve a faster growth rate, and improve the general appearance of the plants. Irrigation should occur in the morning, either by hand or with sprinkles, and growers should make sure that the roots of the plants are indeed receiving enough water, especially during the early stages of growth.

It is also recommended that *S. cineraria* are potted in medium to big containers of at least 2 gal. This will help maintain the medium temperature of plants close to its preferred range and increase the size and plant abundance of plants. If space is an issue, *S. cineraria* could be potted into 1-gal containers during their early stages of growth, but it is recommended to increase the frequency of water and decrease the amount of solar radiation received. It is also recommended to re-pot them into bigger containers later on if greater plant abundance is desired.

Finally, it is strongly suggested to conduct further research on this area and perform more trials in which a greater number of variables are measured, such as solar radiation, proximity of the plants, amount of shade received, precipitation levels, and wind currents. The use of more HOBO meters in future trials is also recommended to decrease variability of experimental results and increase the chance of statistical significance. For example, every plant should have a HOBO meter, instead of just one per container size.

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# Cooling of a South-Facing Wall Using a Double-Skin Green Façade in a Temperate Climate©

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**Green façades made of metal wire screens and mounted to the walls of buildings to support trellised vegetation is increasingly looked to as a means of urban greening and as a sustainable building technology. Here we examine the thermal cooling performance of three candidate vine species (hops, Virginia creeper, and riverbank grape) on a 3-dimensional welded wire frame against a south-facing wall in a temperate climate. We found that from May to September, the green façades kept the wall surface on average 1.84°C (3.31°F) cooler, with grape as the best performer reducing surface temperatures by 2.91°C (5.24°F) in September. In all three species, wall cooling increased with vegetated cover, which increased over the growing season. The effect of vegetated cover on wall cooling was most apparent in hops which re-grows from root stock and basal stems to cover much of the trellis by the end of the growing season, whereas grape and creeper foliage re-grows from stems that remain attached to the trellis, achieving more heterogeneous covering earlier in the growing season. These findings contribute to a growing body of research on green façades and their functional performance as components of the building envelope and as architectural materials.**

## INTRODUCTION

Vegetation, including vining plants trellised up against or directly on the surface of structural walls has been a feature in landscape design and architecture to mask unaesthetic surfaces and increase building cooling via shading and evapotranspiration (Di and Wang, 1999; Akbari et al., 2001; Köhler, 2008; Susorova et al., 2014). Different types of vine trellising structures have been implemented, but most fall within the single skin (abutting up against the building without a gap between the building wall and the trellis) or double skin (set off from the wall creating a pocket of air between the building wall and the planed trellis) types (Stec et al., 2005; Hunter et al., 2014). Wong et al. (2010) in Singapore simulated the cooling load for a building with walls entirely covered with vegetation was 10% greater than bare walls. Di and Wang (1999) in Beijing determined that thick ivy covering a west facing wall can reduce the peak cooling by 28% in a clear summer day. In a modeling exercise, Susorova et al. (2014) estimated the effective thermal resistance of a plant layer to be up to 0.7 $m^2 \cdot K \cdot W^{-1}$ and determined that the thermal behaviour of green façades are (in order of importance): solar radiation, wind speed, relative humidity and outdoor air temperature. Needless to say, trellising vegetation (hereafter referred to as vine façades) is one effective means of cooling building to reduce energy costs during warm weather periods.

Vine façades are rarely incorporated into new development and in landscape architecture, due to the length of time it can take for a mature vine to grow, the amount of soil volume required for the vine, and the perceived potential damage done by vining plants to building infrastructure (for example, eroding wood or brick walls due to the attachment of vine tendrils). However, vine façades can convey an attitude of environmental awareness and as mentioned have been both theoretically and empirically demonstrated to have some cooling benefit (Hunter et al., 2014). Other recent studies have estimated the cost savings of vine façades resulting from building thermoregulation (Alexandri and Jones, 2008; Wong et al., 2010; Ottelé et al., 2011). This has created interest in industry to design vine façade products that optimize the survival, growth, movement and cover of vining plants to maximize their benefits.

Aside from vine survival and the life-cycle costs of implementing different vine façade

designs and materials, the most studied benefits of façades have been thermal performance in warm seasons and in Mediterranean climates (Kontoleon and Eumorfopoulous, 2010; Pérez et al., 2011; Perini et al., 2011; Ottelé et al., 2011; Hunter et al., 2014). Literature on green façades in Canadian regions or those with similar climates is scarce compared with that on green roofs (Dunnett and Kingsbury, 2010; Sutton, 2015). One study in Maryland used a three-dimensional trellis system and four vine species in combination on East and West facings and found vine façade walls an average of 7°C cooler than bare walls (Tilley et al., 2012). However, few studies have compared thermal performance between different vine species, which can vary considerably in absorption of water, reflectivity of solar radiation, transpiration rates and cooling potential, among other variables that impact leaf energy balance and reduction in heat energy transfer (Holms, 1989). As building density and height increase in Canadian cities, so does the proportion of bare wall surfaces and associated building inefficiencies. Since trellising vine façades are not constrained by load and other structural issues that green roofs provoke, they are more easily included in the retrofit of existing buildings to achieve goals addressed by green infrastructure. Vine façades are also more visible to the public from ground and so could be more attractive to clients uncertain as to whether or not they should commit to greening the building envelope during development or renovation. The objectives of the research of this study were to gather baseline information on wall cooling potential of vine façades using the greenscreen® three-dimensional double skin trellising system in Toronto. The trellis system consists of three different vine species and vegetation-free controls. This information is critical for increasing knowledge of vine façades in temperate climates and for determining how different vine species might interact to complement and enhance overall vegetative cover.

## METHODS

### Site

The Green Roof Innovation Testing (GRIT) Lab is located on the roof of the five-storey Daniel's Faculty of Architecture, Landscape, and Design building at the University of Toronto St. George Campus, in Toronto, Ontario (43°39'42"N, 79°23'42"W). Further construction details and description of the facilities is given in MacIvor et al. (2013) and available at the website (www.grit.daniels.utoronto.ca). The double skin façade wall under study is located on this roof and comprised of a south-facing 3D greenscreen trellis against a building wall containing heated office and storage space. These trellises were 2.15 m in height and set 6 cm from the exterior wall creating an insulating layer (Hunter et al., 2014) (Fig. 1).

Three vine species were used in the set up, Nugget hops (*Humulus lupulus* 'Nugget') (hops), Virginia creeper (*Parthenocissus quinquefolia*) (creeper), and river bank grape (*Vitis riparia*) (grape). Each grape was planted with a short 60-cm stake to enable the vine to touch the trellis during establishment. All three species were planted in monoculture in groups of 6 into the façade modules as 1-gal pots in June 2012. Each module measures 102.2×31.8×29.2 cm in dimension and is raised 39.4 cm from the roof surface. Each module comprised of an "organic" growing medium ("EcoBlend" Bioroof™ Systems, Burlington, Ontario) (Table 1). The media was set atop a 25-mm layer of sand, filter cloth and biovoid retention mat (Bioroof, Toronto, Canada) as well as waterproofing membrane and trimmed with aluminum flashing (Tremco, Toronto, Canada) (Fig. 2).

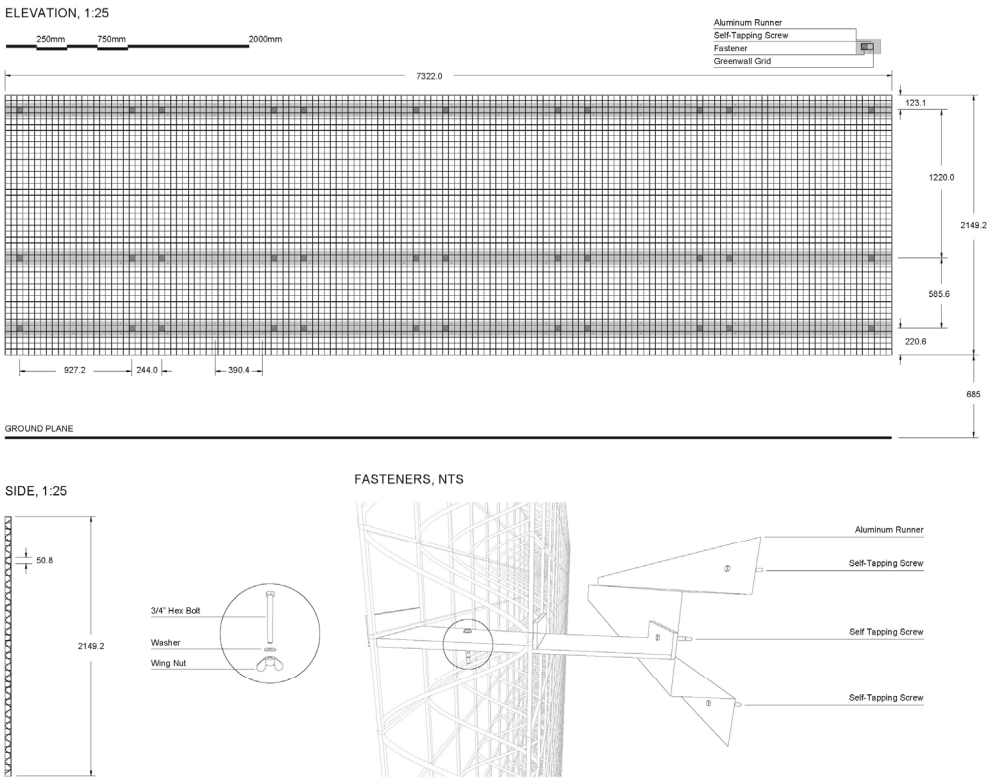


Fig. 1. A drawing of the greenscreen® 3D welded wire panel system.

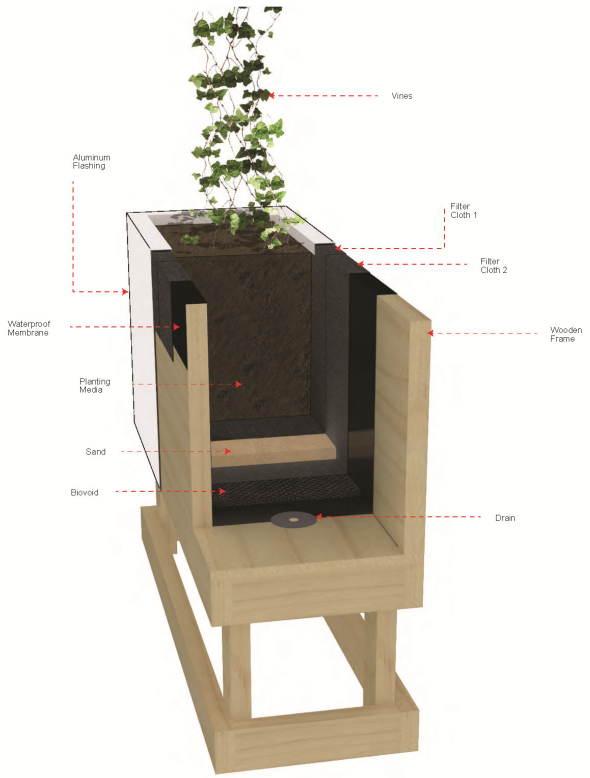


Fig. 2. Annotated drawing of the planter module.

Table 1. Properties of the growing medium used in this study.

| Standard | Property | Bioroof Eco-blend |
|---|---|---|
| Porosity (ASTM E2399) | Pore volume | >60% |
| | Air filled porosity | >10% |
| | Saturated hydraulic conductivity | >0.01 cm/s |
| Moisture (ASTM E2399) | Max. water holding capacity | >60% |
| Density (ASTM E2399) | Max media density at saturation | 1.10 g/cm$^3$ |
| | Dry density | 0.58 g/cm$^3$ |

Each façade module was overlaid with interconnected drip-irrigation line (DH Water Management; The Toro Company, Canada) set up with a pressure of 25 kPa and an emission rate of 0.063 L/emitter/min., to ensure an efficient use of water. Approximately 5 min of water beginning at 8 AM was provided daily. No fertilizer was added during the course of the study. The vine façade modules were weeded regularly and the primary colonizers arriving with growing media or colonizing spontaneously included: chickweed (*Cerastium* sp.), horseweed (*Conyza canadensis*), tree of Heaven (*Ailanthus altissima*), lamb's quarter (*Chenopodium album*), and dandelion (*Taraxacum officinale*). Golden tickseed (*Coreopsis tinctoria*), black eyed susan (*Rudbeckia hirta*) and several *Sedum* species were also colonizers of the façade modules and presumably arrived via green roof test beds sharing the same roof space where these species were planted intentionally.

**Cover**

Vegetated cover was measured non-destructively using digital image analysis (Olmstead et al., 2004) using photos taken with a Canon SLR and analyzed in Adobe Photoshop. Photos were taken at 1.70 m from the roof surface and 2 m from the façade on the first and third week of each month on a sunny day. The image from the third week of each month from Region 1 was cropped to include only the façade area, and in Photoshop, the "sampled colours" and "localized colour clusters" were selected, the fuzziness set to 60, the range set to 100%, before the eyedropper function and the "add to sample" function were used to select the desired vegetation colour range. The number of vegetated pixels in the image was divided by the total number of pixels in order to get a % vegetated cover value for each façade.

**Thermal**

A single temperature probe (110 PV Surface Mount Thermistor, Campbell Scientific) was attached to the surface of the exterior wall centered, and immediate behind each of the vine façades and the three control façades (trellis, but vegetation-free) (Fig. 3). Each thermistor recorded temperature (°C) at five-minute intervals from May to September 2013 (and continuously thereafter). To compare thermistor data recorded from the façade walls, GRIT lab weather station ambient air temperature (°C) and relative humidity (%) (HMP45C Probe, Campbell Scientific), as well as solar radiation (W/m$^2$) (Kipp and Zonen CMP 11 Pyranometer) data were downloaded for the same time intervals.

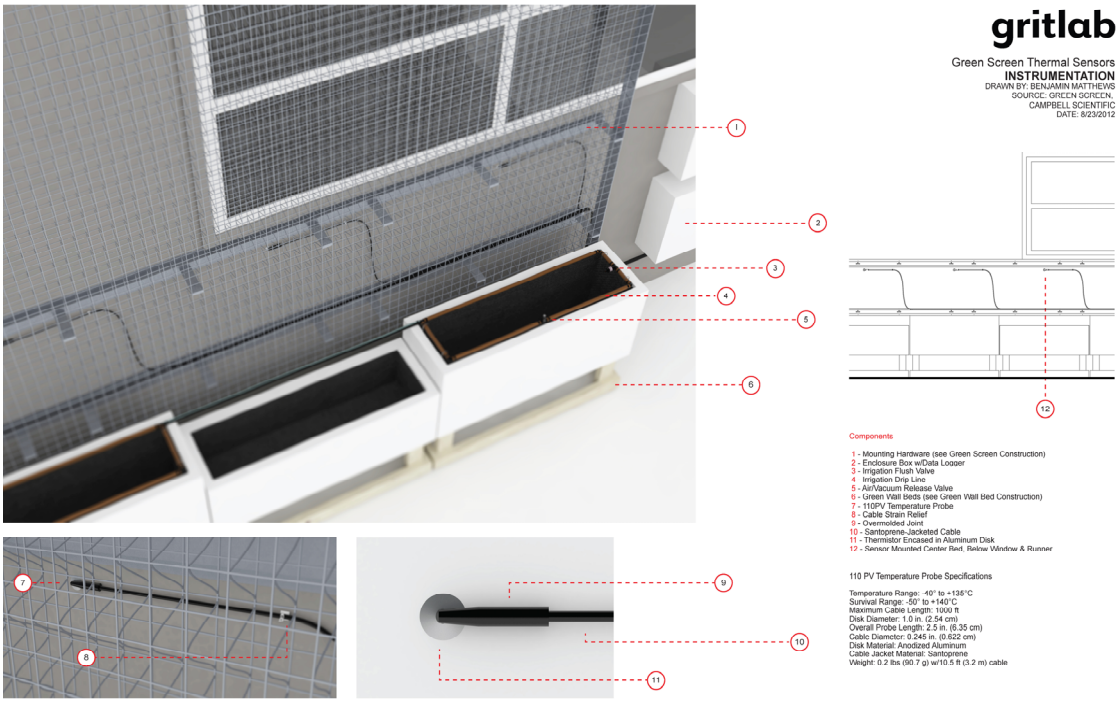


Fig. 3. Annotated drawing of the planter module.

**Statistics**

Data from the temperature probes and weather station were subset by day and night using positive solar radiation readings (>0 W/m$^2$) as an indicator of daytime. Daytime data was then converted to monthly averages for comparison with vegetated façade cover data for each of the three species. A paired t-test was used to compare wall surface temperatures between vegetated façades and non-vegetated controls. In SPSS, an analysis of variance (ANOVA) ($\alpha$=0.05) with post hoc analysis was used to examine the effect of cover and vine type on surface building wall cooling and the change in temperature reduction over the growing season.

**RESULTS**

Of the three vine species, all reached maximum over 50% cover by the end of the study period with grape reaching over 70% cover. The t-test revealed that from May to September, vegetated façades significant reduced wall surface temperature over non-vegetated façade controls (t=-8.576, df=14, t<0.001) (Fig. 4). However analysis of variance revealed no significant difference in reduction in wall surface temperature among the different vine types (F-1.35, df=2, p=0.30). Vegetated façades resulted in a 6-11% reduction in wall surface temperature.

The reduction in surface temperature by vegetated façades increased significantly over the sampling period with the greatest reduction achieved in September [almost 3°C (5.24°F) reduction] (F=5.04, df=4, p=0.017) (Fig. 4). Increasing vegetative cover led to significant reductions in wall surface temperatures (t=-11.169, df=14, t<0.001) (Fig. 5), however since the physiological adaptability to light conditions in vining plants is related to their climbing mechanics (Carter and Teramura, 1988), each vine species displayed a distinct and different growth pattern (Figs. 6 and 7).

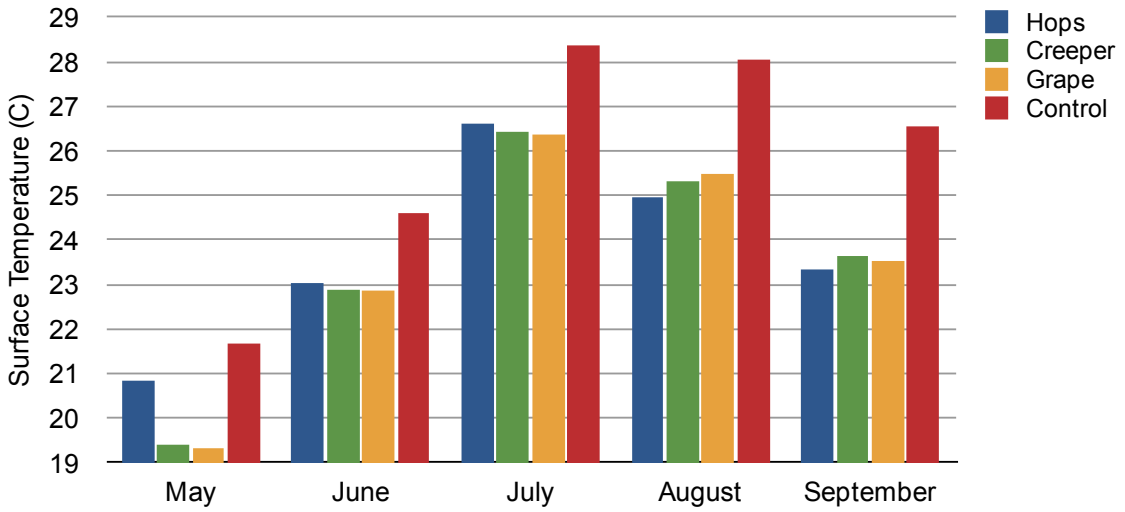


Fig. 4. Change in surface temperature over May to September 2013 behind the vegetated façades and the non-vegetated control walls.

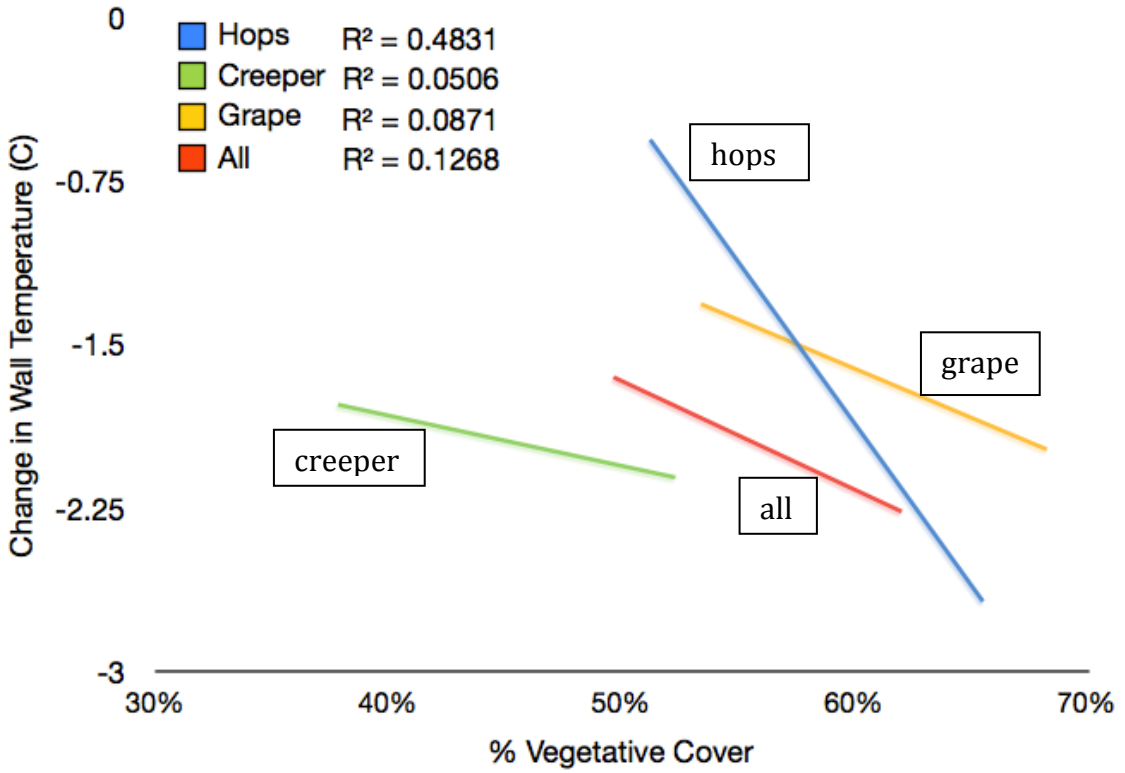


Fig. 5. Change in wall temperature (from the non-vegetated façade controls) plotted against % vegetative cover of all three species and the average change of the species combined.

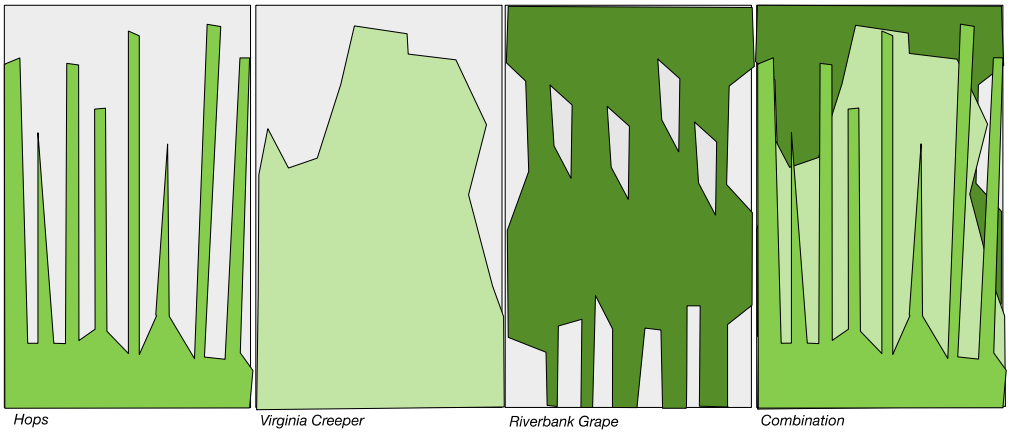


Fig. 6. Conceptual drawing of growth pattern of each of the three vine species on the greenscreen® trellises and a conceptual pattern of all three species in combination.

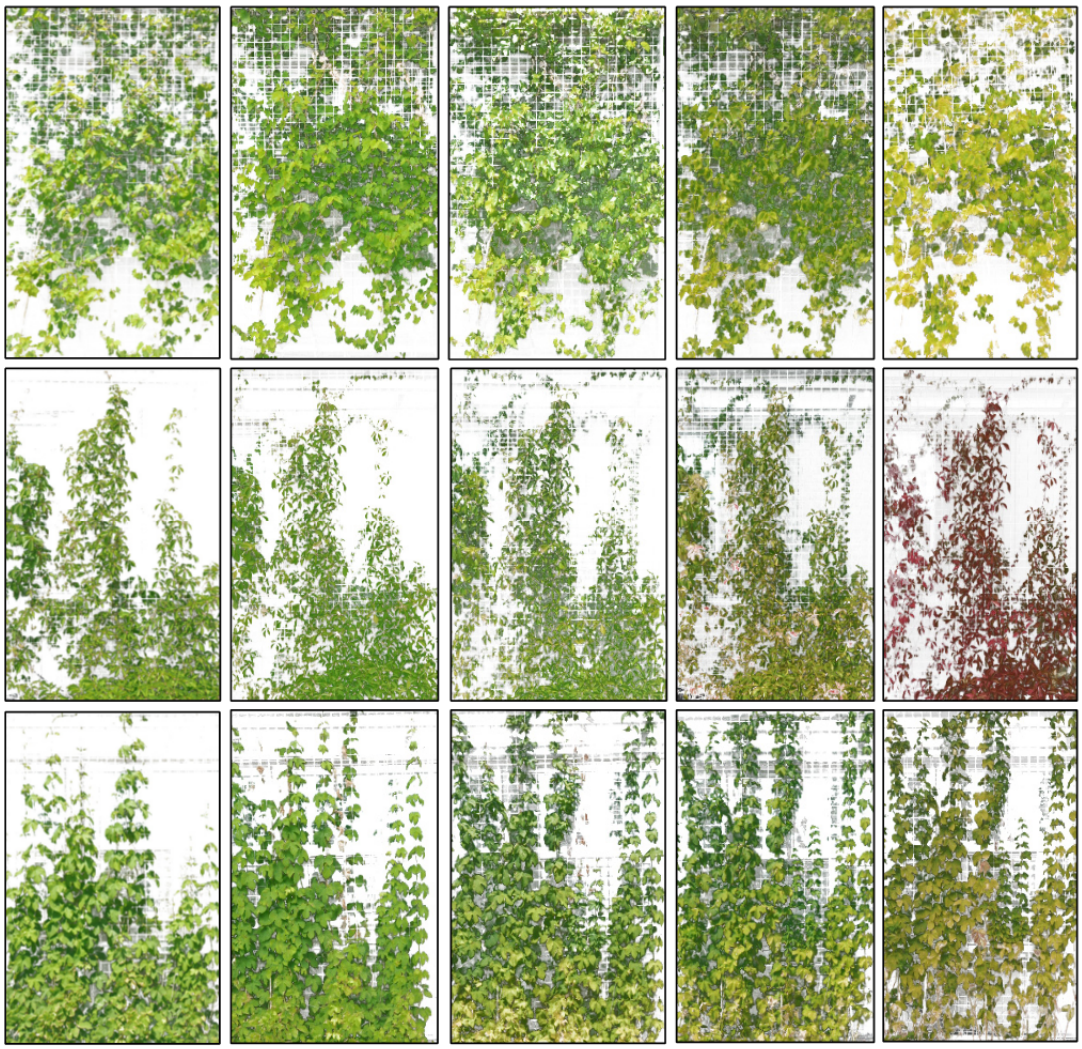

Fig. 7. Cover images for each of the three vine species in Region 1 (South-facing 3D greenscreen® façade wall against a building wall). From top to bottom: hops, Virginia creeper, grape.

## DISCUSSION

Our study indicates there was no difference in wall cooling potential of the three vine species examined, but that vine façades cooled the building wall to a temperature significantly lower than the bare wall. This cooling effect increased over the season and was correlated with increasing vine growth over time. Our finding that vine façades reduced surface temperature by 6-11% is comparable to the temperate climate green façade temperature reduction values determined in Alexandri and Jones (2008) using common Ivy (*Hedera helix*). However, the cooling potential recorded in our study was less than that recorded by Tilley et al. (2012) where the weather is warmer (Maryland, USA) and vine growth enhanced by additional fertilizer, greater available soil depth, and greater volumes of supplemental irrigation. Moreover, our study set up was located on a rooftop experimental testing site whereas most others are carried out on façades immediately adjacent to ground level where conditions are presumably less extreme than in rooftop environments (Oberndorfer et al., 2007).

### Hops

In this non-adhesive tendril deploying species as cover increased over the season, the reduction in surface temperature compared with non-vegetated wall surfaces significantly increased (Fig. 5). Hops had a different growth pattern than both grape and creeper, not only in form, but also phenology; hops grows quickly, but dies back over winter. Because of the dieback, it begins the season with low cover at basal stems that quickly increases from spring to summer using the trellis to support itself. Because of the winter dieback, hops might be a good choice for maximizing multi season thermal benefits of vine façades, as in cold seasons, absorption of solar radiation through building walls will be preferred. However, in application, this species would require more maintenance cleaning dead stalks and restringing new vines in the spring.

### Virginia Creeper

Virginia creeper kept most of its foliage into the winter, eventually it falls but unlike hops, leaves regrow from stems spread about the trellis from previous year(s). As a result, less change in vegetated cover over the study period (2012-2013) was observed, and wall surface temperature was significantly cooler than non-vegetated walls. One potential issue with Virginia creeper in vine façade applications is that it tends to not conform to the trellis. As an adhesive-tendril climbing vine, it grows through the trellis and can attach to bare exterior wall surfaces. Re-stringing can be accomplished in maintenance visits but gaining access to behind installed trellises can be difficult, adding to maintenance requirements. Since Virginia creeper is an understory vine that is adapted to low light conditions (Carter and Teramura, 1988), the slightly more shaded conditions behind a trellis might be preferred, continuing this issue over time and warranting more research on the vine species in trellised applications. One other interesting observation was that as Virginia creeper foliage turns red by September, this apparently has no significant effect on temperature reductions (Fig. 7). The colour change greatly increases visual interest, especially in combination with the other two species.

Anecdotally, we noted that Virginia creeper was more resistant to weeds than the other two vine species. This was perhaps because its foliage tended to cover the growing media surface within the module right away, potentially blocking incoming seeds from germinating. This differed from the other two vine species that had mostly bare substrate areas, and as such, more weeds. If including grapes or hops in a vine façade, it might be useful to include natural mulch or maintain grass or wildflower plantings to suppress weeds.

### Grape

Grape had the greatest overall cover among the three vine species after 2 years (Fig. 5). Grape vine tended to bunch half way up the trellis at the point where the stalking used to support the vines in Year 1 ended, and at the very top of the trellis, at which point the

vines would begin to drape down (Fig. 6). Grape grew aggressively on the trellis so much so that maintenance to re-string the non-adhesive vine tendrils back within the boundaries of the façade module was necessary nearer the end of the growing season. Grape vines also produced berries in the second year, which are attractive to birds, but also to invasive paper wasps (*Polistes fuscatus*) and could be perceived to be a nuisance as staining by berries on the surrounding ground adds to maintenance and avoidance of the area by building users. Grape was also attractive to beneficial insects: leaf cutter bees cut circles out of the leaves to use as nest building materials, which has little impact on plant cover or survival. Grape, like Virginia creeper displays a mix of colour in its leaves over the season, adding to visual interest. Given the colour range and growth patterns of the three vine species examined, aesthetically it would be interesting to combine these in vine façade applications. Further, studies that combine all three species in an experimental setup could interpret whether diversity can improve thermal benefits of vine façades.

## CONCLUSIONS

This study provides much needed evidence of performance benefits of vine façade infrastructure in a temperate climate where demand is high but application rate and success is lower than that in tropical and Mediterranean regions. Although climbing vines on buildings have long been a part of human societies, there is increasing need to quantify their contribution to building cooling in contemporary designs as they become more commonplace in architectural designs.

## ACKNOWLEDGEMENTS

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# Branding How-To for Nurseries and Public Gardens©

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What do you need to know about branding to help your nursery or public garden? You'll learn what a brand is and how to communicate your brand.

As consumers we spend a lifetime buying branded products — from clothing to food to laundry soap and cars most of us are influenced by brand messages. As an industry — we in the ornamental horticulture space have traditionally gotten away with "less marketing." Many of us on the plant production side lived through decades of year over year growth for ornamental plant products. It has only been in recent years with declining demand for many plant products that many are open to the idea of "marketing" as a tool to sell more plants.

We also now have witnessed the success at retail of programs such as Proven Winners®, the Knockout® rose, and Endless Summer® hydrangea. When we conduct surveys asking consumers their awareness of horticulture brands, we see that many recognize brands — with Burpee®. Scotts®, and Proven Winners leading the way.

Table 1. Brand awareness.

| Un-aided Awarness | | Aided Awarness | |
|---|---|---|---|
| Miracle Gro | 31% | Burpee | 76% |
| Proven Winners | 23% | Scotts Miracle Grow | 71% |
| Burpee | 18% | Proven Winners | 58% |
| Scotts | 17% | Knockout | 48% |
| Fiskars | 10% | Wave | 38% |
| Knockout | 6% | All-American Selections | 38% |
| Monrovia | 6% | Bonnie's Plants | 37% |
| Espoma Fertilizers | 6% | Vigoro | 30% |
| Felco | 6% | Endless Summer | 24% |
| Osmocote | 6% | Stepables | 17% |
| Ortho | 5% | Garden Club Select | 11% |
| Bonnie Plants | 4% | Simply Beautiful | 10% |
| Preen | 3% | Flower Fields | 8% |
| Roundup | 3% | Viva | 5% |
| All-America | 3% | Red Fox | 2% |
| Wave | 3% | | |
| Endless Summer | 3% | | |

The question for us is no longer should we "brand" — but rather who should own and develop the brand. Is there a role for a nursery in creating their brand?

According to the American Marketing Association a brand is the name, term, design, symbol, or any other feature that identifies one seller's product distinct from those of other sellers. Typically a "brand" has two parts:

1) Brand Identity (ID) is the outward expression of a brand — including its name, trademark, communications, and visual appearance or logo.

2) Brand Message is the words and images and “feelings” we share when we talk about our brand.

We think that a “brand” is an emotional and intellectual relationship your business establishes and nurtures with its customers. Brands are the amalgam of perceptions and knowledge consumers have formed about your company — from its people, products and services, to its traditions and way of doing business. A positive brand identity is vital for sustained growth through new customer attraction and existing customer retention.

Gardening consumers tell us in surveys that they rely heavily on the internet and social media to get information about plants. In creating your brand, some of the costs of social media tools such as YouTube® and Facebook® are “free,” however putting energy into using social media tools to create a brand will have costs. Time to create good content, time to manage the various social media platforms will all be investments for any brand manager.

For success in the social media content space we suggest that the nursery make their online content both engaging and inspiring. The well-known horticulture brands all have professional marketing staff and frequently hire outside help from ad agencies and other marketing support teams. For the person or company starting a new brand there are a number of choices in creating fresh and engaging content. Having the right person involved in content support is as important as having the right person in charge of pest management or propagation. Companies such as ZRB can support in content creation.

# Propagation: Does it Ever Make You Wonder?©

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## PLANT AGING AND ITS EFFECT ON STEM CUTTINGS

Have you ever experienced or heard someone say that a certain plant is not as easy to root as it used to be? Have you ever wondered why different clones of the same species differ in their rooting characteristics? In *The Plantsman*, McMillan-Browse (2010) writes about plant aging and its effect on stem cuttings. I have found this short article to be very thought provoking while he discusses chronological age of a clone as playing a major role in the ease/difficulty of rooting and how to "recover regenerative capacity by manipulation of the parent plant."

Propagators know that in many cases woody plants become much more difficult to root as they move from their juvenile growth phase into their mature phase (ontogenetic aging). McMillan-Browse states "…it would appear that the ability to regenerate asexually declines with an increasing ability to regenerate sexually.", until reaching their senescent phase when this "…potential is virtually lost." He continues, saying "…the ability of the stem to initiate roots, does not occur as a constant function throughout the life of the plant" — it declines as the plant ages. This context has particular significance for the continuous propagation of a woody plant. The physiological condition of the material is not represented by the immediate age of the individual parent stock, but is a function of the chronological (and physiological) age of the original selection. This is the case however many generations it is removed from the current material. For example, a 10-year-old stock plant of *Ribes sanguineum* 'Pulborough Scarlet' should be regarded as 80 years old because the cultivar originated in the 1930s. He further supported this statement by referencing some well-known groups of deciduous azaleas and the number of years they have been in production: Ghent (150-200 years), Mollis (130-140 years), Knapp Hill (~60-70 years), and Ilam (40-50 years). According to McMillan-Browse, each group gets progressively easier to root as the time in production decreases. The only "tip" I can recall learning about deciduous azalea cuttings is that they would root easier when taken before the bristly hairs on the young shoots fell off. This idea that the total chronological age of the clone can influence the amount of regenerative capacity that can be gained by restoring juvenility is something that I have never considered. No doubt the actual processes at work are much more complicated. In fact, Hartmann and Kester (*Plant Propagation, Principles and Practices*, 7th ed., p.617) commenting on systemic diseases (specifically viruses) in fruit tree production state "…plant virologists have demonstrated that very small, transmissible organisms were the cause of numerous plant disorders and the primary reason for clonal degeneration." Clearly there are multiple views on this question since as clonal vitality degenerates rooting can also decrease.

For better understanding of the concept of chronological aging, I asked Dr. Brent McCown to explain how the above referenced 10-year old *Ribes sanguineum* 'Pulborough Scarlett' could be seen as really being 80 years of age. In his response he said (pers. commun.) "…the oldest (most adult part of a plant) is the original meristem from the embryo. However, on this same plant, in any year much more juvenile shoots may be coming from the basal collar region. Thus your 80-year-old *Ribes* stock plant is only that old if the tips of the original seedling shoots still exist; however, in most shrubs, these shoots have long been replaced by new collar shoots, thus the plants are not physiologically 80 years old anymore." If I continue this same line of reasoning I would therefore have to conclude that the 10-year-old plant would not be 80 years old (physiologically), although I suspect it could easily be much more than 10.

In most cases the propagator is working with clones that were selected for characteristics exhibited in their mature phase, and successive generations of vegetative propagation has resulted in stabilization (fixing) in this condition at the expense of any

juvenile characteristics (*Hartmann and Kester's Plant Propagation: Principles and Practices*, 7th ed., p.610). For cuttings rooted from plants in this mature growth phase, the "fixed" physiological condition of the parent plant is passed on to the newly produced plants. For difficult-to-root plants the propagator must attempt to turn back the clock and restore their stock to a juvenile phase where greater regenerative rooting potential exists. This is usually accomplished by cutting the plants back severely so that only vigorous, upright, non-flowering shoots are produced. Dr. McCown points out that the juncture of the stem and root is referred to as the "basal collar" and remains the most juvenile part of the plant. Shoots which arise from this area will exhibit more juvenility than growth from the main stem of the original stock plant. Additionally, Mr. McMillan-Browse comments "the faster the growth achieved by this process, the higher is the level of regenerative capacity regained. Therefore, it is the speed of growth which is the critical factor in regenerative capacity."

Mr. McMillan-Browse also speaks about the importance of including the "basal swelling" with the cutting. Although he probably means this to include the basal collar, this might also be interpreted as the swelling which is typically seen where twigs/branches/trunks intersect. Using *Salix daphnoides* as an example, but generalizing this concept to include other woody plants… "quality (size and vigour) of the new plant is greatest when derived from the basal cutting, with progressively, declining quality with cuttings taken from the tip of the shoot." "This basal swelling …represents the fastest growth rate of the new shoot…" and therefore, the greatest regenerative capacity. These basal portions are the oldest chronologically, but are the most juvenile in maturity (ontogenically) whereas the tips are the youngest chronologically but the most mature physiologically. It is a commonly accepted nursery practice to leave a "heel'' on the bottom of conifer cuttings, as well as many harder-to-root deciduous trees and shrubs. Many times at our nursery we like to leave a sizeable bit of the older stem and on compact shrubs, like *Fothergilla* and dwarf forms of *Hamamelis* and *Clethra* we will actually take a branched cutting that includes 2- or 3-year old wood. We believe this improves the quality and overwintering success of our rooted cuttings and we have been doing so without even realizing enhanced juvenility might be a factor.

In 2014 I thought I would try some cuttings from a plant my grandmother had grown of *Rosa* 'Harison's Yellow'. Regarded as difficult to root, I found that to be true. I also discovered that it was introduced in 1824. I asked Mr. Bill Hendricks of Klyn Nursery, Perry, Ohio what he thought of the idea of rootability declining with the accumulated age of the original clone. Like me he had never given the question any thought, but he did note that *Malus* 'Bob White', a cultivar introduced in 1876, was one of the most difficult crabapples for his propagator to root. Do these observations have anything to do with total chronological age, clonal degeneration, failure to restore juvenility (rejuvenate), or something else? Probably all of the above are involved.

**HOW LONG SHOULD A PLANT BE MONITORED TO DETERMINE IF ITS DESIRED TRAITS ARE REPRODUCIBLE?**

Growing in one of Ohio's highway rest areas are several unique and interesting specimens of *Ginkgo biloba*. Although they do vary slightly, their distinguishing traits are being tall, narrow, and possessing branches spaced tightly along the trunk, almost to the point of touching at their bases. Branching is so thick that it is difficult to insert your hand and touch the trunk. From a distance the trees appear like thin, tapered paint brushes held upright. Probably planted in the 1970s, I can only assume they were sourced from a commercial nursery, although no one I have spoken to has ever seen a cultivar which resembles this form. No graft unions can be observed — might these be nearly identical seedlings or clonal cuttings? No one really knows.

Dr. Bob Lipka was one of the first to notice just how unique they are and 5 or 6 years ago he gathered some propagating material. He called this plant *Ginkgo biloba* 'Grindstone', named after the area in which they were found. Technically, he felt that each plant could be considered a clone, so he focused on the plant with the thickest,

fullest form. He told others about the plants and soon several propagators were trialing it as well. In 2014 I received bare-root liners from two of these growers. Plants were in the 3- to 4-ft size range. Some of them were upright in form while others exhibited a wider branching habit. Ginkgo are notorious examples of plants exhibiting topophysis — the phenomenon of the location from which the cutting is taken influencing the habit of the plant it produces, and this can create real issues for growers. I contacted four other propagators who had plants in the 3- to 4-year-old range. They reported some plants had wide branch angles but the majority was upright; again, topophysis at work. What I find of interest is that the dense twiggy branch formation of the mother tree is not clearly evident in the young plants being produced from it. Although Dr. Lipka reports a small percentage of his plants have dense branching, none are thick as the mother tree. Should this characteristic not be reproducible? Instead of branches that are packed almost to the point of touching, the limbs on my plants are well within what would be considered "normal" for the species. Is this inconsistency due to vigor and in time will revert to what is expected for this clone? Would cutting produced plants look different than those that are budded or grafted? I would expect own root plants to develop more slowly and have shorter internodes. Again thinking of Mr. McMillan Browse, instead of using propagation material from tips of ascending branches, what would happen if we were to take scions from the base of the same branch or closer to the basal collar? In his article he states: "Woody plants grown from cuttings with basal swellings show the expected characteristics of the mature cultivar by the second season after propagation." Would this solve the problem seen in the 'Grindstone' ginkgo? Lacking time to visit the mother plant, in 2014 I took terminal cuttings from the more upright portions of the 3- to 4-ft liners which we had purchased. Ideally, I would like to take cuttings from different locations on the original tree. The answer must be in there somewhere.

This begs the question, how long should a plant be monitored to determine if its desired traits are reproducible? I believe that this topic can and does stimulate considerable debate. Let me give you but one short example. Our company has in the last 18 years introduced two forms of weeping *Cercis canadensis*, 'Covey' (Lavender Twist® red bud) and Vanilla Twist® red bud. In each case the mother plants were observed for several years, as were young plants produced from them until it was easily discernible that the strongly weeping trait was maintained through propagation. However, I was always hoping to find another *Cercis* that possessed a more upright habit with a dominant central leader as well as weeping branches. Observing several hundreds of $F_2$ seedlings involving 'Covey' and 'Royal White' we found plants that were primarily strongly weeping or exhibited the normal, wide spread form typical of the species. Nothing impressed me as intermediate. However, now nearly 10 years later some plants are beginning to develop a form that appears going in the right direction.

During this time a *Cercis* was found in an old park in Cleveland. It was close to 15 ft tall and had definite cascading branches — very much like I had been seeking. We propagated it and after approximately 7 or 8 years the young plants still have not taken on the form of the parent tree. These examples, along with the previously mentioned *Ginkgo*, suggests two points:

1) Some mature characteristics that we select for may not develop in time to be present in the smaller, younger plants that we offer for sale and possibly.
2) That such a delay may limit the marketability of such a selection.

I have now initiated propagating some of the more interesting F2 *Cercis* hybrids and I will be watching the young plants they produce to see how long it takes for them to develop the same parental forms.

## OBSERVATIONS ON DWARF SELECTION OF GINKGO

Continuing with *Ginkgo biloba*, I have been rooting softwood cuttings of this ancient specie for a number of years. They are quite easy to do but own root plants will be slower to develop into saleable stock than those that are budded or grafted. The fastigate form I am producing is called 'Elmwood' and for whatever reasons, I find this selection easier to

produce with a straight, central leader. Many of the clones I have tried were nearly impossible to develop and keep a central leader without staking. For me, 'Elmwood' is easier. As much as possible I limit my cuttings to new growth taken from branches that are strongly ascending. Even the young 2-, 3-, and 4-year-old plants are showing a very high percentage of central leader dominance and narrow branch crotch angles.

In 2013 I thought I would try rooting some of a dwarf selection called 'Troll'. Cuttings were taken on July 31, treated with 1:10 Dip 'N Grow and placed into mist. One year later, new growth is about 0.5" long and rooting appears weak. This is probably what I should have expected from a dwarf. But then a question occurred to me, does the rootability of any given dwarf form depend at all on the origin of the original plant? In other words could ease of asexual reproduction be additionally influenced by whether it is a genetic dwarf (from seed) or a mutated form (broom) of an otherwise normal growing plant? A broom generated plant would most certainly have arisen in an old, mature or even senescing tree where rooting percentages would be expected to be low. Grafts from these would be perpetuating the mature characteristics and unless the grafted plants were being cut back drastically, one would not expect to find a lot of vigorous new growth (cuttings) being produced. However, I think if I wish to do own root dwarf ginkgo, cutting them back to produce juvenile growth is what I will need to consider.

**OBSERVATIONS ON INCONSISTENT POD FORMATION IN 'DAVES' COLUMNAR HONEY LOCUST**

Several years ago our company introduced *Gleditsia triacanthos* 'Draves', marketed under the name of Street Keeper® columnar honey locust. The nearly 50-year-old mother plant had been found near Buffalo, New York where it had been observed by Mr. Tom Draves for nearly 20 years. During this time he had not noticed it to be a seed producing plant. When one of the distinctive pods of this specie was shown to the owner, who had lived there since it was planted in his front yard; he asked "what is this"? But, shortly after being put into production the mother plant began to produce seeds, sometimes quite heavily. Growers also found that this was happening but oddly enough, not every tree, not every year and not in every nursery. *Gleditsia* is a plant that can change the balance of male and female flowers it produces from year to year, and stress may possibly be a factor in causing this. Trees that have been primarily male can start producing seed and plants that were primarily female can begin producing male flowers. Could it be that the stock plants being used by propagators have become "fixed" into male or female clones? Could some of the 'Draves' selection simply be replicating the mature physiologic age of the parent tree while others are expressing the juvenile (non-fruiting) traits of rejuvenated stock. One grower indicated he found a plant with thorns which would be an indication of a juvenile phase.

The first year we collected budwood we used a bucket truck to reach into the upper portion of the nearly 50-ft-tall mother tree. I recall that there was a small zone in the upper portion that had pods, probably limited to one branch. That was all. We avoided that area in harvesting propagation material. Several years later, however, the tree had started to produce pods throughout, sometimes in very large quantities. Could the scions we gathered after the 1st year have had a different sexual reflection than before? What might have happened to initiate seed production on the entire tree? One individual suggested that the use of the systemic insecticide, Bidrin®, to control honey locust plant bugs, might have encouraged the parent tree to set more flowers. This product has a phosphorus component in its chemistry and apparently there is antidotal evidence to support this side effect in flowering trees. Or, is it possible that the plant bugs had been limiting flower production and once they had been killed by the insecticide, the flowers could carry on as never before? Could it be that the 'Draves' selection is primarily a female clone that will not produce fruit unless it is pollinated by another male clone? With only two licensed propagators receiving scions during this time I thought it might be possible to determine if one of them was working with a primarily female or male clone,

but it appears that plants from both suppliers have seed producing capacity. Once again, the answer to the vexing question of inconsistent pod production remains to be found.

## OBSERVATIONS ON PRODUCTION WITCH HAZEL

In 2009 the idea of a fixed juvenile form crossed my mind when I visited wild populations of *Hamamelis ovalis* (running witch hazel) in Camp Shelby, Mississippi. Mr. Harald Neubauer (Hidden Hollow Nursery in Belvedere, Tennessee) and I were being escorted by Mr. Steve Leonard who had discovered this new species in 2005. Three locations were visited and despite recent fires, we were surprised to find some plants over 8 ft tall and others that spread across the ground like a mat measuring approximately 12 ft wide by 18 in. high. Later that same year I went with Mr. Wayne Webb to observe other colonies in Clark County, Alabama. Here we found plants at least 12 ft tall that were surrounded by what appeared to be short rhizomatous outgrowths from a central location. We had observed the same spreading growth habit in Mississippi. Although I was told that a least one "mat form" had been observed in this area, I was not able to see it for myself.

The question of this low growing form still puzzles me. Could it be a genetic dwarf that still maintains the running characteristic? Is it some sort of abnormal habit that has become "fixed," the result of some environmental factor, such as periodic fires? Is a juvenile form that may not flower as well as more ascending forms? From the most pronounced of the low statured plants I gathered some rhizomes which have been established at our nursery. We are anxiously waiting to see just how they perform and if they will remain short. We are taking cuttings from these as well as about 12 other normal growing clones (grafted) in an attempt to get each of them established on their own roots. So far it has been possible to observe that some clones definitely do root better than others. I imagine the trick is going to be, as it appears to be for most efforts to do *Hamamelis* by cuttings, to get them into their 2$^{nd}$ or 3$^{rd}$ winter without dying. Own root *Hamamelis* are famous for dying during their first winter outdoors, even if they are 2 or 3 years of age at the time. Could lack of root hardiness on cutting grown plants be a sign of juvenility? Dr. McCown told me "…root tissues probably always remain juvenile, but we have no way to measure this since roots do not flower."

## OBSERVATIONS ON PRODUCTION OF RED MAPLE CULTIVARS

When it comes to the production of *Acer rubrum* cultivars the nursery industry has come a long way from the days when budded stocks suffered high failure rates due to incompatibility. Production by cuttings or tissue culture has become the accepted and preferred standard. Several years ago a local landscape architect suggested that I grow him some plants of *A. rubrum* 'Columnare' so I immediately looked to the mainline producers of tree liners for a supplier for this very old selection. Finding none, I asked Kris Bachtell at the Morton Arboretum to send me some budwood from their majestic specimen. This material arrived in October 2006 and the only understock I had available were some containers of own root *A. rubrum* 'Somerset' and 'Brandywine'. Due to the size mismatch I chip budded these anywhere from 3 to 5 ft up from the bottom. Enough survived that I was able to plant out about six of them. At that point I did not record on which understocks the grafts had succeeded or failed. For several of the following years we asked Hidden Hollow Nursery to bud for us additional trees using *A. rubrum* as the understock. The observation I wish to make is that for the stock budded onto *A. rubrum* seedlings a number of plants eventually formed a swollen, bell-shaped flair at the graft union and died from incompatibility. This is consistent with the problem that was expected from budded propagation before the days of own root cultivars. On the other hand, my two remaining plants which are on 'Somerset' and 'Brandywine' have reached a caliper size of 3.5 in. and have perfectly smooth unions and no symptoms of incompatibility after 8 years. This suggests to me that had not the industry developed own root techniques for commercial cultivars of *A. rubrum* and *A.× freemanii* then it might have pursued clonal understocks and cultivar compatibility studies. Of course such a

project might have been academic in nature, since to develop clonal understocks begs the question, by what means would they have been produced if not by rooting or tissue culture (perhaps stooling?) As it stands today, budding onto a specific clone might prove useful only in limited instances where a particular cultivar remains difficult to root or to establish new stock. I would like to point out that we have tried to root this cultivar using softwood cuttings with very limited success. It is my understanding that J. Frank Schmidt & Son and Klyn Nursery have found it difficult as well. I bet Mr. McMillan Browse would suggest the fact this cultivar was introduced prior to 1889 has a lot to do with that.

**WINTER DAMAGE OBSERVATION**

Let me make an observation on winter damage, of which we have seen a lot occur in our fields as of late. Brotzman's Nursery is primarily a producer of field grown stock and we maintain only about 10,000 $ft^2$ of container production. A wide range of both deciduous and evergreen plants are overwintered in white, single-poly covered houses measuring 110×14 ft and either 8 or 11 ft tall. In the past certain plants were chosen to be stored in specific houses only as dictated by available space or their height requirements. Once the houses are closed we try to enter once, if not twice during periods of thaw to water each container thoroughly.

After the winter of 2014 we experienced higher loses than normal, despite being able to water once in mid-winter. At the time I was surprised to find that the greatest losses were in the taller houses. Whereas *Ginkgo biloba* 'Elmwood' (own root) growing in quarts, 1- and 2-gal containers were fine in the short houses, 6-ft standards of *G. biloba* 'Troll' in 15-gal containers were mostly dead. The same observation was made for own-root plants of *Parrotia persica* 'Vanessa'. Quart and 1-gal containers in short houses were mostly alive, whereas most of the 3-gal containers from the high house were badly hurt or killed. Assuming all containers had adequate amounts of moisture during critical periods, I now realize that during the prolonged and extreme cold we faced, the tall houses may have offered less protection than the short houses, primarily due to the greater heat loss from the taller house. Using the formula for Heat Conduction Loss Factor [TSA (Total surface area) × T (max. temp. inside – min. temp outside) × HLV (heat loss value of poly covering, which is .83 for 4 ml)] I determined my 8-ft houses would lose 118,695 BTU/h and my 11-ft houses would lose 178,000 BTU/h. Apparently the shorter houses held more of the ground heat closer to the container, whereas in the higher houses the ground heat escaped more quickly into the ambient air and eventually, to the outside. Clearly during the long periods of below zero temperatures the issue became a matter of root damage from the containers freezing. In the future, using air inflated double poly, laying the plants down and covering with a sheet of poly or a frost blanket or utilizing an alternate location for the suspect species may need to be considered.

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# Management of Boxwood Blight Caused by *Calonetria pseudonaviculata*©

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*Calonectria pseudonaviculata* causes leaf and stem lesions resulting in defoliation and dieback of boxwood. Trials were conducted to evaluate fungicide management of boxwood blight under greenhouse and container nursery conditions in Connecticut using fungicides previously determined to have in vitro activity against conidial germination or mycelial growth. Plants of different boxwood cultivars were inoculated 48 h after fungicide application. Disease progression was monitored over 6 weeks and progressed from leaf and stem lesions to defoliation. The level of disease control achieved by fungicides was generally good, with the most efficacious treatments averaging from 95% to nearly 100% control. Products containing propiconazole, myclobutanil, thiophanate-methyl, fludioxonil, pyraclostrobin, kresoxim-methyl, and chlorothalonil had significant efficacy. The combination of systemic plus protectant fungicides in a single application resulted in superior disease control compared to the use of a systemic fungicide. There were no differences between the fungicide treatments that included thiophanate-methyl and those that included propiconazole as the systemic fungicide. Korean and 'Winter Gem' (*Buxus sinica* var. *insularis*) were the least susceptible of the taxa evaluated, common boxwood (*B. sempervirens*) and true dwarf (*B. sempervirens* 'Suffruticosa') were the most susceptible, and 'Green Mountain' (*B. sinica* var. *insularis* × *B. sempervirens* 'Suffruticosa') and 'Green Velvet' (*B. sinica* var. *insularis* × *B. sempervirens* 'Suffruticosa' were intermediate. These results suggest that *B. sinica* var. *insularis* may have some level of resistance to boxwood blight. Management of boxwood blight will rely on integrated best management practices that include inspection of incoming plant material, sanitation, cultural controls including use of cultivars tolerant to infection, and fungicide application.

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**Full Manuscript Reference**
Plant Disease: <http://apsjournals.apsnet.org/doi/pdf/10.1094/PDIS-02-14-0217-RE>.

# *Calonectria pseudonaviculata* Can Cause Leaf Spot and Stem Blight of *Pachysandra terminalis* and *Pachysandra procumbens*©

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*Cylindrocladium pseudonaviculatum* Crous, J.Z. Groenewald & C.F. Hill (syn= *Calonectria pseudonaviculata* (Crous & al.) L. Lombard & al., *Cylindrocladium buxicola* Henricot) was recently reported infecting boxwood *Buxus* spp. L. in North Carolina and Connecticut. This was the first report of this disease in North America (Ivors et al., 2012). The pathogen caused significant losses in container nurseries and in the landscape in both states and a number of boxwood taxa were shown to be infected. Henricot et al. (2008) reported that all *Buxus* spp. tested and a *Sarcococca* Lindl. (sweet box) sp. tested were all susceptible to this pathogen. Plants in the *Buxaceae* that are either native or grown as ornamentals in North America include *Buxus*, *Sarcococca*, and *Pachysandra* Michx.

Japanese spurge, *Pachysandra terminalis* Siebold & Zucc. is widely grown and Allegheny spurge, *Pachysandra procumbens* Michx., is a native plant that is also grown as an ornamental ground cover in nurseries and landscapes. *Pachysandra procumbens* is primarily reported as a perennial woodland herb or subshrub from the southeastern United States, from Louisiana to Florida and north to Indiana and Pennsylvania. It is relatively rare in nature with locally common populations (Dirr and Alexander III, 1979). It is hardy far north of its natural range and is propagated and sold as an ornamental groundcover in the nursery trade.

We inoculated healthy plants of both *Pachysandra* species in separate experiments to conduct Koch's postulates. Circular lesions (1-4 mm diameter) were evident on leaves within 7 to 10 days after inoculation. Stem lesions were also observed. All inoculated plants developed lesions, and no lesions were observed on non-inoculated plants. Leaves and stems with lesions were surface sterilized in 0.5% NaOCl for 30 s, rinsed twice in sterile distilled water and lesion margins plated onto water agar or ½ PDA (potato dextrose agar). The pathogen was re-isolated from all plants tested.

Stem lesions girdled the plant after 2 weeks and resulted in stem blight and plant death of *P. procumbens*, but not *P. terminalis*. Under humid conditions, heavy sporulation of *C. pseudonaviculatum* was observed on both leaf and stem tissues of *P. procumbens.* Sporulation also occurred to a lesser extent on *P. terminalis*. Microsclerotia were observed in infected leaves and chlamydospores, in infected leaves and stems using both tape lifts and epidermal peels at 400× magnification.

*Cylindrocladium pseudonaviculatum* has now been shown to cause disease on all common ornamental species in the Buxaceae grown in North America. To date, over 20 cases of natural landscape infections in *P. terminalis* have been confirmed in Connecticut (S.M. Douglas, pers. commun.). The discovery of landscape infections of *P. terminalis* resulted in important modification of best management practices for management of this disease in the landscape (Douglas, 2012).

*Pachysandra procumbens*, while not as common as *P. terminalis*, typically grows in environments conducive for the development of disease and may also serve as a reservoir of inoculum for the boxwood blight pathogen in cultivated landscapes and in nature. In addition, *P. procumbens* is listed by the USDA Natural Resources Conservation Service as endangered in states such as Florida and Indiana (<http://plants.usda.gov/java/threat?statelist=states&stateSelect=US12>) and *C. pseudonaviculatum* leaf spot and stem blight may further threaten this species in its native habitat.

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# *Clivia* Breeding at Longwood Gardens©

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Longwood Gardens, in Kennett Square, Pennsylvania, has recently released three cultivars of *Clivia miniata* from their breeding program which began in 1976. At the beginning of the program, most existing *C. miniata* were orange flowered cultivars, and yellow flowers were rare and very desirable. The original goal of the breeding program was to produce a superior yellow flowered *Clivia*. Thirty-four years after the program began, in 2010, *C. miniata* 'Longwood Debutante' was released at the North American Clivia Society Show at Longwood Gardens. "Debutante" is a fitting name as this plant was the first release from Longwood's breeding program to enter into *Clivia* Society. It was revealed in the grandeur of the Longwood Ballroom. *Clivia miniata* 'Longwood Debutante' produces slightly fragrant, buttery yellow flowers, with overlapping tepals, in an umbel set on a sturdy scape, that rises nicely above the dark green foliage. The goal of the breeding program was realized with 'Longwood Debutante'. Superiority of the plant was validated when single blooming fans of *Clivia* 'Longwood Debutante' sold for $900.

Fig. 1. *Clivia miniata* 'Longwood Debutante'.

In 2011, *C. miniata* 'Longwood Fireworks', a second yellow flowered cultivar, was released and again sold for $900 per single blooming division. *Clivia miniata* 'Longwood Fireworks' produces large, soft yellow flowers, with reflexed tepals and protruding stamens, which are held on a spherical umbel, that rises well above the foliage. Fireworks traditionally fill the summer skies over Longwood during the Festival of Fountains, and the reflexed tepals, protruding stamens, and impressive umbel of 'Longwood Fireworks' creates a flower that looks like an explosion of fireworks in the sky.

Fig. 2. *Clivia miniata* ‘Longwood Fireworks’.

In the process of breeding *Clivia* at Longwood, a chance mutation manifested keeled tepals. A keel refers to a raised area on a flower petal that resembles a keel of a boat. In some cases, the keel actually changed the shape of the flower. The keeled tepals were so unique and interesting, that a new breeding goal of producing keeling cultivars was set. Several years of data was collected on keeling seedlings. In some cases, a plant that keeled very well one year had very little keeling other years. After years of observation, *C. miniata* ‘Longwood Sunrise’ was introduced with uniformly keeled orange tepals.

Fig. 3. *Clivia miniata* ‘Longwood Sunrise’.

The evaluation of seedlings continues and several new cultivars are in the pipeline. In 2015 Longwood plans to release a cultivar with orange tepals with a deep bronze cast, and green throats. The tepals fade to a brick red color. Red is a rare and desired color in *Clivia* breeding. A 2008 cross produced a plant with green flowers with an ivory highlights. Green is also a very coveted color in the *Clivia* world. Several other keeled selections of various color combinations may also be released in the future.

It should be mentioned that not all *Clivia* cost $900 for a single plant. Seeds can be purchased relatively cheaply. Unnamed selections of attractive plants can be obtained for reasonable prices. Do not be afraid of *Clivia*. They make great house plants, and thrive on the coast of California. They tolerate low light conditions and are drought tolerant. Protect them from direct sunlight and freezing, and they should grow well for you. They have attractive leaves that look good all year, and amazing flowers if grown correctly.

*Clivia* are easily started from seed. The seed should be planted soon after it is removed from the berry. If it desiccates, it may not germinate. Place the seed on the surface of moist vermiculite in a Tupperware container in indirect sunlight. The seed will produce a huge root that tends to push the seed out of the soil. After the leaf emerges, plant the long thick root in a well-drained mix. Allow the plant to dry between watering's. Be patient. If you are an amazing grower, you may see a bloom 3 years after sowing the seed. In some cases, it could take 7 to 8 years to see a bloom. The plant needs to produce 13 leaves before it blooms. The faster you produce the required leaves, the faster the plant will bloom.

After the required 13 leaves have been produced, the plant needs a cool dry dormancy for at about 40 days. During the dormant period temperatures should be maintained below 50°F and above freezing. Plants should receive very little water during this time. If the proper dormancy is not administered, the flower stalks may not elongate properly, and remain hidden in the foliage. After the dormancy requirements have been met, water the plants and gradually raise the growing temperature to the mid-60s. Two months after breaking dormancy, the plants should bloom and brighten your spring.

# Does Composting Eradicate the Pathogen Responsible for Boxwood Blight? An Outline of Future Investigations©

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## BOXWOOD BLIGHT: AN OVERVIEW

Boxwoods (*Buxus* spp.) have been a staple ornamental in both Europe and the United States for hundreds of years (Bir et al., 1997; Henricot and Culham, 2002; Varela et al., 2009). Controversy exists surrounding the current naming of the pathogen responsible for boxwood blight. This stems from the pathogen being isolated and proposed as a new species independently by two different lab groups in 2002. The first of these reports (Crous et al., 2002), documented a new species of fungus infecting boxwoods in New Zealand and described it as *Cylindrocladium pseudonaviculatum*. Shortly thereafter, Henricot and Culham (2002), published a paper documenting their findings and named the fungus *Cylindrocladium buxicola*. Although the teleomorph has yet to be observed, the name *Calonectria pseudonaviculata* has been proposed for the sexual stage by Lombard et al. (2010). However, within the research community *Calonectria pseudonaviculata* is becoming the preferred name, and will be used in this paper.

Due to the polycyclic nature of the disease, boxwood blight poses a significant threat to the boxwood industry. The adhesive nature of C. *pseudonaviculata*'s spores also contribute to the rapid spread and infection of new hosts (Henricot, 2006). Infested tools and clothing, if not properly sanitized, can vector pathogen propagules inadvertently to healthy plants and non-threatened areas. The life cycle for the pathogen is rather straightforward. Germination takes place approximately 3 h after inoculation, with penetration occurring approximately 5 h post-inoculation under ideal weather conditions (Henricot, 2006). Penetration occurs directly through the cuticle, or through a stoma. The presence of an appressorium has not been reported for this pathogen. Once the fungus enters the host, the mycelium grows intercellularly within the mesophyll; the fungus re-emerges through the stomata 2 to 3 days after initial infection. After 1 week, conidiophores can be observed on the abaxial leaf surface (Henricot, 2006). The presence of microsclerotia, which represents a method of survival during adverse environmental conditions, has also been noted (Henricot, 2006; Ivors et al., 2012).

The disease and symptom progression of boxwood blight is as follows. Circular lesions appear initially on the leaf, forming concentric rings which appear due to the outward growing of the fungus (Akilli et al., 2012; Cech et al., 2010; Crepel et al., 2003; Elmhirst and Auxier, 2013; Gorgiladze et al., 2011; Henricot and Culham, 2002; Henricot, 2006; Ivors et al., 2012; LaMondia et al., 2012; Mirabolfathy et al., 2013; Saurat et al., 2012; Varela et al., 2009). Over time, the lesions expand, eventually coalescing and leading to leaf death. Symptoms are not limited to the leaves. Large black cankers and streaks appear on the stems, eventually leading to total defoliation and plant death (Akilli et al., 2012; Cech et al., 2010; Crepel et al., 2003; Elmhirst and Auxier, 2013; Gorgiladze et al., 2011; Henricot and Culham, 2002; Henricot, 2006; Ivors et al., 2012; LaMondia et al., 2012; Mirabolfathy et al., 2013; Saurat et al., 2012; Varela et al., 2009).

The host range of *C. pseudonaviculata* is not fully understood; however, in vitro experiments have yet to uncover an immune species of *Buxus*. *Buxus balearica* appears to be most resistant to the pathogen. This putative resistance is attributed to its thick leaves, leading to the postulate that the pathogen experiences difficulties penetrating the leaf. Unfortunately, *B. sempervirens* represents one of the most popular boxwood speicies, and shows the most susceptibility towards the pathogen (Henricot, 2006; Henricot et al., 2008). Other member species of ornamental importance in the *Buxaceae* family include *Sarcococca* sp. and *Pachysandra* sp., both of which have been evaluated for susceptibility. *Sarcococca* has illustrated some susceptibility to the pathogen, but not to

the same extent as in *Buxus* (Henricot, 2006, 2008). However, *Pachysandra terminalis* (LaMonida et al., 2012) and *P. procumbens* (LaMondia and Li, 2013) have been confirmed as susceptible.

Severe damage and losses have occurred due to the rapid rate of boxwood blight spread in the United States. Ten thousand plants were confirmed to have boxwood blight in North Carolina alone, with the amount of infected plants found in Connecticut being 15-fold higher. Within two nurseries, 150,000 infected boxwood plants were found (Ivors et al., 2012). The estimated monetary loss in Connecticut alone amounts to $3,000,000 (LaMondia, 2014). Boxwood blight is a major concern for the nursery industry, as the boxwood market is valued at $103 million annually. Fourteen states have confirmed cases of boxwood blight in the USA (Fig. 1) as well as Quebec, Ontario, and British Columbia in Canada, as of December 2014.

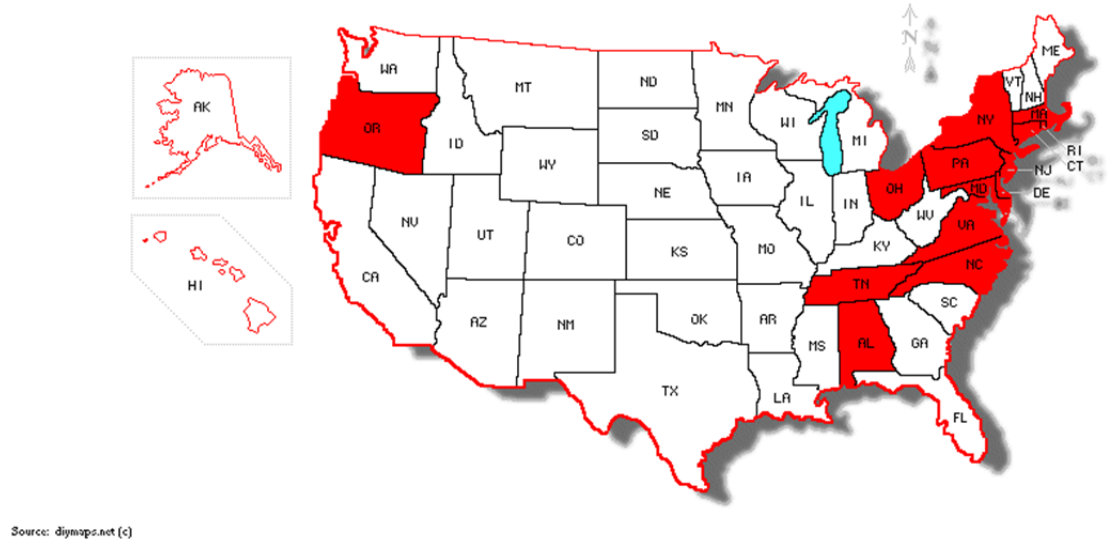


Fig. 1. Incidence of confirmed boxwood blight cases in the United States. Fourteen total states have reported the disease, mainly on the East Coast. Map as of December 2014.

## COMPOSTING AS A METHOD FOR CONTROL

Composting is a complex process involving multiple physical and biological factors. Generally, composting involves microbial decomposition processes that transform heterogeneous organic waste to a homogenous soil-like material. These decomposition processes produce heat, leading to internal temperatures that vastly exceed ambient (Hassen et al., 2001). Overall the composting process can be divided into three separate phases: mesophilic, thermophilic, and cooling (Hassen et al., 2001; Hoitink et al., 1997).

Temperature appears to be the key factor involved with pathogen eradication by composting (Fayolle et al., 2006; Harnik et al., 2004; Hassen et al., 2001; Hoitink et al., 1997; Noble and Roberts, 2004; Noble et al., 2009). Heat can be an effective killer, even when not with in the composting system. Harnik et al. (2004) reported that chlamydospores of the pathogen *Phytophthora ramorum* were killed in 3 min when exposed to temperatures of 53°C. Indirect evidence of pathogen eradication was reported by Hassen et al. (2001), when they observed that fungal populations declined during the thermophilic stage of the composting process, indicating that many fungi cannot tolerate the high temperatures. Generally, many fungi can be eliminated under composting conditions at 52°C for 7 consecutive days (Hoitink et al., 1976; Noble and Roberts, 2004; Noble et al., 2009). However, not all fungi are eradicated under these conditions. Windrow composting produces a temperature cross sectional profile, with uneven

heating, due to air flow and insulation properties of the substrate. Therefore, windrows must be turned on a regular basis to ensure that all material is exposed to high temperatures (Hoitink et al., 1997).

Aeration is another factor that influences pathogen eradication. Fayolle et al. (2006) noted that under aerated conditions, pathogen eradication was successful in compost; however, no aeration led to incomplete pathogen eradication. When compost is not aerated or turned properly, the system can become anaerobic, which results in lower temperatures in the compost pile (Fayolle et al., 2006).

High moisture leads to eradication temperatures that are lower than in drier composts (Noble et al., 2004). Fayolle et al. (2006) demonstrated that *Plasmodium brassicae* eradication was not as efficient in drier composts as compared to composts that had higher moisture contents. There was one exception, however. The level of moisture in wood-chip-compost did not influence eradication by heating (Fayolle et al., 2006).

**RATIONAL/PLAN OF ACTION**

Pathogen presence in compost is an important issue. To alleviate landfill pressure, many green wastes are being diverted to composting operations (Fayolle et al., 2006). However, many states have regulations limiting landfilling of organic wastes. Burning is another method utilized to dispose of organic waste. However, bans on open burning are also increasing (Noble et al., 2009). As a result, yard waste from many locations currently ends up in the compost stream. Such organic waste may include infected boxwood materials. If composting is not able to eradicate the pathogen, then reapplication of the finished compost as mulch near healthy boxwoods could lead to disease outbreak. However, the safety of compost must be ensured, and protocols must be established to ensure pathogen elimination (Fayolle et al., 2006; Noble et al., 2009). Both environmental and plant pathological perspectives must be accounted for, in order to prevent the introduction and spread of pathogens from non-infested to healthy areas (Noble et al., 2009).

*Calonetria pseudonaviculata* produces microsclerotia which are extremely resistant to extreme environmental conditions, and function as survival structures. It is unknown whether the temperatures and environmental conditions within a compost pile are adequate to destroy microsclerotia. However, if composting is shown to destroy the pathogen, then composting could be employed as an environmentally friendly control option. If the pathogen survives temperatures routinely reached in commercial composting operations, then compost being used for mulches or as soil amendments could be a potential source of inoculum, further contributing to spread of the pathogen.

A small bioreactor system has been constructed within the Mushroom Research Center at The Pennsylvania State University (Fig. 2). This system includes three independently controlled incubators, each of which holds three reactor vessels. Each reactor vessel has a diameter of 15.2 cm and a height of 31.5 cm. The benefit of a small bioreactor system is that precise temperature and oxygen controls can be incorporated, eliminating variability found in a windrow or aerated composting systems. Flow regulators control the volume of air that enters the system, and each incubator can be programmed to maintain a different temperature regime. Another benefit is the ability to monitor multiple metrics in the system. Each reactor vessel is connected to a data collection system that gives real-time readings, as well as allowing data storage on a computer. Oxygen and carbon dioxide meters, as well as boric acid traps for ammonia analyses, allow for measurement of exhaust gas from each vessel. Each vessel also has a probe for temperature monitoring.

Overall, this bioreactor design allows performance of carefully controlled experiments to examine specific questions related to pathogen eradication. We plan to first investigate the effect of compost temperature and time on pathogen survival, as this is likely the most important factor. Other options can then be explored, such as comparison of different starting materials to determine if their content plays a role in pathogen eradication. For example, a low C:N ration would mean that more ammonia would be produced, which might help with pathogen eradication. In addition, the effects

of other microbes could be investigated to determine if different microbe populations influence pathogen eradication.

Fig. 2. Three bioreactors inside of a high-temperature incubator. The system consists of three incubators, allowing for the simultaneous operation of nine bioreactors. Humidified air enters the reactor at the bottom, and exits the top. The reactors hold approx. 4 L and are constructed with 15.2 cm diameter PVC.

It is our goal to utilize this system to evaluate the survival of *C. pseudonaviculata* during the composting process. As this new pathogen presents a significant threat to the nursery industry, it is extremely important to recognize and identify any and all pathways by which the pathogen can spread. Results from these experiments can hopefully be used as a tool in developing integrated pest management plans to minimize the spread of boxwood blight.

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# Management of Hail-Damaged Landscape and Nursery Plants©

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## INTRODUCTION

The weather can be fickle with effects of some widespread while at other times quite localized. Hailstorms seem to travel in bands whereby a swath is cut through an area while nearby areas are untouched.

A recent spring hail event in our area resulted in a distinct Christmas-like smell that was combined with a dying plant smell (Fig. 1). While the damage can seem to be overwhelming it's important to move quickly to clean up the site to reduce the impact of secondary infectors and infestations.

Prioritize the treatment of damaged plants. Decide which plants are beyond saving due to severe damage, those that have moderate damage but can be saved, and those that have minimal damage and will survive with limited care. The first plants to be treated should be those in the moderate damage category since immediate attention is needed and those that follow should be the minimally damaged plants. An exception might occur when a specimen plant experiences a high level of damage and "needs" to be saved.

## DAMAGE

It's important to recognize that while hail injury is mechanical damage, it is also a stress-related injury. The impact on plants may continue long after the storm has ended. The following are types of damage and notes on what to consider when reviewing damage.

Damage to herbaceous plants can include damage that extends from holes in the leaves, to shredded leaves, to near total defoliation. This damage can result in significantly reduced photosynthetic activity and create opportunities for disease infection.


Fig. 1. A: Accumulated hail the morning after the storm. B: Evergreen (*Pinus*) buds, catkins, and cones on pavement.

While herbaceous plants are aggressive growers, recovery will depend on the stage of growth when damage occurs. Some plants will come through well while others may not survive. If plants are located in largely defoliated wooded areas, increased sunlight may also modify the plant's environment further limiting recovery.

Foliar damage to woody plants can include symptoms similar to those experienced by herbaceous plants. Young twigs and stems can also be stripped or broken from heavier stems. If enough of the foliage is lost, trees will usually generate new leaves and buds. When partial defoliation occurs, trees will generally not initiate new leaf growth.

Damage to thin-barked trees can vary from tearing to what appears to be pinpoint damage. Tearing will lead to a scaring while pinpoint damage tends to result in a callus tissue bump on the stem. Each type of wound exposes the vascular cambium and will lead to necrotic or dead areas on the stem. Callus will normally form along the margins of the wounds (Fig. 2). Extensive wounding will negatively impact nutrient movement. Early in the year, when the vascular cambium is active, these wounds tend to be more severe and are more susceptible to infection. Later in the year, when wood is tougher and conditions are cooler and drier, infection is less likely. Bruising is another type of damage that is similar to pinpoint damage but without a break in the bark. It is not easily detected and may lead to delayed symptoms that can include dieback.
Bud damage on evergreens can have more impact than bud damage on deciduous plants. Hail damage that occurs in the spring, when there is new growth with many new buds and cones, can result in open wounds that can lead to disease infection and insect pest infestation. Because evergreens have leaves (needles) that are meant to last for several years, stress-related secondary impacts can occur over an extended period and will continue until the water and nutrient supply is balanced against plant growth needs.

**TREATMENT**
Treatment options are related to the type of plant impacted and the extent of damage but the first step is to clean up the area of plant material that has fallen to the ground (Fig. 3).


Fig. 2. A: Torn bark on *Betula*. B: Callused wounds on *Betula*.


Fig. 3. A: Mostly evergreen tissue dropped the day following a hailstorm. B: Cleanup is important: the same area a week later after cleaning.

Flowers and fruit are desirable for their beauty but if damaged, plan to dispose of them as soon as possible. Flowers and fruit are succulent and/or sugary and can easily be infected with diseases. Rain and wind can then spread the infection to other susceptible plants.

When annuals experience moderate to large amounts of damage they will likely need to be replanted. Consideration must be given to one's goals. Flowering periods are generally limited so replanting may be the best option even under limited damage scenarios. Recovery takes time. If there is no regrowth within 1 to 2 weeks following the hail event, plan to replace plants.

While herbaceous perennials will generally survive and initiate new growth, they are at risk because of damage to succulent growth. Plan to remove damaged tissue to reduce the possibility of secondary infection. The crown of many herbaceous perennials is a critical area. When crown damage occurs, they will either decline or have a prolonged period needed to restart growth. Regrowth of vegetative plant parts can be slow or quick depending on the time of year and the type of plant. When damage occurs during flowering or an active stage of growth, new flowers and buds can start appearing within a week.

Mature deciduous trees can generally survive hail damage. Leaves may be stripped but buds will normally survive, ensuring tree refoliation. Younger deciduous trees are most at risk due to the possibility of the aforementioned bark damage.

It may take a couple years to repopulate evergreens with the same number of needles that were there before the storm. During that repopulation period, plants will continue to be under increased stress. For younger trees, plan to manage water needs during dry periods.

Fig. 4. Cleaning up can be a big job. This was load #3 and there was plenty left to do.

While the thought of cleanup can be bewildering, it's imperative to get started as quickly as possible. Remove fallen leave tissue and larger plant parts to help reduce secondary infection. Woody plants that have been damaged will often have a secondary drop of leaf tissue and small stems that have been damaged but most of those will have dried down so cleaning up those is less critical.

There is continuing discussion on the value of pesticide applications following hail damage. The application of fungicides following removal of damaged tissue can help prevent secondary infections. Depending on pest pressure an insecticide bark spray may be useful to help prevent damage from borers and bark beetles. Since there doesn't seem to be a consensus to use or not to use chemical controls, monitoring for problems is important.

## OPTIMIZING GROWING CONDITIONS

It's important to optimize future growing conditions. Plan to prune to eliminate problem areas and to enhance plant structure. In locations where hail damage has reduced the amount of foliage and it has resulted in increased light and temperature, mulch damaged plants to help maintain soil moisture and reduce the soil temperature.

For herbaceous plants, remove tattered leaf tissue while maintaining as much good tissue as possible. Closely examine the crown areas to be sure there is not damage. It's difficult to recommend fertilization practices for herbaceous perennials. Some species respond well to increased fertility while others respond better to lower levels of fertility. Weather conditions following a damaging hail event can have a major impact on recovery. Research has been conducted to determine the relationship between leaf tissue loss and re-growth from animal feeding damage and environmental factors. Results indicated that when environmental conditions limit plant growth, loss of plant tissue will most likely be detrimental to plant performance but when conditions are favorable, limited defoliation may enhance plant growth (Hicks, 1997).

For woody plants, prune using techniques recommended by Dr. Alex Shigo (Shigo, 1982). Remove dead and injured twigs and tissue first. Prune back to a bud; don't leave stubs that will lead to decay. Prune to develop a desirable plant structure. Don't paint wounds in an effort to protect them.

Irrigation may not be needed soon after hail events. Since the root systems have not been affected, there may be more capacity than plants require. Clean up the ground of plant tissue prior to initiating irrigation activities to reduce the possibility of spreading disease. Trickle irrigation is preferred over sprinkler irrigation to avoid wetting damaged leaves. Under high heat conditions, plan to irrigate regularly as soils become dry. Aim for a total of about an inch per week. Irrigate more frequently with less water on lighter soils and less frequently with more water on heavier soils.

The need for fertilization is dependent on the time of the year and the type of plant. Hail damage in the spring can occur after plants have used most stored carbohydrate reserves so hail damage may have high impact. If plants survive the event, they may require initial low levels of nutrition that gradually increase.

Depending on the time of a summer hail event, plants may have adequate carbohydrates stored that will help with re-growth. Look for nutrient deficiency symptoms as new growth generates and fertilize accordingly.

Late-summer and early autumn events can result in an early dormant period or a time of re-growth. If re-growth is initiated, plants need to have time to have that growth mature so additional carbohydrates can be stored before heading into the winter. Young growth that is exposed to freezing conditions can be killed and any additional plant injury can compromise overwintering success. Fall fertilization is usually not beneficial since it can stimulate growth that might continue later into the autumn and risk winter damage.

If a late autumn event occurs, plants should have stored carbohydrates that would not be called upon for new growth until spring. Plant should enter a fairly normal dormancy. Late autumn fertilization is not required.

Nurseries, especially those with container production, have a way to minimize the potential for hail damage and to optimize growing temperatures. If cooler temperature conditions or lower light intensity helps optimize growth, plan to install shade cloth. This is especially useful as related to nursery container plant production. Polyethylene or polypropylene shade cloth can also reduce damage resulting from future hail events.

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Shigo, A.L. 1982. A pictorial primer for proper pruning. Forest Notes. Spring 1982.

# Botanic Gardens Conservation International's Gardensearch and Plantsearch Databases: the World's Botanic Gardens and Living Collections at Your Fingertips©[1]

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## INTRODUCTION

Botanic Gardens Conservation International (BGCI) maintains two free, online databases to support plant conservation in botanic gardens: GardenSearch and PlantSearch. GardenSearch is an on-line directory of the world's botanic gardens and related institutions while PlantSearch provides an account of the plant species held by these institutions. Information included in these databases is provided by each institution which is responsible for regularly updating its own record, using an on-line log-in facility.

### Some Statistics GardenSearch

- Records (institutions): 3,200
- Number of countries represented: 176
- Breakdown of institutions per region (Fig. 1)

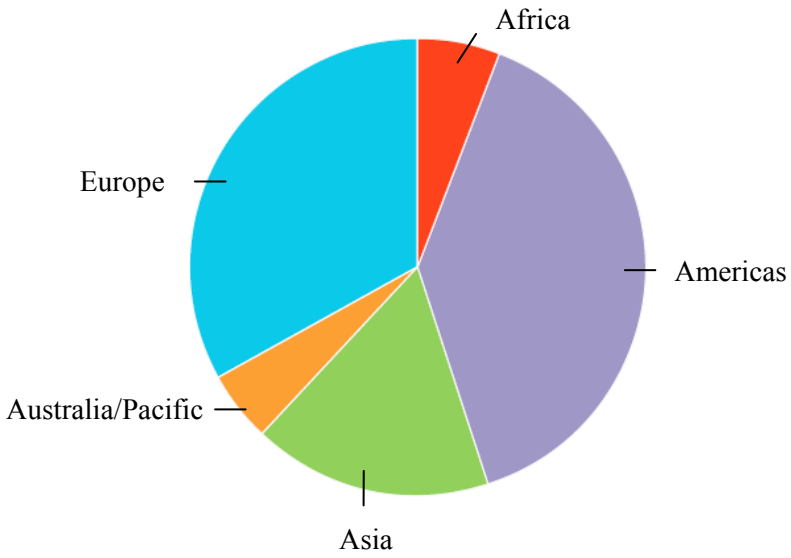


Fig. 1. Regional breakdown of institutions represented in GardenSearch.

[1]This article has been adapted from: Sharrock, S. and Hird, A. 2014. Networking Botanic Gardens for Conservation—the role of Botanic Gardens Conservation International's (BGCI's) Databases. BGjournal 11(2):3-6.

## ONLINE DATABASES

### PlantSearch

- Collection records 1,255,261
- Taxa 413,167
- Institutions providing data 1,079

There has been a significant increase in the amount of data included in these databases in recent years (Fig. 2).

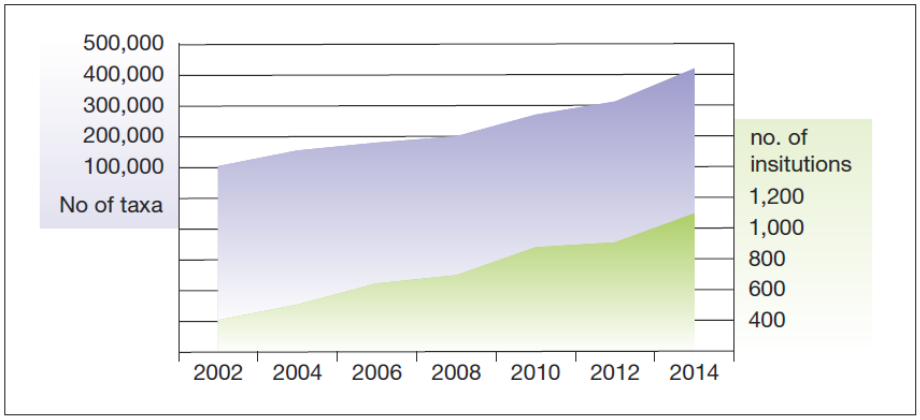


Fig. 2. Number of taxa and number of institutions providing data to PlantSearch.

### GardenSearch

Botanic Gardens Conservation International's GardenSearch database is a gateway to information about the world's botanic gardens (Fig. 3). Each garden record provides basic information about the garden and where applicable, a link to the garden's own website. For smaller gardens that do not have their own website, GardenSearch provides a web presence they would not otherwise have. All records in GardenSearch are georeferenced, allowing easy mapping of search results using a mapping "applet" available via GardenSearch. As well as botanic gardens, GardenSearch also includes an increasing number of related institutions (seed/gene banks, zoos, etc.), with a common interest in conservation and maintaining plant collections.

GardenSearch fields are divided into three sections:

- Section 1: Allows the garden to provide basic information in a free text format, including uploading an image. This information can be provided in the garden's local language and/or English. This provides an opportunity for the garden to promote itself in whatever way it prefers.
- Section 2: Consists of a form to collect information on features and facilities, plant collections, and conservation, research and education programs in a standard format. This section forms the "backbone" of the database and the data provided is compiled into a unique, searchable global directory of skills, expertise, and facilities relevant to plant conservation.
- Section 3: Allows the garden's record to be linked to related resources (journal articles, news items, etc.) that appear elsewhere on the BGCI website.

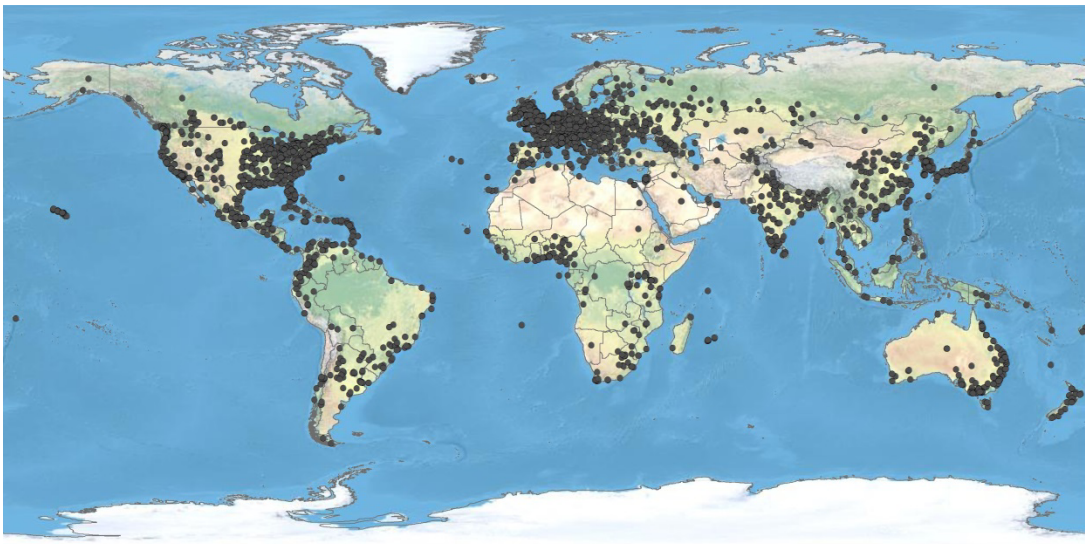

Fig. 3. Global map of institutions recorded in GardenSearch (map by Adam Smith).

**Advanced Searching**

In 2012, BGCI launched an Advanced Search function for GardenSearch. The Advanced Search function not only locates institutions geographically and by keyword, but also allows users to explore in more detail the conservation, research, education and public outreach facilities and expertise offered at botanic gardens around the world. GardenSearch includes a total of 63 searchable fields related to the work of botanic gardens, each of which can be searched at the global or national level.

GardenSearch, as well as providing a unique tool to identify specific expertise and resources in countries around the world, also allows major gaps in botanical capacity to be identified. GardenSearch also supports studies related to plants and climate change, allowing the identification of gardens offering different climatic conditions in which to test and potentially grow plants in the face of changing environmental conditions. An example of this is provided by Smith et al. (2014).

**PlantSearch**

Botanic Gardens Conservation International's PlantSearch database is the only global database of plant species maintained in the collections of botanic gardens and similar organizations. In addition to hundreds of living plant collections around the world, PlantSearch includes taxon-level data from gene and seed banks as well as cryopreserved and tissue culture collections. This dynamic collections database was originally developed to measure progress toward Target 8 of the Global Strategy for Plant Conservation (GSPC) by tracking which threatened species are in botanical collections throughout the world (GSPC 2020 Target 8: At least 75% of threatened plant species in ex situ collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs). Through its online interface, PlantSearch also connects collections directly to conservationists, educators, horticulturists, researchers, policy makers, and many others around the world who are working to save and understand plant diversity.

All data included in PlantSearch are uploaded by collection holders directly to PlantSearch via an on-line facility. Uploaded taxa lists consist of seven taxonomic fields ranging from genus to cultivar name. Before being included in PlantSearch, records are screened against existing names in the database and IPNI (International Plant Names Index) to ensure that only valid names enter the database. As of July 2014, the PlantSearch database included 1,255,261 collection records, representing 413,167 taxa, at 1,079 institutions. Each record in PlantSearch is linked to a record in GardenSearch, thus

providing a georeferenced location for each plant. Location details are however not made public, to ensure the anonymity of species in cultivation. A "blind email" request system has been developed to allow users to request further information on species of interest.

PlantSearch has direct links to a number of other databases, most notably the IUCN Red List, but also other taxonomic databases (IPNI, Tropicos), a list of CITES species and lists of socioeconomically useful plants (medicinal, crop wild relatives). Work is presently ongoing to also add links to information on invasive species.

**Benefits for Data Providers**

PlantSearch provides a useful collection management tool for collection holders. By uploading a plant list, the collection holder will be notified of misspelled or unrecognized plant names in their list. Once uploaded, the list can be compared with the global database, allowing collection holders to identify how many other gardens are maintaining the same taxa. Plant lists are also automatically screened against the IUCN Red List and CITES lists, so that rare and threatened species in the collection can be easily identified. This can facilitate the establishment of conservation priorities for the collection holder and contribute to collection evaluation (Aplin, 2008, 2013).

**Using PlantSearch Ex Situ Surveys**

PlantSearch can be used to carry out surveys of ex situ collections on a global, regional or national level, as well as for taxon-level surveys. At the global level, monitoring progress toward GSPC Target 8 is constrained by lack of progress in Red Listing, with, to date, only 6% of plants having been assessed at the global level. A recent assessment by BGCI identified 29% of globally threatened species in ex situ collections, but the lack of information on which species are under threat means that this is probably a considerable under-estimate. As national and regional lists of threatened species are more widely available, BGCI has also carried out a number of national/regional assessments on ex situ conservation progress. In the USA, a recent review found that 39% of threatened native U.S. species are now maintained in living plant and seed bank collections. This is up from 37% in 2010. This leaves more than 3,000 threatened species to add to collections by 2020 for the USA to meet the 75% ex situ target. For more details on this assessment, visit: <www.bgci.org/usa/naca>.

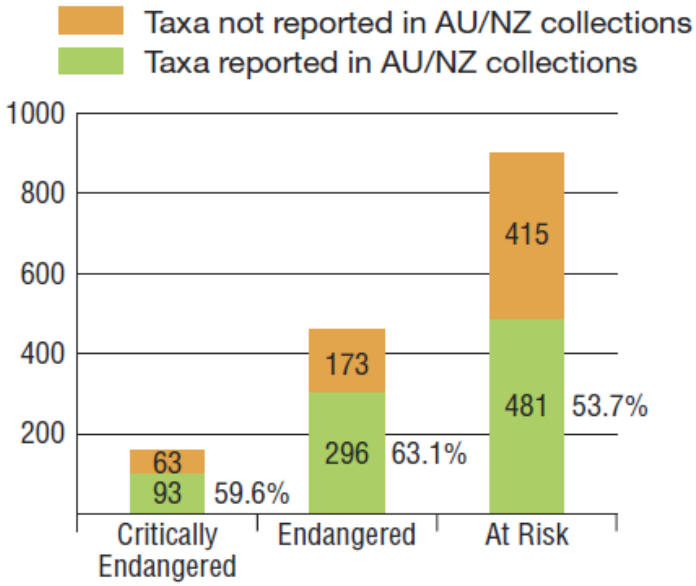


Fig. 4. Results of an assessment of ex situ collections in Australian and New Zealand botanic garden collections.

In Australia and New Zealand, 56% (854 of 1,519) of threatened species are safeguarded in living plant collections (Fig. 4). Although this is the best regional progress toward GSPC Target 8 found so far, there is still work to be done to reach the 75% goal by 2020. Furthermore, nearly 40% of reported threatened native species in the region are reported in only one collection, which suggests that collections contain low levels of intraspecific genetic diversity. For more details on this assessment, visit <www.bgci.org/usa/bganz2013>.

**Taxon-Based Surveys**

BGCI and its partners also use PlantSearch to carry out ex situ surveys of the conservation status of plant family groups. So far, these have included magnolias, oaks, rhododendrons and, most recently, conifers.

These surveys are typically carried out by BGCI following the publication of a Red List for the family or group in question, with the aim of identifying how many collections are cultivating species identified as threatened during the Red Listing process.

A summary of the results obtained through recent assessments:

- Conifers: The survey identified 81% of globally threatened conifer taxa in over 800 ex situ collections. However 134 threatened conifer taxa are known in very few or no collections. These are highlighted as priorities for establishing a more effective safety net against extinction of threatened conifers (Shaw and Hird, 2014).
- Rhododendrons: The survey identified 12,068 rhododendron records from 304 institutions in 42 countries. However, only 276 ex situ records represent just 48 of the 77 most threatened rhododendrons. This means that nearly 40% of the critically endangered or endangered taxa are currently not known in cultivation <www.bgci.org/ourwork/rhododendron_survey>.
- Magnolias: The survey included 2,274 *Magnoliaceae* records from 238 institutions in 47 countries. However, only 362 of these records represent 37 of the 89 most threatened *Magnoliaceae*. This means that more than half of the critically endangered or endangered taxa not currently documented and protected in living collections <www.bgci.org/ourwork/magnoliasmain>.
- Oaks: The survey identified 3,796 oak records from 198 institutions in 39 countries. However, only 91 ex situ records representing just 13 of the 29 most threatened oaks were located. This means that more than half of the critically endangered or endangered oak taxa are not currently reported by living plant and seed collections worldwide <www.bgci.org/ourwork/2358>.

**NETWORKING PROJECTS**

Botanic Gardens Conservation International's databases can also be used to support projects that require a networking approach — helping to identify gardens with similar research interests, or growing specific plant species. One such example is the International Plant Sentinel Project, a new BGCI-coordinated project that aims to bring botanic gardens and arboreta together to share information on pest and disease attacks on plants in their collections <www.bgci.org/ourwork/ipsn>. The overall aim is to develop an early warning system for new and emerging pests and diseases in a globally distributed network. The knowledge of which gardens are cultivating which plant species is an essential tool in the development of this network.

**FUTURE DEVELOPMENTS**

Botanic Gardens Conservation International is keen to further develop its databases as a tool to support the conservation of threatened plant species and to promote and strengthen the work of botanic gardens in this area. There is clearly a high demand for information on plants in collections as evidenced by the approximately 2,000 requests passed through the PlantSearch "blind email" request system every year. While PlantSearch does not publicly identify which gardens hold which species, many gardens are already publishing their collections data online [e.g., the catalogue of the Living Collections of the Royal

Botanic Garden Edinburgh <http://elmer.rbge.org.uk/bgbase/livcol/bgbaselivcol.php>. Botanic Gardens Conservation International is therefore considering various options of how to make information on plants in collections more accessible to bona fide users, while still maintaining anonymity where this is required. Other areas where developments are ongoing are in the identification of synonyms (using information from The Plant List) and better verification of cultivar names (in collaboration with the Royal Horticultural Society in the UK). Of course, as with any database, the value of the GardenSearch and PlantSearch databases is only as good as the data they contain. Botanic Gardens Conservation International continues to encourage awareness of and participation in these unique and powerful tools to support plant conservation and the work of botanic gardens and the broader botanical community.

For further information and to consult the databases please visit: <www.bgci.org/garden_search.php> and <www.bgci.org/plant_search.php>.

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# The U.S. National Arboretum Has a New Interactive Graphical Database of Plants

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The U.S. National Arboretum has implemented a new graphical database of all mapped plants on the grounds of the arboretum. The new interface allows any member of the public to locate over 30,000 plants using interactive maps, view thousands of plant images, explore the grounds through featured tours, find dedicated trees and benches, search for specimens in the herbarium, and plant a visit using the "my Visit" feature (Fig. 1). This new interactive database is of significance to researchers and the floral and nursery industry because it greatly improves access to scientific information about plant material conserved at the U.S. National Arboretum. In addition, the database benefits members of the public and educators by making information available that will improve the quality of their visit and demonstrate the nature and details of preserved germplasm at the Arboretum <http://usna.usda.gov/abe/>.

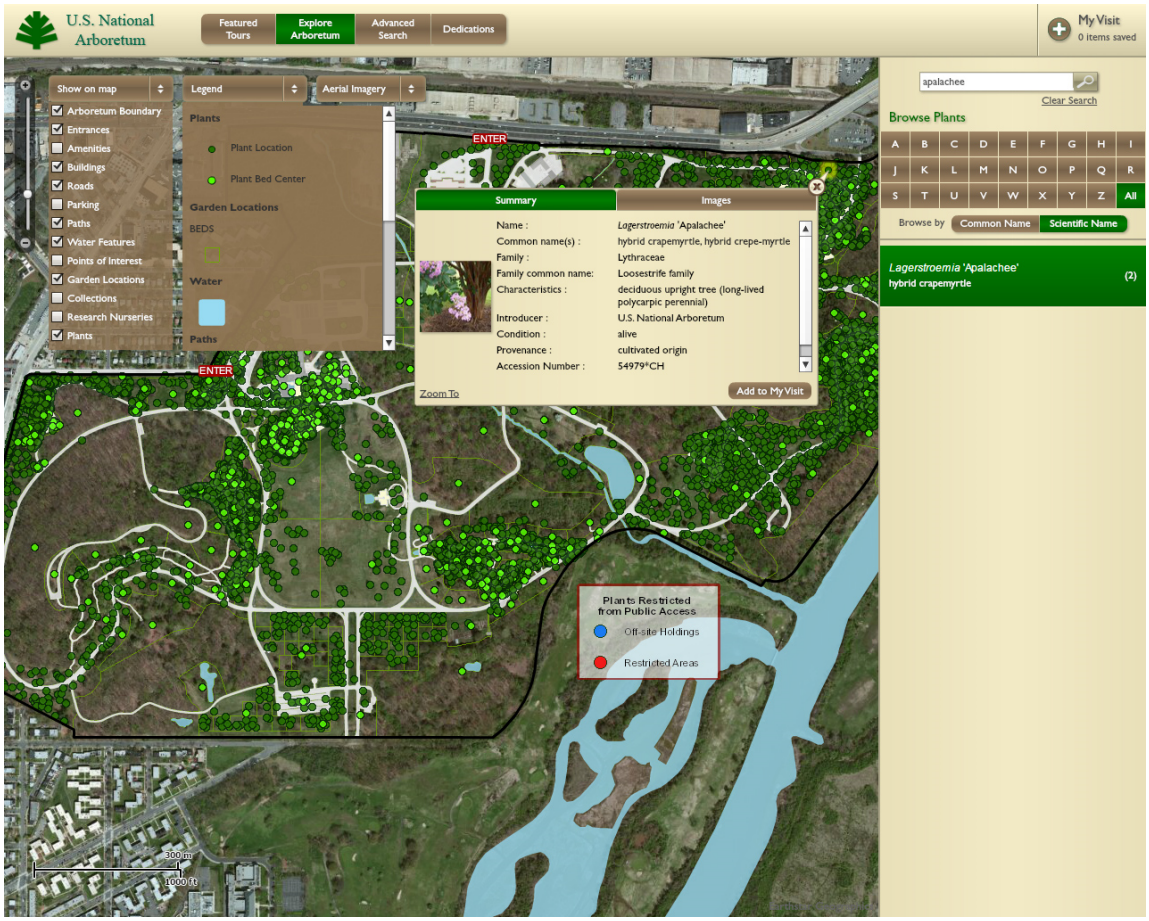


Fig. 1. New graphical database of all mapped plants at the U.S. National Arboretum showing *Lagerstroemia* 'Apalachee'.

# The U.S. National Arboretum Serves as International Cultivar Registrar for *Lagerstroemia*, *Cercis*, and Unassigned Woody Genera

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The U.S. National Arboretum serves as International Cultivar Registration Authority (ICRA) for *Lagerstroemia*, *Cercis*, and Unassigned Woody Genera (Fig. 1). An ICRA serves to collate and publish cultivar names of plant groups in order to prevent duplication of a cultivar name and to provide a resource of all known cultivar names in a checklist form. The International Society for Horticultural Science administers the International Cultivar Registration Authorities via the Nomenclature and Cultivar Registration Commission. The aims of the ICRA are to: prevent duplicated uses of cultivar and group epithets; ensure names are in accord with latest edition of ICNP; to maintain a voluntary, non-statutory system; encourage self-policing of nomenclature; be international in scope; and the success depends on co-operation of all those involved with creation and marketing of new plants. The Arboretum's role as ICRA for three plant groups is of significance to researchers, plant breeders, and those involved with the marketing of new plants. The curation of plant names for those groups can improve the naming, organization, and understanding of those groups for professionals who work with them. In addition there is a general benefit to the aforementioned parties, as well as the general public, that the Arboretum will maintain lists of named plants in those groups that also contain valuable horticultural and historical information. This information may aid industry professionals and homeowners interested in attaining the correct plants for their particular usage <http://www.usna.usda.gov/Research/Herbarium/Lagerstroemia/index.html>.

# THE UNITED STATES NATIONAL ARBORETUM

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## Floral & Nursery Plants Research Unit

## CULTIVARS AND NAMES OF *LAGERSTROEMIA*

COMPILED BY RUTH L. DIX

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This ***Lagerstroemia* Checklist** is an updated edition of the original *Lagerstroemia* Checklist of Cultivar Names, published in 1978. It is the compiler's opinion that in recent years, the search for clarity in the names of various crapemyrtle selections goes beyond just the inclusion of valid cultivar names as dictated by the rules of the *International Code of Nomenclature for Cultivated Plants–1995*. For the nurseryman, consumer, or other interested person, trade names with their synonyms need to be included so that the public can make knowledgeable decisions about the crapemyrtle they may wish to grow or market.

The format of the list is basically the same as in the previous checklist:

- Regardless of rank, all names (sub-species), botanical varieties, botanical forms, cultivars, trade names, or trademarked names are enumerated in alphabetical order. Since all entries are alphabetized, no index appears in this list.

- The reference(s) for a name is placed in parentheses. This is followed by a notation if a description is absent, and a second reference cited that includes a description. Subsequent pertinent references are also cited.

- Important information from the original bibliographic citation follows the name and is preceded by a colon. Descriptive information is presented in the following order: Habit; leaf characters; flower characters; and miscellaneous data such as hardiness and disease resistance. When available, the source, discoverer, selector, namer, and introducer (with significant dates) follow. Information undocumented by published references is often included and segregated by periods.

Fig. 1. *Lagerstroemia* checklist.

# Laboratory Assessment of Boxwood Blight Susceptibility of *Buxus* Accessions from the United States National Arboretum©

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## INTRODUCTION

Boxwood (*Buxus*) is a very important landscape staple in the Northeastern United States in part because it is an evergreen that is not prone to deer browse. The new disease boxwood blight is caused by *Calonectria pseudonaviculata* (= *C. buxicola*), an invasive pathogen first noticed in the mid-1990s in the United Kingdom (Henricot and Culmam, 2002), spreading through Europe and to New Zealand (Crous et al., 2002) thereafter. The disease was first detected in the United States in 2011 in North Carolina and Connecticut (Ivors et al., 2011; Douglas et al., 2012). It has caused serious concern in the nursery/landscape industry not only because it can weaken and disfigure plants, destroying their aesthetic value, but also because infected leaves and stems contain microsclerotia that might persist in soil and organic debris for years (Weeda and Dart, 2012; Dart and Shishkoff, 2015). The ability of microsclerotia to germinate and produce conidial inoculum years after diseased plants are removed from a site makes replanting of boxwood in contaminated field nurseries or gardens difficult. In addition to boxwood, pachysandra (*Pachysandra terminalis*) has also shown symptoms of *C. pseudonaviculata* infection in the landscape, presumably originating from inoculum produced on diseased boxwood (LaMondia et al., 2012; Douglas, 2012). Learning which species and cultivars of *Buxus* are least susceptible to this new disease will be important information for landscape designers, as the disease has shown itself to be highly destructive in gardens where the pathogen has inadvertently been introduced. For this study, we collected cuttings of 42 boxwood accessions from the US National Arboretum in late July, 2013. Some of these cuttings were propagated for planting at different sites in Connecticut, North Carolina, New Jersey, and New York, where they will be either inoculated or exposed to natural infection by *C. pseudonaviculata*. Two sets of unrooted cuttings were promptly tested in vitro for their susceptibility to *C. pseudonaviculata* in a dip inoculation, and these results are reported here.

## MATERIALS AND METHODS

A representative *C. pseudonaviculata* isolate (cbs114417) from the United Kingdom was used. Microsclerotia were produced by placing culture plugs of the pathogen onto the surface of autoclaved cellophane sheets (Biorad GelAir cellophane support, Bio-Rad Laboratories, Inc.) covering the surface of glucose-yeast extract-tyrosine (GYET) agar plates. After 1-2 months of incubation at 20°C, the surface of the cellophane was covered with microsclerotia. The cellophane could then be peeled from the surface of the culture and placed on fresh GYET agar, which caused the microsclerotia to produce copious numbers of conidia. These were collected in water and adjusted to 2000 spores/ml.

Each cutting was immersed in the spore suspension and then the cut end was placed in a 50-ml centrifuge tube filled with water. In each of the two consecutive trials, four cuttings from each cultivar were inoculated, and one was immersed in water alone to serve as a negative control. Cuttings were placed in a mist tent overnight exposed to the fog

produced from a model DK625 ultrasonic fogger. Cuttings were then placed in the greenhouse at 25°C and misted every 10 min. Symptoms of boxwood blight were observed and recorded at 7 days and 11 days after inoculation. At 7 days, the number of infected leaves and the number of leaves total per cutting was counted, along with the number of spots per leaf. Any fallen leaves were also rated and counted. At 11 days, the number of infected leaves and fallen leaves were recorded, as was the number of lesions per stem. These data were analyzed using General Linear Models for significance of the variables and Fisher's Least Significant difference to look for differences in susceptibility among cultivars.

## RESULTS AND CONCLUSION

Many of the cuttings developed black leaf lesions that were evident within a week; leaf abscission followed in most instances and stem lesions were also noted (Table 1). As expected based on earlier research and observations, the English boxwood, *B. sempervirens* 'Suffruticosa,' was one of the most susceptible of the accessions. A number of American boxwood cultivars also proved highly susceptible in this detached-cutting assay, with some showing as much leaf spotting as English boxwood. Although laboratory studies are sometimes misleading, the relative performance of a number of these accessions in our study was found to be similar to field results reported by Ganci et al. (2012). The additional planned field trials will add more to our knowledge of the relative susceptibility of different *Buxus* species and cultivars, by including factors related to plant form — and under less conducive environmental conditions. This study has, however, identified a number of plants with the potential to show less susceptibility than English boxwood (and certain American boxwood cultivars) to this highly damaging new boxwood disease.

Table 1. Susceptibility of cuttings of 42 accessions of boxwood to *Calonectria pseudonaviculata*.

| No.[a] | *Buxus* species and cultivar | Diseased leaves (%)[b] | | Spots/ leaf[c] | Lesions/ stem[d] | Fallen leaves (%)[e] | |
|---|---|---|---|---|---|---|---|
| 9548*H | *sempervirens* 'Scupi' | 80.9 | A | 2.75 | 10.63 | 12.2 | |
| 59820*H | *sempervirens* 'Pendula' | 76.4 | AB | 2.33 | 0.63 | 1.3 | |
| 29703*H | *sempervirens* 'Suffruticosa' | 74.2 | AB | 1.99 | 1.50 | 6.5 | |
| 36365*J | *sempervirens* | 71.5 | ABC | 2.22 | 2.75 | 14.3 | |
| 35494*H | *sempervirens* 'Rotundifolia' | 70.4 | ABC | 1.74 | 6.88 | 34.7 | AB |
| 34196*H | *sempervirens* 'Denmark' | 67.5 | ABCD | 2.83 | 3.38 | 15.2 | CDEF |
| 4233*H | *sempervirens* 'Handsworthiensis' | 63.0 | ABCDE | 1.81 | 2.38 | 18.3 | CDE |
| 51910*H | *sempervirens* 'Northland' | 62.1 | ABCDE | 1.47 | 5.38 | 21.5 | BCD |
| 31793*H | *sempervirens* 'Arborescens' | 59.2 | BCDEF | 2.48 | 5.00 | 17.2 | CDEF |
| 29701*H | *sempervirens* 'Northern New York' | 59.5 | BCDEF | 1.88 | 1.75 | 15.7 | CDEF |
| 18834*H | *harlandii* | 52.5 | CDEFG | 3.93 | 1.88 | 20.8 | CD |
| 29694*H | *sempervirens* 'Marginata' | 52.5 | DEFG | 1.19 | 1.25 | 4.2 | |
| 54327*H | *sempervirens* 'Newport Blue' | 49.2 | DEFGH | 1.04 | 2.13 | 10.5 | |
| 57953*H | *sempervirens* 'Arborescens' | 48.4 | EFGHI | 2.88 | 12.50 | 40.4 | A |
| 51907*H | 'Green Velvet' | 48.1 | EFGHIJ | 2.25 | 3.00 | 5.4 | |
| 68631*H | *sempervirens* 'Dee Runk' | 46.5 | EFGHIJK | 2.65 | 3.88 | 22.3 | BC |
| 33789*H | *sempervirens* 'Graham Blandy' | 46.6 | FGHIJK | 2.93 | 7.25 | 6.6 | F |
| 35487*H | *sempervirens* 'Edgar Anderson' | 44.0 | FGHIJKL | 1.97 | 2.63 | 8.2 | EF |
| 29224*H | *microphylla* 'Grace Hendrick Phillips' | 42.9 | FGHIJKLM | 2.51 | 1.75 | 9.0 | |
| 51905*H | 'Green Mountain' | 41.5 | GHIJKLMN | 1.67 | 1.63 | 16.8 | CDEF |
| 34198*H | *sempervirens* 'Myrtifolia' | 41.5 | GHIJKLMN | 0.96 | 1.88 | 9.6 | DEF |
| 7025*H | *microphylla* var. *japonica* 'National' | 40.4 | GHIJKLMN | 2.06 | 3.13 | 26.8 | ABC |
| 33810*H | *microphylla* 'John Baldwin' | 39.8 | GHIJKLMN | 1.22 | 1.25 | 9.1 | |

Table 1. Continued.

| No.[a] | *Buxus* species and cultivar | | Diseased leaves (%)[b] | Spots/ leaf[c] | Lesions/ stem[d] | Fallen leaves (%)[e] | |
|---|---|---|---|---|---|---|---|
| 72213*H | *microphylla* var. *japonica* 'Jim Stauffer' | 37.4 | GHIJKLMNO | 1.70 | 0.63 | 7.1 | |
| 52423*H | *bodinieri* | 36.2 | HIJKLMNOP | 2.29 | 0.75 | 13.9 | |
| 51904*K | 'Green Gem' | 34.8 | HIJKLMNOPQ | 1.91 | 0.38 | 7.3 | |
| 68273*H | 'Glencoe' | 33.3 | IJKLMNOPQ | 1.81 | 2.88 | 7.6 | |
| 51896*H | *wallichiana* | 31.7 | JKLMNOPQ | 1.16 | 1.00 | 6.8 | |
| 6395*H | *sempervirens* 'Vardar Valley' | 31.8 | KLMNOPQR | 0.98 | 1.88 | 3.0 | |
| 69558*H | *sempervirens* 'Ohio' | 31.8 | KLMNOPQR | 1.50 | 3.25 | 0.0 | |
| 78079*H | *microphylla* var. *japonica* 'Gregem' , Baby Gem™ boxwood | 28.5 | LMNOPQRS | 1.89 | 2.38 | 0.9 | |
| 71429*H | 'Krazgreen', Green Ice® boxwood | 28.6 | MNOPQRS | 1.06 | 5.00 | 0.0 | |
| 17078*H | *sempervirens* 'Decussata' | 26.4 | NOPQRS | 2.56 | 3.63 | 16.2 | CDEF |
| 37772*H | *sinica* var. *insularis* 'Wintergreen' | 23.8 | OPQRS | 1.14 | 4.50 | 8.9 | |
| 57950*H | *Buxus* sp. | 21.6 | PQRS | 2.11 | 3.63 | 0.5 | |
| 51906*H | 'Green Mound' | 20.4 | QRST | 1.00 | 1.50 | 1.3 | |
| 51900*H | *sinica* var. *insularis* 'Winter Beauty' | 17.5 | RST | 1.66 | 4.25 | 3.7 | |
| 51898*H | *sinica* var. *insularis* 'Pincushion' | 16.6 | ST | 1.10 | 0.25 | 5.7 | |
| 54326*H | *microphylla* var. *japonica* 'Winter Gem' | 7.3 | T | 0.63 | 1.88 | 4.6 | |
| 4899*CH | *microphylla* 'Compacta' | 14.1 | | 0.13 | 2.63 | 0.0 | |
| 4227*R | *microphylla* var. *japonica* | 19.3 | | 0.73 | 2.88 | 9.3 | |
| 60705*H | *sinica* var. *aemulans* | 6.3 | | 0.33 | 1.13 | 4.7 | |

[a] Accession number for the U.S. National Arboretum collection.

[b] The percentage of diseased leaves 11 days after inoculation. Numbers followed by the same letter do not differ significantly by General Linear models with LSD. Data not followed by a letter had to be excluded from the dataset because of excessive zeros preventing the normalization of the dataset.

[c] Spots counted on infected leaves 7 days after inoculation.

[d] Lesions counted on each stem piece 11 days after inoculation.

[e] The percentage of leaves that had dropped off over the 11-day period after inoculation. Numbers followed by the same letter do not differ significantly by General Linear models with LSD. Data not followed by a letter had to be excluded from the dataset because of excessive zeros preventing the normalization of the dataset.

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# The Effect that the Amount of Leachate Obtained in Pour Thru Tests and Irrigation Has on pH and EC Readings©

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## INTRODUCTION

Nutritional problems of container-grown plants are very common in greenhouses and may go undetected for prolonged periods of time (Iersel, n.d.). Over and under fertilization might result in reduced plant vigour and make them more susceptible to diseases and insects. Two important measurements that can be collected are the pH and the electrical conductivity (EC). The pH is a measure of how acid or basic the growing medium is, on a scale from 0 to 14, and it is important since it affects the availability of micronutrients in the growing medium (Iersel, n.d.). Electrical conductivity is a measure of the total amounts of salts in the growing medium, and it can be used as an indicator of the presence of macronutrients (Iersel, n.d.).

For the past years, Gro-Bark has worked closely with its customers in testing the growing medium of container-grown plants and checking its pH and EC. These field tests are conducted on a 3 week rotation by performing a pour thru test on selected crops and recording their pH and EC levels. The idea behind the pour thru method is to pour distilled water on top of the growing medium, collect about 50 ml of leachate and measure the pH and EC with a calibrated Hanna® pH and conductivity meter. Gro-Bark prefers this method because of its simplicity, inexpensiveness, and rapidness. Even though it is well known that this test is ideally done 2 h after irrigation and that over-leaching should be avoided, it is still unknown to Gro-Bark how much these two factors affect the accuracy of pH and EC readings. Therefore, the purpose of this trial is to investigate the effects that two factors have on pH and EC readings: (1) the amount of leachate obtained in pour thru tests and (2) the irrigation time. Having a better understanding of these two factors and their effect on pH and EC readings could provide some insights for Gro-Bark into how their pour thru tests can be improved.

## MATERIALS AND METHODS

### Methodology

The Pour Thru trial was conducted for 2 days from 31 July 2014 to 1 Aug. 2014 and took place at Putzer Hornby Nursery in the Main Green House located on 7314 Sixth Line, Milton, Ontario, Canada. The following section explains the materials used, the experimental set-up, and the procedure and data collection for this study.

### Materials

- 24 replicates of *Helictotrichon sempervirens* in 1-gal containers
- Hanna® pH and conductivity meter
- Distilled water
- Plant rack and collecting tray
- 2 flags
- 24 plant tags
- 30-ml testing cup
- 550-ml measuring cup
- 250-ml measuring cup
- 250-ml graduated cylinder
- Data collection sheet
- Timer

### Experimental Set-Up

Set-up for the trial began on the first day during the afternoon when 24 replicates of *Helictotrichon sempervirens* were placed at the front of Bay 6 and evenly divided into two sections based on their treatments, as shown in Figure 1. Plants in section A (Treatment A) were irrigated on the same day at 1:30 PM by placing a hose on top of each plant and watering it until a bed of water of approximately 1 cm. was visible. Plants

in section B (Treatment B) were irrigated on the next day at 9:35 AM, 2 h before the pour thru test took place. Within Treatment A and Treatment B, plants were separated into three different rows depending on the amount of target leachate to be obtained in the pour thru test. Plants with a target leachate of less than 50 ml were placed in the first row; plants with a target leachate between 50 ml and 150 ml were placed in the second row, and those with a target leachate of more than 150 ml were placed in the third row. Each row had a total of 4 plants.

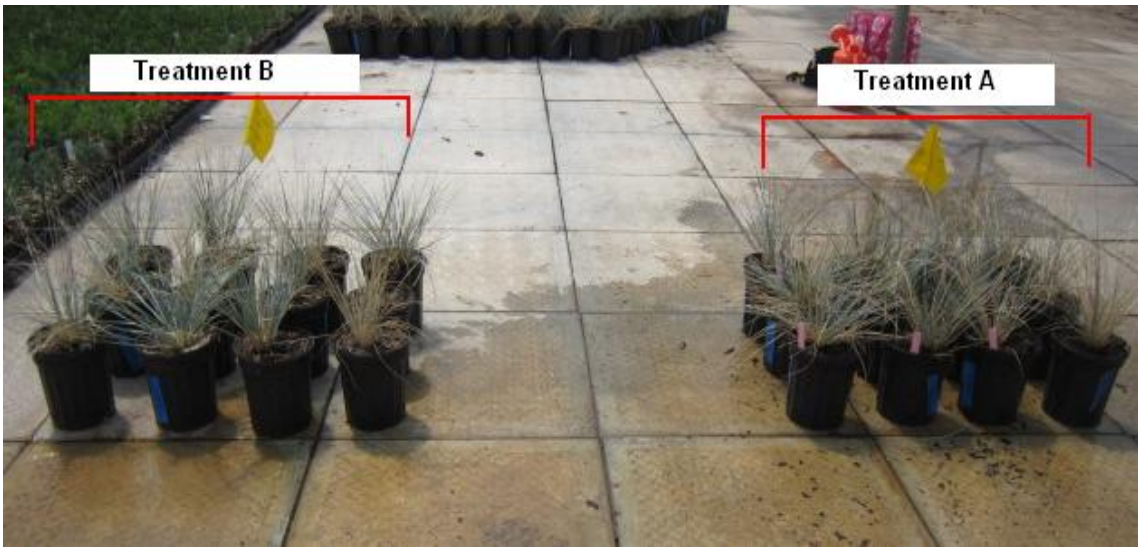


Fig. 1. Experimental set-up.

**Procedure and Data Collection**

The data that the pour thru trial looked at was the amount of leachate obtained, soil temperature, pH, and electrical conductivity (EC). The first set of pour thru tests was conducted on 1 Aug. 2014 at 9:45 AM for the plants in Treatment A with a target leachate of less than 50 ml. After this, the same procedure was done for the four samples with a target leachate between 50 and 150 ml, and also for the remaining four samples with a target leachate of more than 150 ml. The second set of pour thru tests was conducted on the same date at 11:35 AM for the remaining plants in Treatment B. All pour through tests were conducted in accordance with the procedure below:

1) Place sample upon a rack with collecting tray.
2) Measure 100 ml of distilled water and pour this into the pot. It is important to pour the water in the center of the pot and to pour slowly to avoid water running down the inside wall of the pot without being filtered through the soil.
3) Set the timer to 5 min and wait for plant to leach. If there is no leachate, slowly continue to pour water onto the soil in 50-ml increments and wait 1 min between each increment until no more than the target amount of leachate is obtained.
4) Pour the leachate into a small 30-ml testing cup.
5) Record the amount of leachate by pouring the remaining leachate in the collecting tray into the 250-ml graduated cylinder and then adding this amount to the 30-ml of leachate that was poured into the testing cup.
6) Record the amount of water poured into the pot.
7) Obtain the calibrated Hanna pH and conductivity meter and rinse with distilled water.
8) Turn on the probe and set it to the pH function.
9) Insert the probe into the testing cup and wait for the pH to stabilize.
10) Once the pH has stabilized enter the EC mode by pressing the EC button located on the meter, wait for the EC to stabilize and record this number on the data collection sheet.

11) Enter the pH mode once more and record this number on the data collection sheet.
12) Rinse all equipment with distilled water.
13) Place plant back into its corresponding section.
14) Repeat steps 1-13 for all remaining plants.

**RESULTS**

Results of the pour thru tests were divided depending on the treatment (A – irrigated the day before, and B – irrigated 2 h before) and on the amount of leachate obtained.

Results for Treatment A indicate that a target leachate of less than 50 ml (TL <50) yielded an average pH of 6.68 and an average EC of 2.38. They also indicate that a target leachate between 50 and 150 ml (TL 50-150) retrieved an average pH of 6.55 and an average EC of 2.85. Finally, a target leachate of more than 150 ml (TL >150) retrieved an average pH of 6.33 and an average EC of 2.37. Samples 3 and 4 of TL <50 showed the highest pH levels of 6.8, whereas sample 1 of TL >150 showed the lowest pH level of 6.2. As for EC readings, sample 2 of TL 50-150 showed the highest level of EC of 3.86, and samples 3 and 4 of TL >150 showed the lowest level of EC of 1.47. Electrical conductivity and pH results were most constant between the 4 samples in TL 50-150. A graph was constructed depicting the results of all samples in Treatment A and a trend line was created for both pH and EC. In general, pH of plants in Treatment A seemed to decrease as the amount of target leachate increased, as shown in Figure 2. EC levels had a tendency to increase as the amount of leachate obtained increased as well, even though averages do not show this.

Test results for Treatment B indicate that a target leachate of less than 50 ml (TL <50) yielded an average pH of 6.58 and an average EC of 1.94. They also indicate that a target leachate between 50 and 150 ml retrieved an average pH of 6.40 and an average EC of 3.01. Finally, a target leachate of more than 150 ml retrieved an average pH of 6.58 and an average EC of 1.60. Samples 1 and 2 of TL <50 showed the highest pH levels of 6.7, and sample 4 of TL <50 and sample 1 of TL 50-150 ml showed the lowest pH level of 6.3. As for EC, sample 1 of TL 50-150 had the highest level of 4.23, and sample 4 of TL >150 had the lowest level of 1.11. EC and pH results were more constant between samples in TL >150. A graph depicting the results of all samples and pH and EC trend lines was also constructed for Treatment B. The pH had a general trend to remain fairly constant between all groups of target leachate, and EC had a tendency to decrease as the amount of leachate increased, as shown in Figure 3.

When comparing the test results between both treatments, they both had fairly similar pH readings and share the same pH average of 6.52, as shown in Table 1. Another similarity between both treatments is that E.C. results are the highest when the target leachate is between 50 and 150 ml. EC levels were slightly higher for plants in Treatment A, with an average of 2.53 compared to Treatment B's EC average of 2.18. Figures 4 and 5 show this comparison. Plants in Treatment A required higher amounts of water to leachate and retrieved a smaller percentage of leachate than plants in Treatment B, as shown in Table 1.

Table 1. Leachate, leachate percentage, pH, and EC. Averages for Treatments A and B.

| Treatment | Target leachate (ml) | $H_2O$ added (ml) | Leachate (ml) | Leachate (%) | pH | EC ($mS \cdot cm^{-1}$) |
|---|---|---|---|---|---|---|
| A: Irrigated the day before | <50 | 337.50 | 33.75 | 10.00 | 6.68 | 2.38 |
| | 150-150 | 500.00 | 132.50 | 26.50 | 6.55 | 2.85 |
| | >150 | 625.00 | 221.25 | 35.40 | 6.33 | 2.37 |
| Overall average | | | | | 6.52 | 2.53 |
| B: Irrigated 2 h before | <50 | 225.00 | 27.50 | 12.22 | 6.58 | 1.94 |
| | 150-150 | 262.50 | 90.00 | 34.29 | 6.40 | 3.01 |
| | >150 | 500.00 | 182.50 | 36.50 | 6.58 | 1.60 |
| Overall average | | | | | 6.52 | 2.18 |

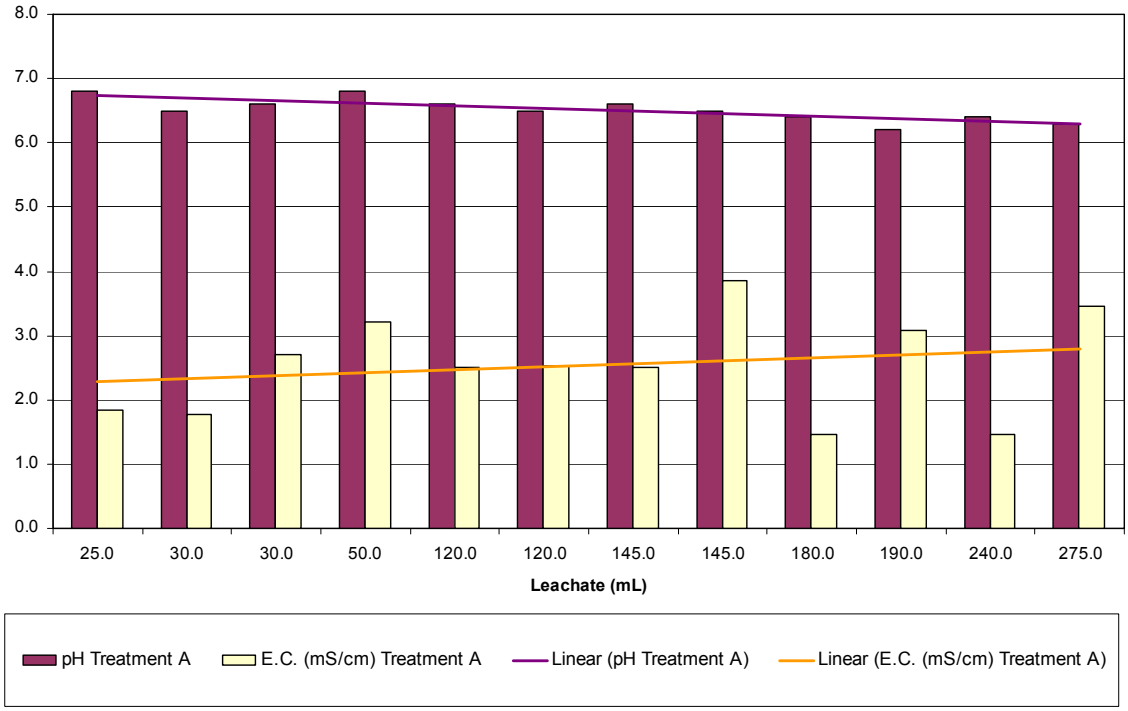


Fig. 2. Comparison of pH and EC levels based on amount of leachate obtained for Treatment A.

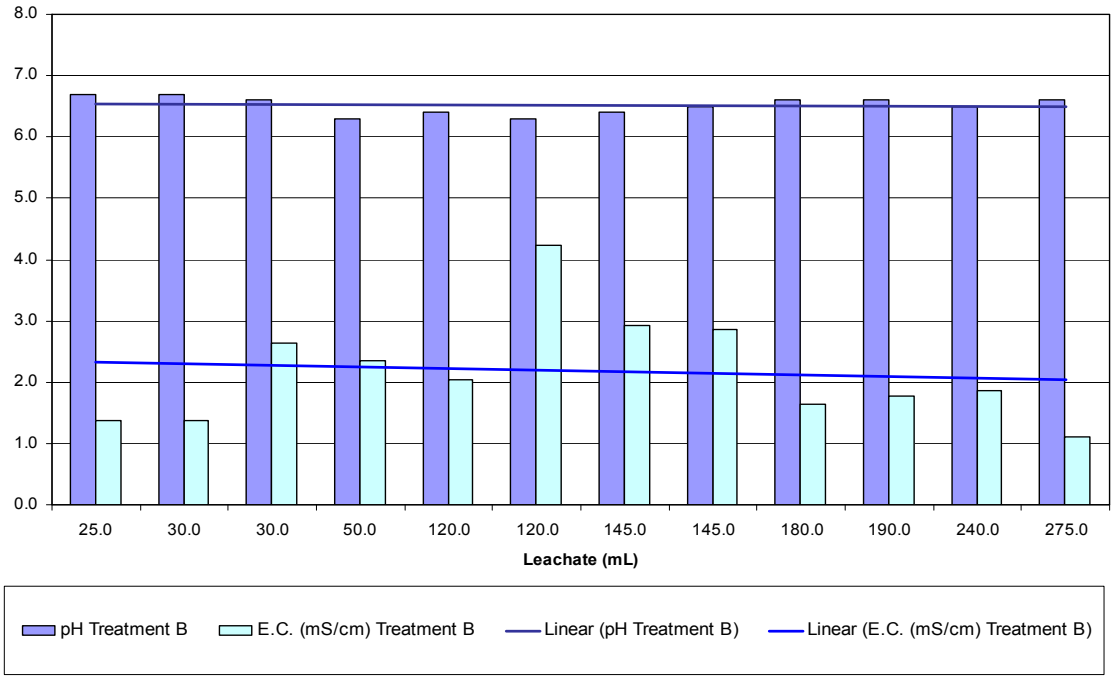


Fig. 3. Comparison of pH and EC levels based on amount of leachate obtained for Treatment B.

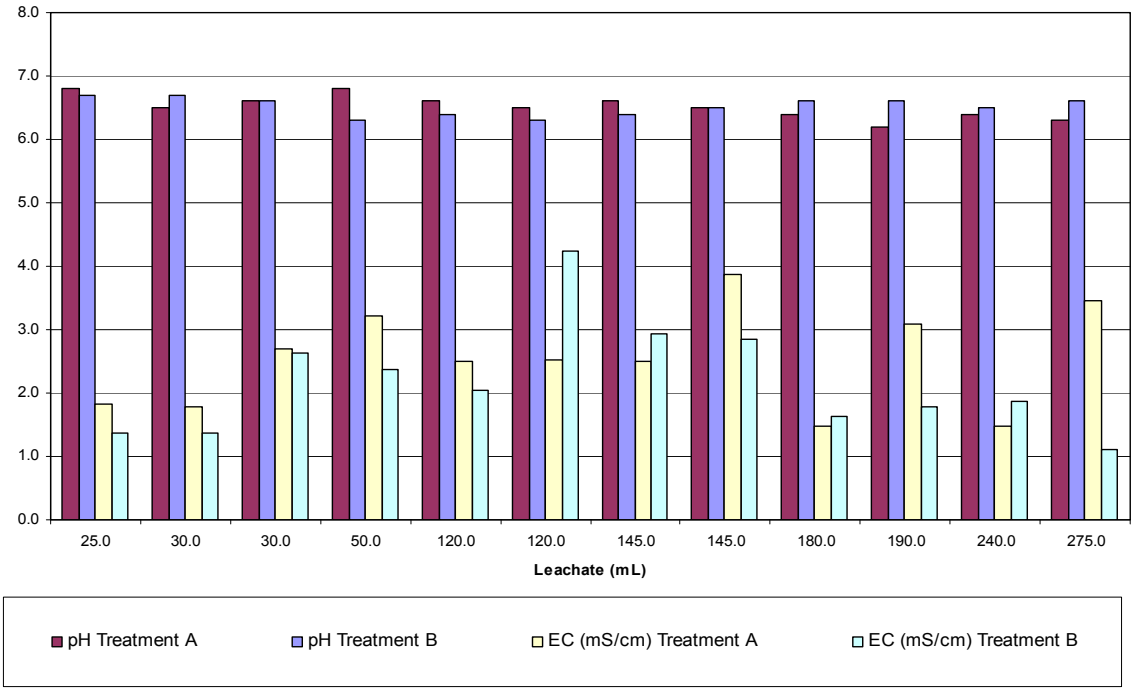


Fig. 4. Comparison of pH and EC levels between Treatments A and B based on amount of leachate obtained.

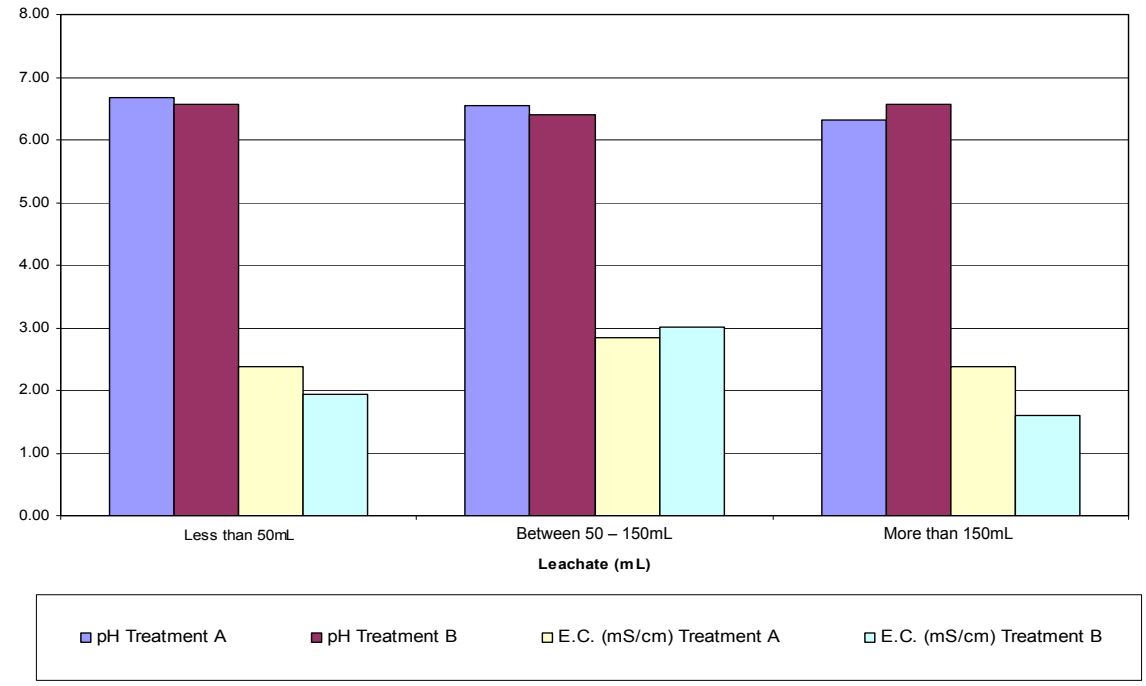


Fig. 5. Comparison of average pH and EC readings for Treatments A and B based on amount of leachate.

## DISCUSSION AND INTERPRETATION

Once all the data was organized, theories could then be revised. The first half of this section will place more emphasis at the effect that different amount of leachate obtained had on pH and EC readings for both treatments. The second half will look at the effect that irrigation times had on the results and will compare overall results between Treatment A and B.

### Comparison between Different Amounts of Leachate

According to Iersel (n.d.), it is best to use the least amount of water that will still allow the tester to collect at least 30 ml of leachate, and Mirza (April, 2014) indicates that over-leaching should be avoided if the same water is used for measuring both pH and EC. Cavins and others (2000) explain that this is because leachate volumes over 60 ml will begin to dilute the sample and retrieve lower EC readings. This theory seems to be supported in Treatment B as the EC had a tendency to decrease with increasing amounts of leachate. However, this was not the case in Treatment A as EC actually had a tendency to increase with increasing amounts of leachate obtained.

The pH results show that for Treatment A, pH had a tendency to decrease as the amount of leachate obtained increased. However, it was interesting to notice that for Treatment B, pH results remained fairly constant between different amounts of leachate obtained, with a standard deviation of only 0.14, and they did not have a tendency to either increase or decrease. This could potentially indicate that pH results tend to remain constant between different amounts of leachate collected when pour thru tests are conducted about 2 h after plants are irrigated. In fact, besides the EC result of sample 1 in TL 50-150 which can be considered an outlier, EC results between different amounts of leachate are also more constant in Treatment B.

### Comparison between Treatments A and B

There were also some interesting observations when comparing results of both treatments. According to Iersel (n.d.), it is important that the pots are watered thoroughly before collecting the leachate; otherwise, the water that is poured on top of the growing medium may simply run through the pot. In that case, one would be measuring the pH and EC of the water poured on the pots, instead of the pH and EC of the growing medium. Most experts recommend irrigating the crops 1 to 2 h before the test (Ruter and Garber, 2002). Knowing that the distilled water used for Gro-Bark tests has a pH of 8.04 and an EC of 0.76, it would be expected that pH and EC results of Treatment A would be closer to those numbers, as the medium is not near its maximum water-holding capacity. However, this was actually not the case in this trial as EC results of Treatment A were generally higher than the ones in Treatment B, with averages of 2.53 and 2.18 accordingly. As for the pH, results were fairly similar between both treatments, sharing the same average pH of 6.5.

Another interesting observation is that plants in Treatment A required more water to obtain the target leachate when compared to plants in Treatment B. Plants in Treatment A also yielded lower percentages of leachate, which could indicate that their mediums absorbed more water and thus pots did not leach as fast. This is because plants in Treatment A were not at their maximum water-holding capacity since they were watered the day before (Ruter and Garber, 2002). On the contrary, plants in Treatment B required less water to leach and yielded higher percentages of leachate. Since plants in Treatment B were irrigated only 2 h before conducting the test, they were already at their maximum water-holding capacity, and thus it was easier for them to leach.

It is important to note that these findings should be taken in the strictest manner. As the trial was conducted on *Helictotrichon sempervirens* in 1-gal pots using custom mixes supplied by Gro-Bark, the estimate is only valid under the same conditions.

## CONCLUSIONS AND RECOMMENDATIONS

The pour-thru trial generated numerous conclusions about the effect that the amount of leachate and irrigation has on pH and EC results of pour thru tests.

### Conclusions and Recommendations on Leachate

Two conclusions on the effect that the amount of leachate collected has on pH and EC results for both treatments were made. The first one is that, for Treatment A, it could be possible that increasing amounts of leachate collected tends to yield lower pH and higher EC results. The second one is that, for Treatment B, different amounts of leachate collected could not necessarily impact pH results, but it could tend to generate slightly lower EC results, although further research on this is necessary. Based on these results and conclusions, it is difficult to estimate an ideal target amount of leachate that should be collected when conducting pour thru tests. The best recommendation is to keep this amount consistent between all samples and repeats of the test so that results are not being skewed.

### Conclusions and Recommendations on Irrigation

Two conclusions on the effect that irrigation has on pH and EC results were made based on the results obtained in this trial. The first one is that it might be possible that watering crops 2 h before conducting a pour thru test tends to yield more constant results, especially when collecting different amounts of leachate. The second is that watering crops the day before conducting a pour thru test could still yield similar pH results when collecting different amounts of leachate, but increasing amounts of leachate could tend to yield higher EC results, although more research on this topic needs to be made. It is recommended that pour thru test should be conducted approximately 2 h after irrigation in order to obtain more accurate results. In the case that employee or schedule availability makes this difficult, it is then recommended to quickly water the samples to be tested and wait a few minutes for the medium to absorb it so that the plants can be at an appropriate water-holding capacity. Nevertheless, further study should be conducted in this area to verify the accurateness of these conclusions, perhaps with the use of different plants species and in a different potting container size.

### Further Recommendations

This trial provided much insight for prospective investigations and generated opportunities for further experiments. Additional studies on the effect that irrigation and leachate has on pH and EC readings are strongly recommended to verify the results and conclusions that this trial provided. It is also recommended to perform an analysis on why EC results in this trial were highest when collecting leachate between 50 and 150 ml. More trials using a virgin mix with no plants are suggested.

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# A Plant Risk Evaluation Tool for Assessing the Invasive Potential of Ornamental Plants©

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Weed Risk Assessment (WRA) methods for evaluating invasiveness in plants have evolved rapidly in the last two decades, but none were specifically designed to screen ornamental plants prior to being released into the landscape. For a WRA tool to be accepted as an evaluation tool by the nursery industry, it must be able to accurately predict non-invasiveness without falsely categorized them as invasive. We used a science-based and systematic process to develop a new Plant Risk Evaluation (PRE) tool for screening ornamental plants as part of a prevention strategy. The final PRE tool included 19 questions, which was narrowed down from 56 original questions obtained from other existing WRA tools. We evaluated the 56 WRA questions by screening 21 known invasive and 14 known non-invasive ornamental plants. After statistically comparing the predictability of each question and the frequency the question could be answered for both invasive and non-invasive species, we eliminated questions that provided no predictive power, were irrelevant in our current model, or could not be answered reliably at a high enough percentage. We also combined many similar questions. The 19 question PRE tool was further evaluated for accuracy using 57 additional known invasive and 37 known non-invasive ornamental plant species. The resulting evaluation demonstrated that when "needs further evaluation" classifications were not included, the accuracy of the model was 100% for both predicting invasiveness and non-invasiveness. When "needs further evaluation" classifications were included as either false positive or false negative, the model was still 93% accurate in predicting invasiveness and 97% accurate in predicting non-invasiveness, with an overall accuracy of 95%. We conclude that our new PRE tool (Table 1) should provide growers with a method to accurately screen their current stock and potential new introductions. It is our hope that the tool will be accepted for use by the industry as the basis for a nursery certification program.

Table 1. PRE tool questions and their statistical predictability in separating known invasive and non-invasive species. Fisher's Exact Test compared the 57 invasive species against the 37 non-invasive species for each question. Percent of each question (Q) answered is also included. Brackets after question indicate citation were question is included in WRA model. From Conser et al. (2015). PLOS ONE (in press).

| # | Question in PRE tool | Fisher's exact test (2-tail) | % Q was answered for invasive plants | % Q was answered for non-invasive plants | Point values Yes/No |
|---|---|---|---|---|---|
| 1 | Has the species become naturalized where it is not native? | $P<0.0001$ | 100 | 100 | 1/0 |
| 2 | Is the species noted as being invasive elsewhere in the US or world? | $P<0.0001$ | 100 | 100 | 2/0 |
| 3 | Is the species noted as being invasive elsewhere in the US or world in a similar climate? | $P<0.0001$ | 100 | 100 | 3/0 |
| 4 | Are other species of the same genus invasive in other areas with a similar climate? | $P<0.0001$ | 100 | 100 | 1/0 |

Table 1. Continued.

| # | Question in PRE tool | Fisher's exact test (2-tail) | % Q was answered for invasive plants | % Q was answered for non-invasive plants | Point values Yes/No |
|---|---|---|---|---|---|
| 5 | Is the species found predominately in a climate that matches those within the region of introduction? | - | 96 | 100 | 2/0 |
| 6 | Dominates in areas this species has already invaded (displaces natives). Can overtop and/or smother surrounding vegetation. | $P<0.0001$ | 100 | 100 | 1/0 |
| 7 | Is the plant noted as being highly flammable and/or promotes fire and/or changes fire regimes? | $P<0.0001$ | 79 | 97 | 1/0 |
| 8 | Is the plant a health risk to humans or animals/fish? (Toxic tendencies) Has the species been noted as impacting agricultural/grazing systems? | $P=0.0001$ | 100 | 100 | 1/0 |
| 9 | Does the plant produce impenetrable thickets, blocking or slowing movement? | $P=0.0002$ | 93 | 100 | 1/0 |
| 10 | Reproduces vegetatively via root sprouts/suckers or stem/trunk sprouts/coppicing. | $P=0.0314$ | 98 | 100 | 1/0 |
| 11 | Plant fragments are capable of producing new plants. | $P=0.0002$ | 100 | 100 | 1/0 |
| 12 | Does the plant produce viable seed? | $P=0.0001$ | 100 | 100 | 1/0 |
| 13 | Produces copious viable seeds each year (>1000). | $P<0.0001$ | 86 | 78 | 1/0 |
| 14 | Seeds quick to germinate. | $P=0.1296$ | 75 | 68 | 1/0 |
| 15 | Short juvenile period. Produces seeds in first 3 years (herbaceous) or produces seeds in first 5 years (woody). | $P=0.0078$ | 89 | 54 | 1/0 |
| 16 | Long flowering period with seeds produced for more than 3 months each year. | $P=0.2320$ | 86 | 86 | 1/0 |
| 17 | Propagules dispersed by mammals/insects or birds or via domestic animals. | $P<0.0001$ | 100 | 97 | 1/0 |
| 18 | Propagules dispersed by wind or water. | $P<0.0001$ | 98 | 97 | 1/0 |
| 19 | Propagules dispersed via agriculture, contaminated seed, farm equipment, vehicles or boats, or clothing/shoes. | $P<0.0001$ | 100 | 94 | 1/0 |
| Average | | | 97 | 97 | Range of 23/0 |

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# Field Trials of Bio Additives for Nursery Stock©

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## INTRODUCTION

In 2009 the Danish government introduced its long-term Grøn Vækst (Green Growth) plan which defines environmental, nature, and agricultural development policies up to 2020. It aims to ensure that a high level of environmental, nature, and climate protection goes hand in hand with modern and competitive agriculture, horticulture, and food industries.

Among its targets are the minimisation of the environmental and health impacts of crop protection products and wider adoption of more sustainable agricultural and horticultural production practices such as integrated pest management (IPM).

In order to help growers achieve a reduction in the use of chemical crop-protection products, the Danish Nurseries Association has started to look for alternative products and methods to ensure ornamental crops can continue to be grown economically. To help with this programme the association has been conducting trials on the application of biostimulants, biopesticides, and compost since 2012.

## BIOSTIMULANTS

Biostimulants have no direct effect on pests – they are not pesticides. Plant biostimulants are products containing compounds or microorganisms which stimulate the plants' own defence system and enhance the nutrient uptake and tolerance to stress.

Trials undertaken in 2012 and 2013 tested: potassium bicarbonate, silicon, and the biopesticides Vacciplant®, AQ-10, Serenade®, and Prestop® against several leaf spot and mildew diseases.

Potassium bicarbonate, Vacciplant, and Serenade all showed positive effects against leaf spots. Potassium bicarbonate caused some leaf spotting when tested on *Ligustrum* (Fig. 1).

Fig. 1. Spraying with potassium bicarbonate caused leaf damage on *Ligustrum.*

None of the materials tested gave any clear effect against mildew in these trials. In the first year the treatments were started too late in relation to mildew attack and were not

able to reduce the disease or keep it under control. The dry, warm summer of 2013 was conducive to high levels and rapid spread of mildew which none of the biopesticides nor biostimulants could control (Fig. 2).

Most growers who use biostimulants are using them as a supplement to chemical fungicides. Biostimulants alone are not usually enough to control an outbreak. The Danish Nurseries Association recommends that biostimulants are used in combination with crop protection products, and because biostimulants tend not to have a very long persistence weekly spraying is recommended. In combination, the biostimulants provide a trigger to the plants natural defence system making it more resistant to attacks while the crop protection product prevents or cures infection.

Fig. 2. Mildew on rose leaves in 2013.

**COMPOST**

Growing media used in Denmark typically consist of peat, fertiliser, and lime. In 2014 the nursery association began testing growing media containing a proportion of green compost. The aim is to see if including compost could improve root development, growth, and the ability of the plants to resist diseases.

Compost can also stimulate soil-life and suppress soil-borne diseases. Its high cation exchange capacity helps buffer most plant nutrients and so minimises the likelihood of stress due to nutrient deficiencies or toxicity. Composts also release nutrients slowly into the growing medium as they decompose.

Composts based on green waste and on horse manure were tested in three nurseries by mixing into the grower's standard medium at each site. The tests were carried out in roses (*Rosa*), *Potentilla*, *Philadelphus*, and *Picea glauca*.

Analysis of the composts showed a high pH and high levels of potassium and chloride. The compost based on horse manure was very high in pH (pH 9.2) and salinity (EC of a 1:1.5 extract was 4.25 $mS \cdot cm^{-1}$).To avoid plant damage the admixture rate was restricted to 15% v/v. Liquid feed was added to the irrigation to maintain optimum nutrient levels in

the growing media.

Yellow leaves and poor root development were observed soon after potting but after 2 months there were no differences in growth and root development in roses or *P. glauca* between the media containing either type of compost or the nursery's standard mix.

The *Potentilla* and *Philadelphus* did poorly from the start in media containing both types of compost and many of the plants turned yellow and remained so for 3 months (Fig. 3). Analysis of the different growing media showed that pH was a little high, and the level of nitrate, magnesium, and manganese was low despite the liquid feeding.


Fig. 3. Potentilla growing in media containing compost, August 2014.

Trials on the use of compost are being continued during 2015. A range of different rates of peat, compost, fertiliser, and lime will be compared in order to optimise nutrient levels, plant growth, and disease suppressive effects.

# Investigation of Mulch Materials for Weed Suppression and Water Management in Container Grown Nursery Stock©

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**Weed control is one of the main production problems for growers of nursery stock in containers. In Northern Ireland ornamental nurseries are family businesses growing relatively small numbers of a wide range of plants for the local wholesale market and direct sales to the public. The reduced range of chemical herbicides available and the difficulty of applying them on nurseries with a diverse crop range has encouraged adoption of alternative methods including loose mulches and container mulch materials or pot covers.**

**As part of the knowledge technology transfer programme at the Greenmount Campus, CAFRE, horticulture centre, container mulch materials have been assessed under local conditions for a range of criteria including their performance in reducing weeds and their influence on water management in the container. New technology available to accurately record moisture levels in the growing media has assisted in evaluations. This paper examines results for new types of container mulches such as wool-based materials. Some of these materials have been shown to give effective weed control and retain moisture in the container. The CAFRE technology investigation programme has involved working in conjunction with local growers who have adopted container mulches to share experience and results.**

## INTRODUCTION

In Northern Ireland there are more than 100 wholesale and retail nurseries producing ornamental plants with a "nursery gate" value of approximately £16 m. The nurseries are family run businesses characterised by production of small numbers of a wide crop range to suit the local market. There is limited specialisation and little exporting.

Chemical weed control programmes are often difficult on such nurseries because of the susceptibility of some species to herbicide damage. Some growers therefore do not use chemical weed-control methods and rely on hand weeding. Bark mulch is used by some growers especially on herbaceous plants. Where herbicides are used, much of the industry relied on Ronstar® granules (oxadazinon) but this product has recently been withdrawn.

There are a number of limitations to existing container weed-control systems relying on herbicides:

- There are no effective contact herbicides that can be sprayed to kill existing weeds on containers and which are safe to the crop.
- Most herbicides used in container plant production are "pre-emergence" so have to be applied to weed free surfaces.
- More than one application of herbicide may be required as persistence in many cases is not long enough for most hardy nursery stock production schedules.
- Some herbicides, such as Flexidor (isoxaben) have a restriction on the number of applications per year.

An alternative to herbicides or hand weeding is to use container mulch materials placed on top of the container after potting. Several new container mulch products, which are generally a fabric or layered material designed to act as a pot cover have been developed in recent years.

In Northern Ireland the College of Agriculture, Food and Rural Enterprise (CAFRE) is responsible for a programme of knowledge and technology transfer and provision of education and training for students and growers. As part of this programme, some of these new container mulch products were evaluated between 2010 and 2014 to test ease of application; durability; permeability; and prevention of weed germination.

## INITIAL COMPARISONS

In the initial evaluation five materials were investigated: coco-fibre discs, geo-textile discs, hemp discs, loose pine bark, and rubber crumb.

*Ilex* × *altaclerensis* 'Golden King' liners were potted into 2-L containers in August 2010 and placed in a polythene tunnel. Forty seeds of chickweed (*Stellaria media*) were applied per container except control pots which had none. Laboratory germination of the chickweed seeds was 62%. The average number of weeds per pot for each material is shown in Figure 1.

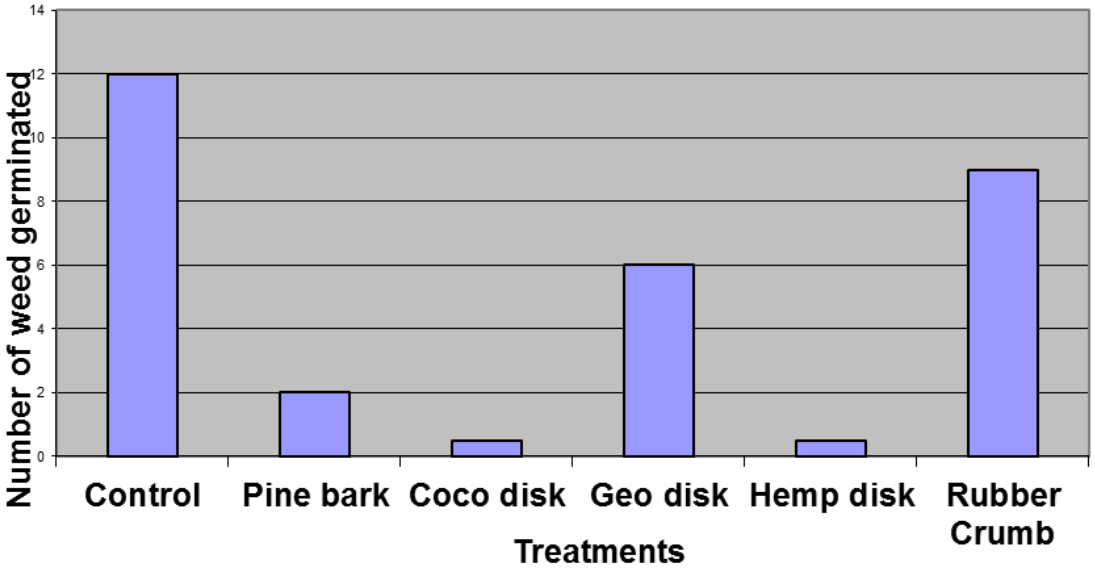


Fig. 1. Average weed germination per container.

Where pots had been seeded but no mulch applied, there was an average of 12 weeds per pot at the end of the trial (approximately 30% germination). The most effective treatments were coco-fibre discs and hemp discs which prevented almost all the seeds from germinating, followed by loose bark with an average of two weeds per pot.

Following this trial a number of local growers were starting to test mulch materials for themselves. One important factor in encouraging interest was that some nurseries had begun to record the costs of the labour requirement in hand weeding and found that they were higher than they had assumed.

## 2013 TRIALS

In 2013 a new project was initiated to evaluate a locally produced mulch material (Unique Pot Topper made from a blend of recycled fabrics, mostly wool) in more detail. These trials were not intended as a comparison of available container mulch materials. The product was tested for its ability to suppress both liverworts and weeds.

### Liverwort Evaluation

The pot topper was put in place 3 weeks after potting when there was already an average 25% liverwort cover. Over a period of 3 months it prevented any further growth of the liverwort, and the existing liverwort died back (Fig. 2).

Fig. 2. Liverwort development in pots with and without recycled wool fabric mulch discs (photographed in October 2013).

**Weed Evaluation**

The pot topper was evaluated for weed control in April 2014 using box (*Buxus sempirvirens*) liners potted into 2-L containers and grown on in a polythene tunnel. Forty weed seeds of chickweed were placed on each container surface except for the non-weed experiment control. The chickweed laboratory germination was 63%.

Figure 3 shows typical results from each treatment. There was significant weed germination on seeded containers which had no mulch (bottom left of photo). The pot topper prevented the majority of weeds germinating. A very small number of weeds germinated around the edge of the mulch (equivalent to 0.4% germination).

Fig. 3. Weed growth in pots with and without recycled wool fabric mulch discs (pot top left was unseeded).

**Moisture Levels**

Moisture levels in the substrate were measured using Delta T moisture probes (Fig. 4) and the results can be seen in the graph (Fig. 5). The top line shows the moisture levels in the pots with the pot topper. The bottom line shows the moisture with no pot topper.

Moisture levels with the pot topper were slightly higher to start with and rose quickly in both pots (as is shown by the vertical lines). The moisture level in the mulched pot rises to 46%, compared with 32% in the unmulched. Over the next 7 days moisture levels fall gradually to 31% for the mulched pot and 17% for the unmulched. Moisture levels also fluctuated less rapidly in the mulched pot.

**Ease of Application**

Where the container mulch material is flexible (as in this case) it is not as crucial that the size of the disc matches exactly the pot size. If it is slightly bigger than the pot it can still be put on.

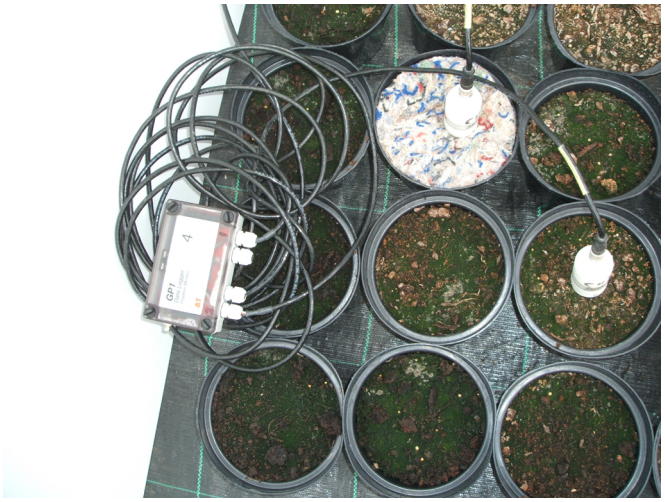

Fig. 4. Delta T moisture and temperature measurement equipment in place. Probes inserted in pot with pot cover and pot without pot cover.

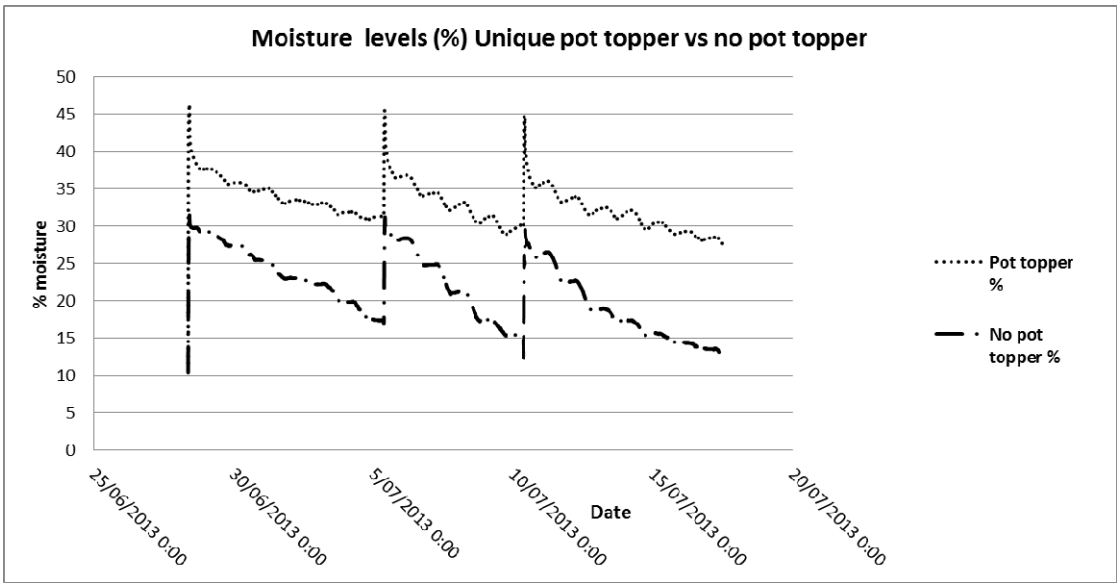


Fig. 5. Changes in moisture level with and without wool container mulch. Vertical axis shows percentage moisture and the horizontal axis time. Readings started June 28 and pots were watered for 1 h. They were watered again on July 5 and 10.

## CONCLUSIONS

A number of container mulch materials gave significant and commercially acceptable levels of weed control.

It is important that the container mulch material allows the normal cycle of wetting and drying with no restriction on water entering the container. In the 2013 evaluation where the moisture level was higher to start with, the use of the Unique Pot Topper led to longer moisture retention. The material is itself able to absorb and hold moisture. In practice this could reduce the frequency of watering needed for container plants but this needs to be investigated further in a range of locations.

Mulches made from rigid material take longer to apply than flexible materials and have to exactly fit the container — and in practice container diameter varies between manufacturers for each volume size. It is important that pot toppers or container mulches do not leave any gaps at the edge as this is where weeds are likely to germinate.

Visual appearance of mulch materials can be important for the retail market and can be an indication of degradation. After 12 months the appearance of the Unique Pot Topper was still acceptable. There was some tendency for the material to turn a darker green colour but the discs retained their shape and did not shrink. This means the discs would prevent the majority of weeds germinating and remain intact and functional for at least one growing season.

The investigations at Greenmount have provided information to growers about the performance of container mulches and given them more confidence to adopt them on specific crops such as shrubs or trees in containers.

On plants such as some herbaceous species with a number of stems from the base, discs are not effective in covering the pot surface and loose mulch materials such as bark will be more effective.

Growers have found that container mulch materials do not always give 100% weed prevention. This is because a very small percentage of weeds can germinate in any small gap at the edge of the mulch and the rim of the pot. Growers sometimes have a problem in persuading staff to check batches of plants where container mulches are used as they perceive there are no weeds present.

While it is recommended to apply the mulch at potting, some growers prefer to apply them 3 weeks after potting when any early germinating weeds can be removed, and this

may be more likely to coincide with periods of low labour requirement.

Growers have found that the time saved at dispatch in cleaning and preparing plants is valuable in reducing the labour peak.

Greenmount trials have not looked at container mulches for young plants or liners but some local growers have assessed these and found that they further reduce carry over of weeds to the finished plant.

Growers also have to consider the initial cost of mulches and those who have recorded or measured the labour costs of hand weeding and preparing plants for dispatch are the most likely to adopt container mulches.

**Additional Reading**

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# Controlled Release Fertilizers: Recent Nursery Trials in Sweden©

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## INTRODUCTION

The development of controlled release fertilizers (CRF) parallels the progress of container growing with most of the advances being made in the 1980s and 1990s. The first CRF sources to become commercially available were only nitrogen (N) but the technology has expanded to include potassium (K), phosphorus (P), and other nutrients, including micronutrients.

Controlled release fertilizers use several mechanisms to limit the amount of nutrient made available at any one time. In the first types, nutrient prills were coated with materials as molten sulphur, clay, and wax. The problem with these materials was that cracks in the coating meant the release-rate was not uniform. Today this problem has been overcome by using other materials. For example, Osmocote® uses a resin coating of an alkyd-type, while Multicote® and Plantacote® use a polyurethane-like coating and Ficote® uses thermoplastic resins. All these materials allow a controlled release of nutrients by osmosis, where the thickness of the coating determines release timing and rate.

Today CRF fertilisers are widely used in container production of nursery stock all over the western world and in Japan. Growers in Sweden started to use them in the early 1970s. At that time the only available product was Osmocote. Today we also use Multicote, Plantacote, Ficote and Basacote®.

## TRIAL 2013

A trial in 2013 was sponsored by Osmocote manufacturer Everris and the aim was to show the differences between "2nd" and "4th" generation Osmocote and some other current CRF products. The trial was located on a commercial nursery in south west Sweden, where the growing season is about 210 days. The crops were: *Cotoneaster dammeri* 'Coral Beauty' and *Spiraea japonica* 'Little Princess'. Rooted cuttings were potted in 2-L containers with the grower's standard peat-based mix — though the lime rate was reduced to 2 kg·m$^{-3}$ instead of 4 kg, because of the high concentration of calcium in the irrigation water.

The trial fertiliser treatments were: Osmocote Exact Hi.End 8-9M, in two rates; Osmocote Pro 8-9M; Multicote 8M, and Basacote Plus 8M. The rates for cotoneaster and spiraea are shown in Table 1. The fertilizers were applied into two drilled holes per pot.

Table 1. Fertiliser rates used in the trial.

| Treatments | *Cotoneaster* rate (g·L$^{-1}$) | *Spiraea* rate (g·L$^{-1}$) | Label colour |
|---|---|---|---|
| Osmocote Exact Hi. End 8-9M (Rate 1) | 3.5 | 4.5 | Blue |
| Osmocote Exact Hi. End 8-9M (Rate 2) | 4.5 | 5.5 | Red |
| Osmocote Pro 16-4.8-10.8, 8-9M | 3.5 | 4.5 | Orange |
| Multicote 8M | 3.5 | 4.5 | White |
| Basacote Plus 8M | 3.5 | 4.5 | Rose |

Note: g·L$^{-1}$= kg·m$^{3}$.

Plants were potted and fertilised with CRF on May 20. At this date the cotoneasters had begun to grow, but not the spiraeas. The trial was assessed monthly during the growing-season. The final assessment was made on September 27. The weather during the growing-season was normal for the region Sweden, except for periods with exceptionally

warm and dry weather in July and August. September was also warm with temperatures above average.

## RESULTS

### Cotoneaster

Until the August assessment there were small differences in growth and colour between the treatments. After this date, however, plants with Multicote and Basacote were of slightly inferior quality. The final assessment showed that all plants, in all treatments had reached saleable size and quality, according to Swedish Standards. However, there were some differences in growth and colour.

The best growth was in the treatment with Osmocote Hi.End, Rate 2, closely followed by Osmocote Hi.End, Rate 1 and Osmocote Pro, then Multicote and Basacote. In general, all the Osmocote-treatments gave plants with a dense centre and more and longer shoots, compared with the other fertilisers.

Osmocote Hi.End, Rate 2 produced plants with the darkest foliage, while Osmocote Hi.End, Rate 1 and Osmocote Pro were somewhat lighter, but still darker than Multicote and Basacote (Table 2).

Table 2. Final quality assessment *Cotoneaster dammeri* 'Coral Beauty'.

| Treatment | Growth | Colour | Damaged plants |
|---|---|---|---|
| Osmocote Exact Hi. End (Rate 1) | 4.5 | 4.5 | 0 |
| Osmocote Exact Hi. End (Rate 2) | 5.0 | 5.0 | 1 |
| Osmocote Pro | 4.5 | 4.5 | 1 |
| Multicote | 4.0 | 4.0 | 1 |
| Basacote | 4.0 | 4.0 | 0 |

### Spiraea

At the first assessment, 2 weeks after potting, all plants had begun growth. There was some variation in plant development, and a number of plants had grown less than others. This variation was more or less the same in all the treatments. By the final assessment all plants, in all treatments, had reached saleable size and quality, according to Swedish Standards.

The best growth was from the two treatments with Osmocote Hi. End, followed by Osmocote Pro and Multicote. The best colour was from Osmocote Hi. End, Rate 2 and Osmocote Pro. Slightly lighter were Osmocote Hi. End, Rate 1, while Multicote and Basacote were the lightest (Table 3).

Table 3. Final quality assessment *Spiraea japonica* 'Little Princess'.

| Treatment | Growth | Colour | Damaged plants |
|---|---|---|---|
| Osmocote Exact Hi. End (Rate 1) | 5.0 | 4.5 | 0 |
| Osmocote Exact Hi. End (Rate 2) | 5.0 | 5.0 | 0 |
| Osmocote Pro | 4.5 | 5.0 | 0 |
| Multicote | 4.5 | 4.0 | 0 |
| Basacote | 4.0 | 4.0 | 0 |

## OBSERVATIONS ON THE USE OF CRF FERTILISERS IN SWEDEN

Today all Swedish nurseries growing containerized nursery stock use CRF. Growers of these crops in Sweden now rarely use liquid fertilizers nowadays. The most widely used brand at present is Multicote. This product has by tradition been significantly cheaper than, for example, Osmocote. Most crops in Sweden are grown for one season, which

means potting in April-May and saleable plants in late August or September. Growers in Sweden only use peat as growing media and the standard fertiliser and lime rates are ($kg \cdot m^3$):

- 3 kg CRF, 8-10 month formulation
- 1 kg NPK 11-5-18 micro or PG-mix
- 2 kg Mg-lime
- 2 kg lime

For fertilization the 2nd year and beyond, Swedish growers use: NPK 11-5-18 micro, Osmocote Topdress or, in some cases, liquid fertilizers. There have been numerous trials in Sweden to compare different brands of fertilisers during the last 20 years. This includes various types of Osmocote, Multicote, Plantacote, Ficote, and Basacote. In the same trial we have always used products with equal release periods.

The conclusions of all these trials are that the differences between the various brands in terms of plant quality and colour are small, except for Basacote, which in general has given plants of inferior quality under Swedish conditions. In practice this has led most Swedish growers to chose CRF products by price rather than brand.

# Label Flexibility from Nursery to Customer©

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## INTRODUCTION

Floralabels A/S was established in 2005 to provide flexible, customised labelling for nurseries, garden centres and other horticultural companies. The system enables users to create labels, tags, signs and banners, in colour, on demand and is available through our partners in most European countries, Africa, USA, and New Zealand.

The ideas presented in this paper draw on my knowledge from previous work in the marketing and packaging of what are known as "fast moving consumer goods" and my knowledge of recent research on consumer behaviour in garden centres and other retail outlets where plants are sold. I have supplemented this with non-scientific interviews with consumers visiting garden centres in Denmark, Spain, and the United Kingdom.

## THE IMPORTANCE OF LABELS

Labels are used on all types of products, from plants and flowers to shampoo, food, and drinks to cars and airplanes. You would not be able to tell the difference between one type of shampoo and another without a label, and many consumers could not tell the difference between two different plants without the labels.

Labels are used for many purposes. They give basic consumer information such as what the plant is and how much it costs, and, often, plant care information and planting advice. A label normally also contains a barcode for scanning at the cashier.

Labels can also be used for tracking purposes, so that companies in the supply chain can track the life of a plant from seed to retail shelf or even beyond if, for instance, the garden centre gives a growth guarantee. Current label projects even include an RFID tag to track Christmas trees over their life.

Anti-theft devices can now be built into the labels, so an alarm goes off if someone tries to steal a plant — these labels also have to be designed so that they cannot easily be removed from the plant. Anti-counterfeit systems can also be built-in in the form of hidden codes or holograms — this is useful if you need to be able to confirm that the plant is the genuine one as named and not a cheap copy.

Factors such as durability, material type, and thickness, the environment it will have to survive, whether it is to be permanent or removable, and the part of the product to be labelled (e.g., pot labels, hanging labels, loop labels, or adhesives), will play an important role in deciding what kind of label you want.

I have offered biodegradable labels for a few years at the same price and with the same characteristics as more traditional materials but, disappointingly, sales have not taken off. As so few pots are recyclable, perhaps growers and their retail customers feel that just changing the labels will have too small an environmental impact. I believe it's important to take care of our environment, so Floralabels will gradually move to produce most of its labels from bio-degradable materials anyway, at no extra cost.

## USING LABELS, SIGNS AND BANNERS TO SELL YOUR PRODUCTS

Fast-moving, consumer-goods companies spend considerable sums each year on optimising labels and packaging to improve the impact of their products on the retail shelf — they treat labelling seriously. They know that 70% of purchasing decisions in supermarkets are made right there when the consumer is looking at the shelf, in about the time it takes to read this sentence.

I am not sure plants are fast-moving consumer goods, but one recent American study showed that only 5% of garden centre visitors know what they want when they arrive at the site. In other words, 95% buy on impulse which means we have plenty of scope to influence their decisions.

Consumers and plants are often left “on their own” in garden centres and in other plant retailer situations. If there is no one around to ask, the consumer’s decision can only be made based on the plant itself, its label, and any adjacent promotional material such as posters. The labels have to sell the plants especially during the times of the year when the plants are not in full leaf or flower.

So it is important to understand what gardeners are looking for. I have found two studies that show the importance consumers place on the different types of information on plant labels. In summarising these studies, consumers want to see a photo of the mature plant and they want answers to these questions:

- Does it prefer sun or shade?
- When does it flower and what is the flower colour?
- Is it annual, perennial, evergreen, deciduous, tree or shrub?
- How hardy is it?
- What are its water requirements?
- How tall will it grow and how much will it spread?
- How and where should it be planted?
- How should it be cared for?
- And, of course, how much does it cost?

And, of course, all this information must be written in the local language where the plant will be sold.

The job of selling the plant must be done by your labels and signs. Do your labels do all of this?

Growers are all plant experts. But it is important to understand the level of knowledge and interest of the average consumer so that your labels and promotional information will engage with them.

Studies have shown that, on a label or poster, consumers tend to look at images in preference to text, are attracted by colour contrast, and respond best to information that is easy to read.

It is therefore important to include a big picture, so the consumer can see the plant at its best. Remember, you want to sell your plants before, during, and after the time that the plant is looking its best. Combining that with the information listed in the previous section will go a long way to maximising your opportunity to sell the plant.

Symbols are popular as a means of conveying information but work best if placed alongside a short, precise text.

It is also interesting to note what gardeners do with the labels. They use them to make their choice in the garden centre or supermarket, of course; some keep them for a while to use the care instructions or as markers to remind them what the plant is when planted, or keep them as a reference for future purchases — but many just throw them away after planting.

Finally, remember that the vast majority of plants are bought by women. Does that make a difference as to how the labels should be designed?

## THE IMPORTANCE OF TESTING AND FLEXIBILITY

It is important to continually test new ideas as there is no answer the question of what is the best label. For example, put labels of different styles or designs on the same type of plant in the same garden centres and measure the impact. Adapt your labels as you learn the results.

This kind of market testing is best done using a flexible label system so that you can design and print your labels, signs and banners. This lets you customize your labels and easily test what works best for your plants in your markets.

It also enables you to respond quickly and easily to your customers’ wishes. If they want their logo on the labels, you can print that. You can even offer to print their prices for them so each plant only has one label. You can also put the information they prefer on the labels. You may even be able to charge for that service.

A flexible on-nursery system also enables you to adapt the language to the countries

where you sell. Sometimes I see labels on plants in Danish garden centres written in English, German, or Dutch, not in Danish. Not very professional and will put-off some consumers, who may only speak one language. Some labels are printed in several languages but the amount of space this takes up means much of the information consumers want is cut. A customised label ensures the consumer gets the information he or she needs to decide to buy your plant.

A label that says the plant is grown in the country where it is being sold can be a strong selling point and suggests that the plants are adapted to the local climate. You can print that on the labels.

Flexibility also means being able to introduce new plants during the year whenever you are ready. You don't need to wait for the labels to be made. And you can print them in the quantity you need as sales takes off.

You can also print the labels when it suits you and your customers, such as the time you pick the orders or earlier . This way you never run out of stock of labels. You can say yes to rush orders and you don't risk ending up with huge quantities of labels for obsolete plants at the end of the season.

You can also print your own merchandising, signs, and banners that promote your products, all from the same system. And adapt to the branding of certain garden centres or help them with their promotional campaigns assuring they stock and sell your products.

**CONCLUSION**

Labels have many purposes, but make sure you include the selling aspect. Big consumer goods companies know the importance of the labels. They are often your only salesperson along with your healthy plants.

If you have the opportunity to use a flexible system, you can test and adapt to consumer behaviour and trends.

# Danish Trials of Quality Monitoring System (QMS) Boomteelt: a Decision Support System for Hardy Nursery Stock Production©

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The appearance and severity of pest infestations or disease epidemics are determined, at least in part, by environmental conditions. Forecasting models may therefore be designed based on occurrence of these conditions. Such models are best used as a support to crop inspections to evaluate the risk of damage. Detecting the appearance of pathogenic fungus at an early stage is often more dificult than detecting insect pests so models that predict disease infection risks at the start of the season are particularly helpful.

Quality Monitoring System Boomteelt is a warning system developed by René van Tol for nurseries in The Netherlands. It was introduced by DLV Plant Holland in 2012, and already more than 40 Dutch nurseries use it.

Quality Monitoring System is used in conjunction with an on-site weather station. QMS uses the geographical position of a nursery to call-up a meteorological institute 10 day weather forecast for that location. The data from forecast can be combined with data collected by the weather station and used to run models that will forecast the occurrence of specific diseases and pests and identify the right time to apply biological or chemical controls.

The data can also be used to help manage crop scheduling, for example by predicting flowering.

DLV Plant Holland will provide a weather station which every hour logs data on eight different climate parameters These are send to the server in The Netherlands via the internet. The forecast program estimates the occurrence of spores or pests, and gives suggestions for the pesticides or biological agents to use and the optimal time for applying them during the following 3 days.

Growers can subscribe to several modules for the disease or pests that might be relevant in a particular nursery. Modules are available for powdery mildew, rusts, downy mildew, anthracnose, beech wooly aphid, vine weevils, scale insects, thrips, boxwood psyllid, boxwood leafminer, and boxwood mite.

# Easy Hedge: the Development of a Nursery Stock Brand©

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## INTRODUCTION

The idea for the Premium EasyHedge® brand (in Danish, Prima Færdighæk®) arose more than 20 years ago when nurseryman Lars Strarup watched his neighbor erect a new fence. It occured to him that it must be possible to produce hedges in a form that could be used as quickly and easily as fencing but which would be far more attractive. He developed his idea inspired by the principles of the rolled turf market — a product that makes it easy for gardeners to achieve good results without special expertise or equipment.

While developing his plans for marketing he also began preparing his production system and started to grow hedging plants to much larger size grades than was common at the time. He also realised the importance of protecting his idea, so registred the brand.

At that time Møllegårdens Planteskole was a part of the sales company Prima Plant. Its sales staff began promoting Prima Færdighæk hedging to Danish garden centers.

## THE PREMIUM EASYHEDGE PRODUCT

Premium EasyHedge is a range of instant hedge plants. The range now includes more than 20 different species including *Fagus* (beech), *Lonicera* (privet), *Malus sargentii*, and *Syringa vulgaris*. The plants are available in different sizes ranging from 125-220 cm. During the production, the plants are trimmed and pruned several times to ensure they are well branched. The roots are also undercut regularly to aid establishment. For most species the pruning and undercutting treatments enable year-round lifting and despatch. The product is dispatched as individual root-balled plants ready to plant. Each plant is despatched with a label which is the customer's garantee of quality.

## MARKETING

At first the promotional activity at garden centres was based on simple displays of the hedging plants themselves. However, the concept has now been developed so that we now have displays based on containers of finished ready hedges and accompanying display posters. The product is also promoted at trade exhibitions and public garden and "life style" festivals in Denmark, Sweden, and Germany.

Advertising media has included newspapers, magazines and TV as well as some unusual formats such as posters on buses on on main routes in Copenhagen. The company also uses the brand to sponsor TV shows. Danish gardening TV presenter Kim Tang was hired for a day to plant a hedge and speak about the product on a promotional video. Future plans include more online promotions including the use of "adwords" on search engines to drive visits to the company's comprehensive website.

The company also takes opportunities to promote the product to young people studying landscape architecture. The current promotional slogan "spring over hvor hækken er lavet" (roughly translated as "jump over the hedge" or "do it the fast and easy way" was a result of a project with high school students.

# The Uniqueness of IPPS and Why We Need it©

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## INTRODUCTION

To understand why I believe we need the unique organization that is IPPS, you need to know a little of how it has helped shape my horticultural life.

In the early spring of 1965 I had just finished 3½ years of service in the Danish Army. Before that I had completed a four year apprenticeship in nurseries in Northern Jutland in Denmark and in the Copenhagen area. After a year at the Vilvorde Horticultural School I had graduated with a diploma in 1961.

In March of 1965 I boarded a steamer in Copenhagen, with a suitcase, a footlocker and a wooden crate. I was bound for America to see the world, learn more about my trade, and then come home to Denmark to start a nursery. Little did I know that it would be in America where I would start that nursery.

My destination was the old D. Hill Nursery in the village of Dundee, north west of Chicago where my boss to be, Jack Hill, picked me up at the railway station. We loaded my luggage into his car and drove out of the city on motorways such as I had never seen.

The arrangements for the job had been made with the help of Anton Thomsen from the Thomsen Nursery in Skalborg by Aalborg in Denmark. I knew that I was to become a "supervisory trainee" for a year — in the propagation division.

I soon learned that the propagator would be leaving at some point and that I, if I was worth something, would be taking over his job. What nobody had told me was that his 1 year notice was up in 4 months and he was committed to a job in another nursery. So 4 months after I arrived, I had the choice of taking over as propagator and manager of the whole propagation division — with an acre (0.4 ha) of greenhouses, 10 acres (4 ha) of outdoor frames, and 30 acres (12 ha) of stock plants — right away, or finish the year of training but with nobody to train me.

I choose the first option and now found myself with responsibilities in many ways far higher than I had as an army engineer platoon leader — and with things I knew far less about. The old propagator, who was leaving, was very helpful. He lived about an hour's drive away, and I now found myself driving to his place every 2 weeks and spending an evening with him learning what I should do next. If it had not been for that and my military experience — and what was about to come from IPPS, I would never have made it.

In December of that first year, Jack Hill took me to the Eastern Region IPPS conference in Cleveland. Jack Hill, my boss, was good to introduce me to many of the 400 to 500 plant propagators, professors, and scientists attending from half of America. I sat through the lectures and went on the tours. In the breaks and the evenings over a beer and on the tours, I was welcomed. Propagators and professors took me under their wings and were helpful in a way I had never experienced. I made connections.

And of course I became a member of the IPPS. But that was not so easy in those days. You had to have three sponsors who were already members. I had my boss and a propagator I had met in Minnesota, Dick Cross, who in turn said he would get Mr. Vincent Bailey from the famous Bailey Nurseries to sign for me — so we found Mr. Bailey. He said that he could not just do such a thing — he didn't know if I knew anything about plants and propagation. So I ended up in a 20 min. examination by Mr. Bailey. I must have passed, because he then signed me up.

So I was "hooked" and helped by the IPPS. In the almost 50 years since, I don't think I have missed more than four or five conferences. My boss, Jack Hill, never came to a conference again. He said now I was the company's man in IPPS. Jack Hill became involved in politics and sadly was killed in an accident a few years later. And I came to be the propagator at the D. Hill Nursery for several years.

## WHAT IS SO UNIQUE ABOUT IPPS

The IPPS is a strange mix of practical plant propagators, professors, and scientists that seldom come together under other circumstances. They respect each other and learn from each other in a most unusual way. They listen together, tour together, share a meal and a drink together, and exchange information all the time.

There was an acceptance and welcome of young people without much experience to a degree I have not seen anywhere else. Nobody asks how rich you are or how big your father's nursery is. We are all together about plant propagation and plant growing. There is an opportunity to meet and learn from the top people in academia, botanical gardens and arboretums, and commercial nurseries the like of which you rarely find.

There is an opportunity to build networks with plant propagators, plant growers, and plant business people, not just in your area but throughout a good part of the world. And then there is the *Proceedings* — the "Black Book" — with all the lecture papers since the start in 1951. Of course it is now also on a CD-ROM disc and can all be had on the internet.

This brings me to one of my pet subjects. Many people nowadays think they can get all they need from the internet: no need to be a member of an association or go to meetings, classes and conferences as all can be had on the screen in the propagation house, the office or at home. I don't dispute that the internet is a wonderful tool, faster, and more efficient than a stack of black books, or green books or whatever. It is, nevertheless, a tool to help us accomplish our task of producing good and valuable plants. To do real things and become real people, we have to interact with real people. That is what we do at IPPS gatherings. To sit and have a drink and share some thoughts with your computer is just not the real thing.

## A NURSERY OF ONES OWN

In time my wife and I started our own nursery, Midwest Groundcovers, not in Denmark but in America. John Wilde, the old propagator who became my mentor in plant propagation, was very helpful in this.

From the early years of growing and selling only groundcovers, we have come to produce a wide spectrum of landscape and garden plants. Even the plants that the farmers ploughed under when they broke the prairie, have now become landscape and preservation plants.

In the early years of our nursery, when things were much tighter than they are today, we started to take our young people to the IPPS conferences. We feel, and they feel, that has tremendously enhanced the growth and quality of our business.

At one IPPS conference in Norfolk, Virginia, I found myself sitting at the bar with IPPS founder Jim Wells. Jim asked about my new nursery. I answered that it may never become more than a "one-and-a-half-man" business, but we were going to try. Jim said, make it a two-man business and I asked why? He replied, because otherwise you can never get away — and you need that sometimes. There was a lot of truth to that. We also talked about financing and I expressed concern that the banks would not take plant inventory as collateral. Jim suggested that I seek out the local branch of the Farm Credit System and this connection became a key to the growth of Midwest Groundcovers.

Over the years as I became more and more involved with the IPPS, I have written articles in the newsletter and given papers to conferences. I have served on and chaired committees and served on the Eastern Region North America Board to become its President. This was great learning in dealing with many kinds of people — to get the job done. Later I served on the International Board and became its President. There were great years of traveling to conferences and excursions around the world. It was an invaluable experience and sometimes challenging, to work with all the different nationalities and cultures. We have brought so much back home, of ideas and inspiration, that all has been paid for many times over.

Can there be any doubt that we need IPPS, now and in the future? I don't think so!

# Plant Tissue Culture in Crop Improvement©

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**Plant tissue culture, the art and science of growing an organelle, cell, tissue, or organ on a defined medium under controlled conditions in an aseptic environment, has come a long way since it was discovered over a century ago. The obvious advantages of extra-rapid multiplication while maintaining genetic uniformity and freedom from pathogens and pests brought this technique into the plant propagation industry after Morel successfully cultured orchids in vitro in 1960. Since then, thousands of plant species have been micropropagated and more of them, once thought recalcitrant, are being multiplied through this method. This article gives a brief history and description of the various techniques that are still relevant and beneficial, especially when used with conventional breeding and modern molecular methods.**

## INTRODUCTION AND BACKGROUND

At Dry Creek Labs we are involved in the business of micropropagating improved fruit and nut cultivars and their rootstocks. The list includes almonds, apples, blueberries, blackberries, citrus, olives, pomegranate, raspberries, stone fruits, pistachios, and walnuts. The recent additions to the list are avocados and pecans. We have also been selecting clones for salt tolerance and eliminating known pathogens and viruses through meristem culture, thermotherapy, and cryotherapy in order to provide "clean plants" to our customers.

Plant tissue culture is defined as the art and science of growing a plant organelle, cell, tissue or an organ in a test tube on a defined medium under controlled environmental conditions (Hartman et. al., 1990*)*. For many who have worked in the tissue culture field, it's as much an art as science that. Perhaps that is the reason why many laboratories are successful in culturing a specific plant while others cannot duplicate the process.

Following the discovery that all living beings are made of smaller compartments called cells (Schleiden, 1838; Schwann, 1839), Haberlandt was the first to try, albeit unsuccessfully, to culture plant cells in vitro in Germany (Haberlandt, 1902). It was left to Gautheret (1934) in France, to demonstrate the successful culture of an isolated plant tissue. White (1939) developed techniques to continuously grow carrot root cell cultures for prolonged periods of time. Plant tissue culture got a real boost with the development of the theory of totipotency which postulated that each living cell has all the ingredients to become a complete organism if given the right conditions (Stewart et al., 1958; Street, 1967; Vasil and Hildebrandt, 1965). The recognition of the role of plant hormones, like auxins (Went, 1928), gibberellins (Kurosawa, 1926) and cytokinins (Miller et al., 1955 ) in plant growth and their availability enabled the plant tissue culturist to grow plant tissues into unorganized masses of cells called callus or to induce the formation of roots, shoots, or whole plants. How these hormones actually function in plants is still being worked out more than a century after they were discovered. Some excellent reviews have recently appeared that describe the history and development of plant tissue culture (Vasil, 2008; Sussex, 2008).

The applications of plant tissue culture got a real boost in the early sixties after Morel (1960) grew orchids and other plants in vitro. Following the development of basic growth media like MS (Murashige and Skoog, 1962) and Woody Plant Medium (Lloyd and McCown, 1980) several commercial tissue culture labs sprang up all over the globe during the seventies. Prominent ones were Twyford in England doing date palm, Oglesby in Florida culturing bananas, and Oki Nurseries in California doing ornamentals amongst other crops. The 1980s saw the proliferation of many labs doing orchids, foliage crops,

and other ornamentals in Florida, California and other states. However, commercial tissue culture, being a labor intensive operation, invited stiff competition from developing countries where labor costs are relatively low. As a result, many of the labs in the USA closed down in the 1990s. Only those laboratories that were producing high-value crops or had adjoining nurseries coupled with good business acumen survived. During the past two decades, the advances in molecular biology have shifted the emphasis and funding of research away from plant tissue culture. The recent recognition of the existence of endophytes in many tissue cultured plantlets and the imposition of stricter quarantine controls has restricted plant movement across borders and revived the local tissue culture micropropagation industry. The development of new cultivars in perennial horticultural crops through various breeding programs and their demand in the market place has further encouraged their micropropagation so they are available to growers in a much shorter span of time.

## TECHNIQUES

There are several tissue culture techniques that have been developed and utilized to improve crop plants. They have found useful applications in improving crops and the work done during the last 50 years is beginning to show up in the horticultural and forestry enterprises. Some of the techniques that have found favor are listed below:

### Somatic Embryogenesis

Somatic embryogenesis refers to the in vitro conversion of vegetative cells into viable embryos which are later induced to become complete plantlets. The conversion of callus and cell suspension cultures into somatic embryos was first achieved in 1958 (Reinert, 1958; Stewart et al., 1958). In general, the procedure involved pulsing the tissue with a high dosage of an auxin like 2,4-D for a brief period followed by growing on a hormone-free medium. Most of the genetically transformed varieties of crops, forest trees and several vegetable, fruit and ornamental plants are being multiplied by this technique. Figure 1 depicts somatic embryos of Chandler walnut regenerating shoots.

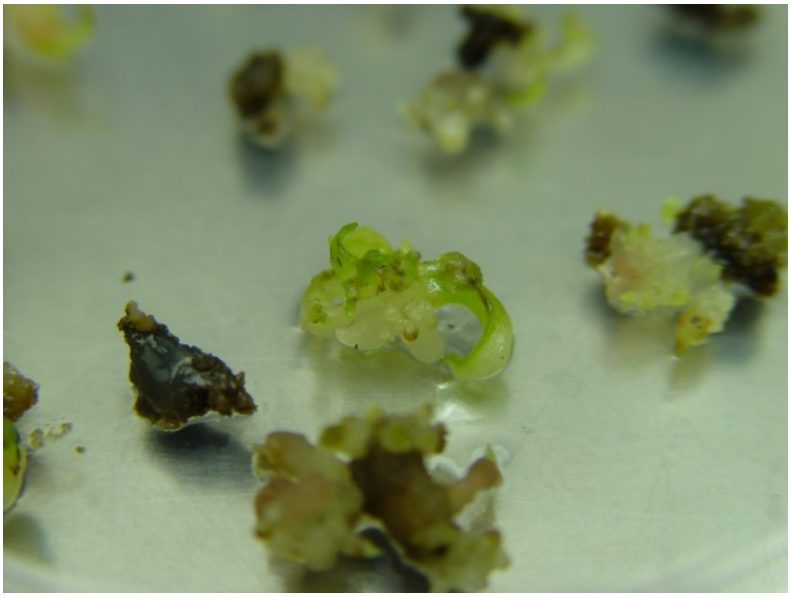


Fig. 1. Somatic embryos of walnut regenerating into shoots.

### Anther Culture and Embryo Rescue

The pollen grains or anthers, the organ containing these male spores, when successfully cultured on a defined medium and conducive environment, generate into haploid plants that contain only half the normal number of chromosomes. They are very useful in

breeding programs to develop genetically uniform homozygous-haploids. The technique was developed by Guha and Maheshwari (1966) and has since been successfully employed in several plant species. Some improvements like selecting the proper stage of anther development for successful culture, double-layer medium, and determining ploidy levels through flow cytometry in plants further enhanced the reliability and application of this technique (Sharma et al., 1983). The haploid plantlets germinating from *Nicotiana paniculata* pollen grains are depicted in Figure 2.

Somewhat similar methodology was employed to develop whole plants from unfertilized or fertilized embryos in vitro. Intergeneric hybrids like plumquats, apriots, apriums, and peachquats have been developed by inter-crossing peach, plum and apricot through "embryo rescue" technology which would not be possible otherwise.

Fig. 2. Germinating pollen grains from *Nicotiana paniculata* anthers.

**Protoplast Culture and Fusion**

Plant protoplasts were isolated for the first time in 1960 by treating cells with enzymes like cellulase, pectolyase, and hemicelluloses that would dissolve cell wall (Cocking, 1960). These protoplasts coming from diverse cultivars or species could be fused together under specific conditions and grown and regenerated into a new plant (Fig. 3). Alternately, a gene of interest could be engineered into a vector like the Ti (tumor inducing) plasmid and either be physically injected into the nucleus of the protoplast by "microinjection," by applying electric current to open up the pores for easy introduction (electroporation) or being briefly co-cultured for incorporation with protoplast nuclear DNA. The resulting fused or transformed protoplast products could be sorted out from the rest of the population by flow cytometry and regenerated into whole plants (Galbraith and Harkins, 1982). New improved citrus cultivars and rootstocks have recently been released that were developed through protoplast fusion at the USDA at Citrus Research and Experiment station in Florida (Grosser, 2012).

**Transformation**

It was discovered that the whole tissue, like an epicotyl segment from a germinated seed, can also be transformed by co-culturing briefly with *Agrobacterium tumefaciens* carrying the Ti plasmid with the gene of interest. It is later transferred to an antibiotic-containing medium to kill the bacterium and the transformed tissue is recovered and regenerated into a whole plant (Sharma et al., 2006). The latest arsenal in biotechnology is the Gene Gun

(Sanford, 2000) where the microprojectiles coated with genes of interest are bombarded at high velocity to successfully transform a range of plant species.

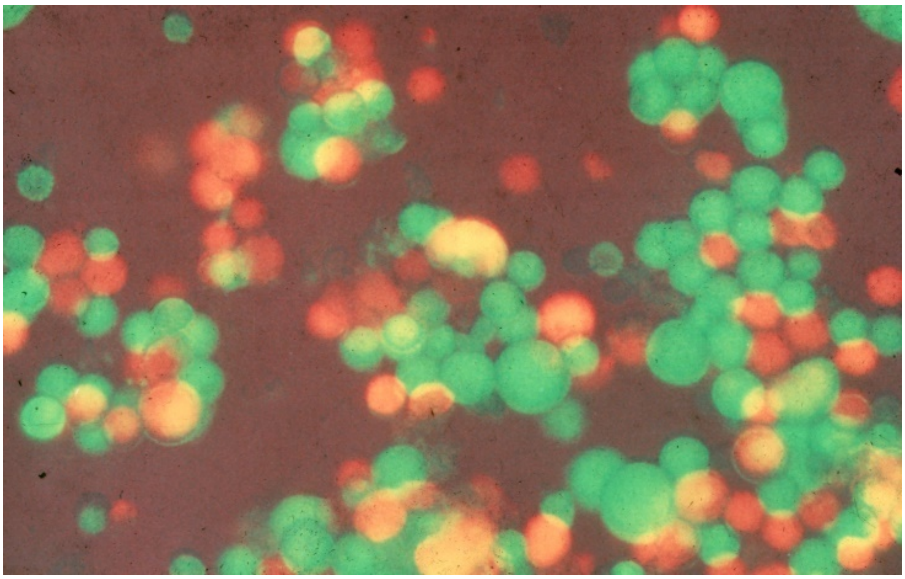


Fig. 3. Fusing protoplasts of *Nicotiana sylvestris* (stained with Fluoresceinisothiocyanate, light gray) and of *N. paniculata* (stained with Rhodamine, dark gray). The fused protoplasts turn orange in color and can be sorted out.

**Developing Stress-Tolerant Plants**

Various types of abiotic (air, water, salts, chemicals, temperature, etc.) and biotic (insects, pathogens, viruses, etc.) stressors are known to adversely affect the quality and productivity of crop plants. At Duarte Nursery we have an interest in developing rootstocks for fruits, nuts, and vines that can withstand saline soils and brackish irrigation water. An aspect which is becoming more important as good quality fresh water is becoming limited in supply in the central valley of California. A relatively simple procedure was employed for the situation where salts equal to or twice the concentrations that existed in a representative sample of brackish San Joaquin Valley well water (Sanden et al., 2009) were added to the plant growth medium. The tissue-cultured shoots of various cultivars of fig and rootstocks of *Prunus*, grape, and the selected in vitro lines from the hybrid seed of pistachio rootstock UCB-1 (*Pistacia atlantica* × *P. integerrima*) developed at the University of California, Davis through controlled crosses, were placed on media containing different salt concentrations and evaluated for growth. In general, figs could withstand saline conditions better than pistachio, *Prunus* and grape rootstocks (Fig. 4). The plants that are already known for their tolerance or susceptibility to salts like Salt Creek grape and 'Lovell' peach showed similar behavior in this in vitro experiment and proved the fidelity of the technique (Figs. 5-7). The experiment also provided information on rootstocks for which salinity tolerance data is still not available. The results of these experiments shall be further tested in field trials.

The high concentrations of chlorides, sulfates, carbonates, and bicarbonates of calcium, magnesium and sodium individually or in combination are the main causes of saline and alkaline soils. In addition, high boron also adversely affects plant growth. Different concentrations of these individual salts ranging from zero to 10,000 $mg \cdot L^{-1}$ were added to the growing medium and the influence on the growth of 7 fig cultivars, 20 grape, 25 *Prunus* rootstocks, and 35 UCB-1 pistachio seedling lines was studied. The results are summarized in Table 1. The plants showing high level of tolerance to salts are being evaluated in the field trails.

Table 1. Tolerance limits of plant cultivars/rootstocks to individual salt concentrations in the medium.

| Salt | Maximum survival limit ($mg \cdot L^{-1}$) | Fig cultivars | Growth[+] | Grapes cultivars | Growth | *Prunus* cultivars | Growth |
|---|---|---|---|---|---|---|---|
| $CaCl_2$ | 10,000 | Calimyrna | 4.0 | Salt Creek GRN-4* | 4.75 | Hansen | 1.5 |
| $MgCl_2$ | 10,000 | Sierra | 7.25 | NA | | Nemaguard | 7.00 |
| NaCl | 10,000 | Calimyrna Sequoia* | 3.75 | Salt Creek | 1.00 | Krymsk-1* | 2.0 |
| $CaSO_4$ | 10,000 | Adriatic | 6.0 | Salt Creek | 8.00 | Hansen | 5.75 |
| $MgSO_4$ | 10,000 | Calimyrna | 7.0 | GRN-5* | 8.00 | Br.Hy.5-7* | 8.00 |
| $Na_2SO_4$ | 10,000 | Calimyrna | 5.25 | Salt Creek | 0.50 | Hansen | 1.00 |
| $CaCO_3$[++] | 10,000 | Sequoia* | 7.75 | RS 3-1* | 6.75 | Hansen | 5.25 |
| $MgCO_3$ | 10,000 | Brown Turkey | 3.5 | GRN-5* | 2.5 | Br. Hy. 5-7* | 1.75 |
| $Na_2CO_3$ | 5,000 | Brown Turkey | 2.00 | RS3-1* | 3.25 | Br.Hy 5-7* | 1.00 |
| $NaHCO_3$ | 1,000 | Brown Turkey | 4.00 | GRN-4* | 4.00 | Nemaguard | 1.75 |
| $HBO_3$ | 100 | Sequoia* | 3.00 | Salt Creek | 3.00 | Nemaguard HBOK-1* | 3.5 |

+ Growth based on visual rating from 0 (no growth) to 10 (shoot filling the 4" tube).

++ Because of low solubility, observations are based on medium saturated with $CaCO_3$.

* Patented clones. Details in Table 2.

Table 2. Details of the patented clones evaluated in the trial for their salt tolerance.

| | Clone | Patent# | Patent holder | Notes |
|---|---|---|---|---|
| FIG | SEQUOIA13-4 | PP20038 P3 | The Regents of the University of California | |
| PRUNUS | ADARA 12-20 | Not Filed | P2G™ Progressive Genetics Group | |
| | BB 106 | Patent Pending | Bright's Nursery Inc. | |
| | BRIGHT'S HYBRID DCL5-3 | PP18,782 | P2G™ Progressive Genetics Group | Brights Hybrid 5 |
| | BRIGHT'S HYBRID DCL5-7 | PP18,782 | P2G™ Progressive Genetics Group | Brights Hybrid 5 |
| | 5C | | The Regents of the University of California | Controller 5 |
| | EMPEREAN 1 | usppaf | P2G™ Progressive Genetics Group | Empyrean©1 |
| | HBOK 1-4 | | The Regents of the University of California | Under Testing |
| | HBOK 10 | PP22505 | The Regents of the University of California | AKA Controller 8 |
| | HBOK 28 | | The Regents of the University of California | Under Testing |
| | HBOK 32 | PP22845 P3 | The Regents of the University of California | AKA Controller 7 |
| | HBOK 50 | PP22208 P3 | The Regents of the University of California | AKA Controller 9.5 |
| | KRYMSK 1 | PP15,995 | P2G™ Progressive Genetics Group | |
| | KRYMSK 2 | PP15,957 | P2G™ Progressive Genetics Group | |
| | KRYMSK 5 | PP15,723 | P2G™ Progressive Genetics Group | |
| | KRYMSK 6 | PP16,114 | P2G™ Progressive Genetics Group | |
| | KRYMSK 7 | PP16,353 | P2G™ Progressive Genetics Group | |
| | KRYMSK 9 | PP20,847 | P2G™ Progressive Genetics Group | |
| | KRYMSK 86 | PP16,272 | P2G™ Progressive Genetics Group | |
| | PENTA | usppaf | P2G™ Progressive Genetics Group Empyrean" | |
| | SAM 1 | | Varieties lnternationai | Under testing |
| | WIEROOT 13 | | P2G™ Progressive Genetics Group | No patent information |
| GRAPES | MCKENRY RS3-1 | PP16291 P3 | The Regents of the University of California | |
| | MCKENRY RS9-1 | PP16115 P3 | The Regents of the University of California | |
| | 8909-05 WALKER UCD GRN 1 | PP19981 P2 | The Regents of the University of California | |
| | 9363-16 WALKER UCD GRN2 | PP199993 P2 | The Regents of the University of California | |
| | 9365-43 WALKER UCD GRN3 | PP20051 P2 | The Regents of the University of California | |
| | 9365-85 WALKER UCD GRN4 | PP21358 P3 | The Regents of the University of California | |
| | 9407-14 WALKER UCD GRN5 | PP23532 P3 | The Regents of the University of California | |

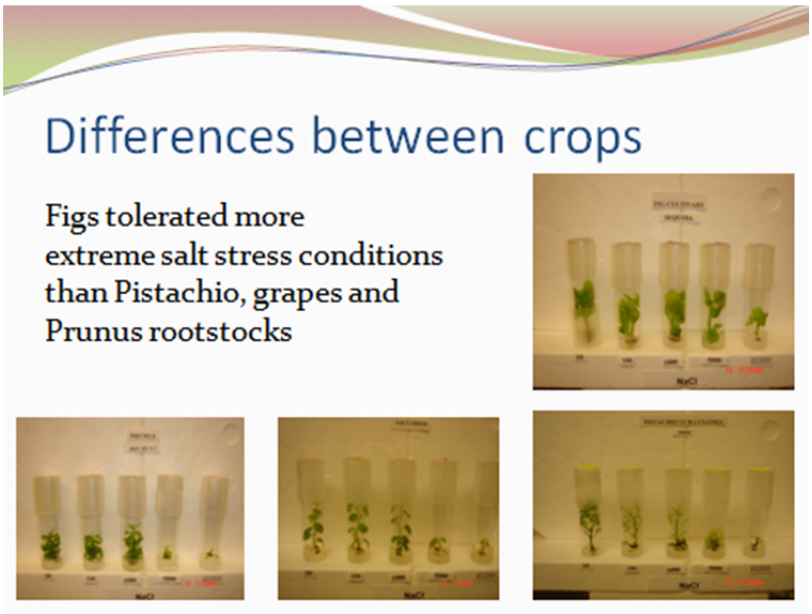



Fig. 4. Differences in the tolerance levels of crops to salt stress.

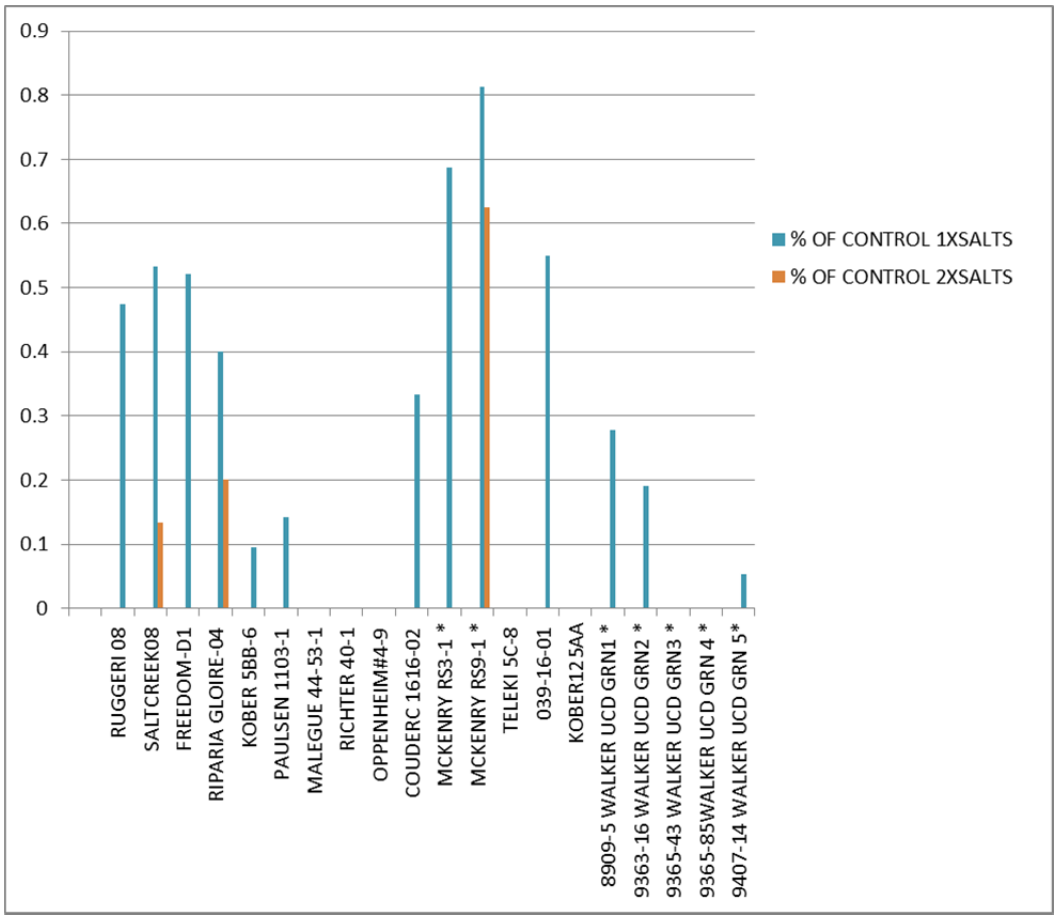



Fig. 5. Influence of salt concentrations equal to (1X) or twice the amount (2X) in San Joaquin well water (Sanden et al., 2009) on different grape rootstocks cultured in vitro. The names marked with * hold patents and are detailed in Table 2.

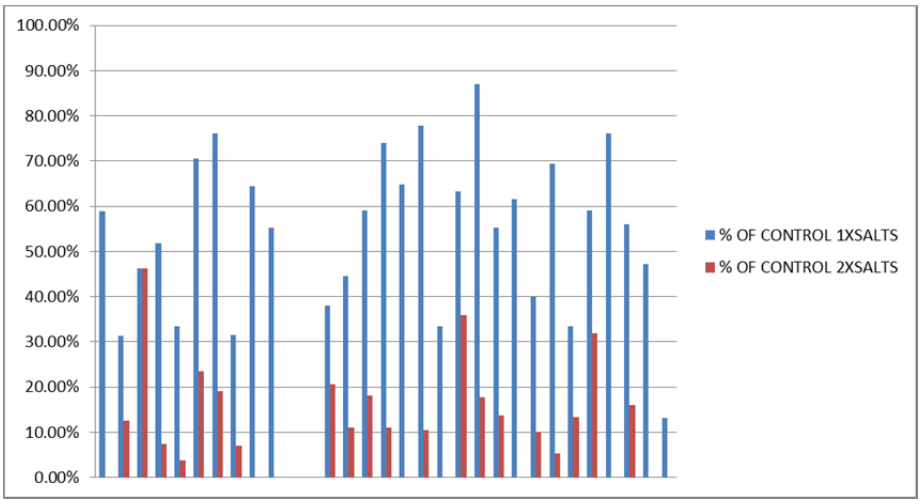



Fig. 6. Influence of salt concentrations equal to (1X) or twice the amount (2X) in San Joaquin well water (Sanden et al., 2009) on different UCB-1 pistachio seedling lines cultured in vitro. The code names for the clonal lines on X-axis are excluded here being proprietary in nature.

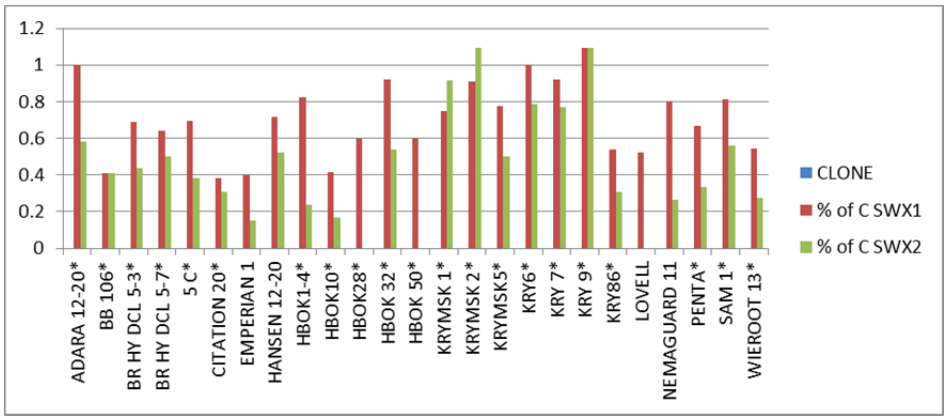



Fig. 7. Influence of salt concentrations equal to (1X) or twice the amount (2X) in San Joaquin well water (Sanden et al., 2009) on different *Prunus* rootstocks cultured in vitro. The names marked with * hold patents and are detailed in Table 2.

**Removing Microbes and Viruses from Plant Tissues**

Various studies have confirmed the presence of viruses and other microorganisms in tissue-cultured plants that can withstand surface sterilization and stay in the tissue without showing up until conditions become favorable. This can result in serious losses and the spread of diseases if not controlled in the initial stages of micropropagation. Normally, an apical meristem, less than 0.2 mm tall, excised from the actively growing shoot apex should be relatively free from most of the pathogens. However, some still remain for which the tissues are subjected to high temperatures for a given period that can kill pathogens but not the plant tissue. We were able to get rid of fig mosaic virus from several fig cultivars by combining these two procedures (Sharma, 2010). Some obstinate endophytes, like *Badnavirus* complex in figs (Laney et al., 2012), leaf roll virus in grapes (Pathirana et al., 2013) and bushy dwarf virus in raspberry (Wang and Valkonen, 2009) which are tightly embedded within the apical dome of the meristematic tissue still stay and can be eliminated only by combining apical meristem culture and heat therapy with cryotherapy as the last step. This three-step procedure can be very challenging to the

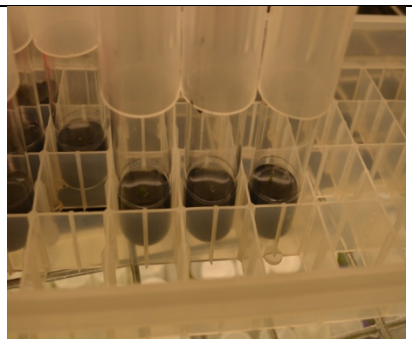
survival of the tissue and certain specific cultural supplements are required to keep it alive (Wang et al., 2009). Figure 8 shows 'Calimyrna' fig that underwent and survived this three-step procedure to eliminate *Badnavirus* complex.

Fig. 8. Cleaned fig (*Ficus carica* 'Sierra') that survived the three-step cleaning process: meristemming, thermotherapy and cryotherapy.

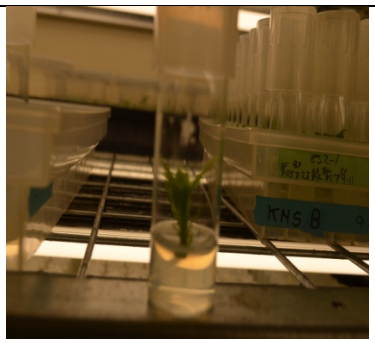
**Micropropagating New Crops**

The procedures for the micropropagation of several crops have been established, but still some remain that are recalcitrant or too slow in culture to be commercially viable. There are so many unknown variables that are simultaneously at play and have not been defined. So every new plant species or cultivar becomes a challenge to put into culture. Sometimes the rooting of some species like walnut has posed challenges that have been partially solved by understanding the physiology and modifying the growing media (Sharma et al., 2006).

Dry Creek Labs has recently achieved success in commercially micropropagating avocado rootstocks and the finished trees should be available in the 2015 growing season (Fig. 9). The micropropagated rootstocks shall save at least 2 years in growing time. The conventional procedure for avocados employs growing of seedlings in the first season and grafting the rootstock on it the following year. The graft point is covered with soil or other medium to encourage the rootstock portion to develop roots. Finally, the scion cultivar is grafted onto the rootstock and the seedling part severed to finish the tree in the following season. Figure 9 illustrates the steps being followed for micropropagating avocados after endophytes have been eliminated from the explants by the procedures described earlier.



A. Excised meristems.



B. Growing shoot.

C. To rooting medium.

D. Acclimation.

E. To pots.

F. Ready for grafting.

Fig. 9. Different steps followed in micropropagating avocado rootstock.

**ACKNOWLEDGEMENTS**

I am grateful to Mr. John Duarte, President, Duarte Nursery, Inc., and Dr. Javier Castillon, Director, Dry Creek Labs, for providing funding, encouragement and resources without which it would not be possible.

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**QUESTIONS AND ANSWERS**

Douglas Justice: How was it discovered that plants could withstand the very low temperatures involved in the cryotherapy treatment?

Dharam Sharma: The technique was developed by Bart Panis in Copenhagen within the last 5 years or do. It's a very harsh technique which requires that the tissue be infused with dehydrating solutions that will protect it.

Jim Conner: What kind of work have you done on avocado scion cultivars?

Dharam Sharma: We are trying new procedures for micropropagating scions also.

# Small Fruit Research, New Introductions and Virus Indexing©

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## BACKGROUND

The University of the Fraser Valley (UFV) was designated the Agriculture Centre of Excellence for British Columbia by the Province's Premier in May, 2013. The message was that the Ministries of Advanced Education and Agriculture must work together to establish a hub at UFV that brings together the efforts of all other institutions in the province that have capacity in agriculture. While a work in progress, many avenues have been covered and many collaborations struck to develop the most environmentally, socially, and economically sustainable industry in North America and provide industry with resources to be proactive.

## THE PACIFIC BERRY RESOURCE CENTRE

The berry growers in the province of British Columbia (BC) are very progressive and have had to respond to many critical changes in their respective industries. At this juncture, because of increased competition from foreign markets, the strawberry industry in BC has switched almost entirely to fresh market production from an earlier time when nearly 100% of the product was processed locally.

The raspberry industry recently saw very low prices, up until 3 years ago, for their products. Both processing and fresh sales have seen a surge, but are now pulling back with the 2012/13 seasons being poor by virtue of weather and 2014 coming in as a good year.

The blueberry industry in BC, with nearly 30,000 acres and a 150 million pound total harvest expected for 2014, is riding a wave of health awareness that is yielding high returns to growers. As expected, in 2014 the price trend was downward as all of North America produces at full capacity.

The cranberry industry dealt with a price collapse 15 years ago and has just recently emerged with increasing prices and production for a more healthy industry overall.

That was the perfect time to combine resources with renewed vigor to develop an industry that is a leader in sustainable growing techniques, including soil management, cutting edge marketing and new product development. With the advent of the "100 Mile Diet," combined with BC's Agriculture Land Reserve (ALR), local farming is becoming increasingly important for production of locally grown food as well as for the preservation of green space for future generations.

It is necessary to have a network of co-operators in BC. Our industry is well-situated with an excellent climate, which produces the highest yields of raspberries, cranberries, and blueberries in the world, as well as the highest quality strawberries. To tackle the production challenges associated with these commodities, such as cultivar development, plant husbandry, postharvest management and marketing, UFV is to lead the efforts of this network of cooperators through the Pacific Berry Resource Centre. This Centre of Excellence will act as a hub to education, research, extension, and other industry efforts. Major cooperators will be the growers, processing industry, BC Ministry of Agriculture, Agriculture and Agri-Food Canada, private consultants and the Pacific Northwest berry groups.

## WHAT IS THE VISION TO ACHIEVE THIS GOAL?

Common goals for all organisations are to:

- Bring all research and resources together at the Pacific Berry Resource Centre of BC (PBRC) associated with the Agriculture Technology Department in UFV's Faculty of Applied and Technical Studies.

- Create superb cross-connections with various government levels as well as producer and other industry groups.
- Draft the terms of reference for the Centre. The premise is that the berry industry has control over the general direction and activities of the PBRC. A strong advisory committee was established out of the respective research committees. The PBRC also entertains projects funded by private entities and helps advance the industry portion thereof.
- Represent the research and development for the four commodities. Together they are larger, based upon number of acres and total dollars produced, than any other British Columbian horticulture sector, even more than all tree fruit and grapes. The berry industry in British Columbia has adopted and adapted many ways of sustainably growing their crops; their research programs and the goals of their associations have long incorporated sustainable industry goals. As such, the industries have developed integrated pest management (IPM) options, spinning off private companies that not only deliver the services needed but also spearheading new developments. Developments such as use of non-pest biologicals as a key component of integrated crop management.
- There was a small need for facilities, which are now provided by UFV. Through strong association with the BCMA and AAFC, as well as UFV lab facilities (in place by 1 April 2014), there is no anticipated need for any other physical space. A new greenhouse facility will house a wide range of industry related trials and observations.
- A field facility, where irrigated row crops can be grown, has been added. This could be used for research as simple as establishment of row crops (e.g., blueberries) so that researchers can perform a range of experiments in isolation from commercial plantings. University of the Fraser Valley has recently also secured relevant spots with greenhouse and land space in south Surrey as well as on Vancouver Island.
- The PBRC is well-suited to help rebuild a more complex extension service; something the industry has great need for, but neither the federal nor the provincial governments have set as priorities. A USA land grant university model is suggested, whereby teaching, research, and extension go hand-in-hand and each participant has varying degrees of joint appointments.

## ACTUAL RESEARCH ACCOMPLISHED OR UNDERWAY

### Blueberry

- Cultivar improvement through collaboration with the BC Berry Breeding Program, together with the BC Blueberry Council. This includes field trials with brand new cultivar releases from foreign programs, as well as advanced selection testing out of the BC Berry Breeding Program. The plant breeder is an adjunct professor at UFV.
- Field trials to test new cultivars or advanced selections under conditions encountered at different farms in various regions of the Fraser Valley.
- Fruit quality improvement with fertility management for each individual cultivar, such as calcium supplementation for some cultivars with calcium deficiency problems.
- Fruit set management in poor pollination years with plant growth regulators.
- Pruning management, differentiating the benefits of heavy versus light pruning and the influence on fruit yield.
- Irrigation management tools such as one versus two drip lines and additional overhead irrigation.
- Stopping overly vigorous plant growth for some cultivars and encouraging growth in others, similarly, keeping plants dormant longer and putting them into dormancy earlier.
- Researching the physiological cause of region-wide crop losses due to such factors as dry fall weather and/or severe winter cold damage.
- Improving propagation techniques, both by cuttings and tissue culture.
- Combating disastrous diseases and pests such as spotted wing drosophila.
- Advocating systemically acquired resistance to diseases and pests, as well as testing green pesticides for their merit and the veracity of the claims made.

- Growing under tunnels and various means of season extension.

**Cranberry**
- Differentiating field establishment of plugs vs. cuttings.
- Establishing the damage levels and methods of control against the cranberry tip worm.
- Evaluating new cultivars for their merit.

**Raspberry/Blackberry**
- New cultivar testing.
- Propagation by tissue culture as compared with root cuttings or traditional handling practices versus plug plants.
- Cultivar adaptation to local climate.
- New cultivar development with the BC Berry Breeding Program funded through the Raspberry Industry Development Council.
- Registration of new cultivars with Plant Breeders Right's Office.
- Raspberry yield decline study over many years with our partners in Washington State and Oregon. This intense study eliminated one after another of the possible reasons for the decline and drilled down to the actual causes, which is information that will be used in fertility research and breeding trials for superior adaptation to our soils and disease/pest background.
- Growing under tunnels and various means of season extension.

**Strawberry**
- New cultivar testing for the BC Berry Breeding Program on behalf of the BC Strawberry Growers Association. Field testing for adaptation. Concentrating mainly on fresh cultivars, since the processed market has been greatly reduced.
- Season extension with day-neutral cultivars and tunnels, as well as raised beds and plastic culture.
- Runner suppression by application of naturally occurring plant growth regulators.
- Table-top growing of fresh strawberries.
- Testing different cultivars to survey customer acceptance.

**Other Berries/Crops**
- Goji as a minor commercial crop — not too much acceptance yet.
- Haskap/honeyberry/blue honeysuckle — the following talk with focus on that topic.
- Working with propagators of new varieties of hazelnuts that are resistant to eastern filbert blight.
- Elderberries — assess varieties for commercial potential.
- Seabuckthorn — evaluated as a future crop.

**Strange and Wonderful**
- Rice for Sake production and table consumption — trials concluded successfully for the Fraser Valley climate. Tested various propagation methods, water levels, fertility management options and varieties.

**Other Activities**

The PBRC focuses on collecting new accessions from around the nursery industry to hold the genetic resource available to the specific contributor or, if they so desire, to whomever wishes to have a license for propagating the material. This, once again, provides industry access to novel plant introductions.

While we are still developing rapidly to build our capacity, a portion of our facilities are entirely designated to house and manage CFIA certified, virus-free propagation material under quarantine for controlled access to the nursery industry. The facility is faculty and student-run and requests for propagation material will be possible through the PBRC.

The novel, 12-meter-tall greenhouse with the most modern light diffusing covering

materials, ultra low-energy consuming fans and a closed structure without vents except the fans, has so many features it would take another 10 pages to discuss. Again, this is designed to move industry forward and make sure the local industry remains at the cutting edge.

**THE FUTURE**

We find ourselves blessed with the most progressive growers, as well as local and international collaborators in the Pacific Northwest and beyond. We are able to pull together research, technology transfer, and instruction and extension services under one (BIG) roof! This closely resembles some of the collaborations at USA universities with their local and USDA partners, where we have our provincial, private, and federal government partners. More and more research is falling under the purview of universities and private entities, with organisations such as the grower councils leading the way. While we lament the government's withdrawal in some areas, we welcome the closer role that industry plays in research, learning, and extension services.

**QUESTIONS AND ANSWERS**

Katreen Gradowska: Is the taste of new cultivar tested?

Tom Baumann: This is a very important characteristic. Yes, taste is evaluated. We bring the berries to food outlets, for example direct food marketing, and we interview people who come to purchase the crops. We give them up to 10 choices to evaluate.

Joe - Duluth, Minnesota: Do you have any connection with the University of Minnesota?

Tom Baumann: We get their cultivars for testing, but beyond that we don't collaborate directly with them.

Larry Rupp: Could you elaborate on the program you have working with nurseries that help you develop new cultivars?

Tom Baumann: There's really much more to it than that. We collect material from different nurseries and propagators. Bring it into our screenhouse and clean it up with heat therapy if it isn't clean already. Once cleaned, we'll keep it free of any pests or diseases. We then offer propagation material to growers from this cleaned material. Students at the University run the program.

Anna - Washington: Can you elaborate on the design of your greenhouse?

Tom Baumann: It is 12 m tall and we manage the above air space for energy savings and air movement using vertical fans. The glazing material is double-layered polycarbonate with dead airspace between the layers. The light transmission is ~82% and the light diffusion is ~95%. The material is called SolarSoft™ and originates in Israel. It costs less than glass and its insulation factor is greater than glass. The greenhouse is built to hurricane and earthquake standards using steel infrastructure. Using spacers, there is no direct contact between the steel infrastructure and the outside air. This eliminates water condensation and dripping inside the greenhouse. All cooling is done actively with fans; there is no passive cooling. More information can be found online at: <http://www.ufv.ca/agriculture/pacific-berry-resource-centre/>.

# Propagation, Management and Adaptation of the Blue Honeysuckle©

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***Lonicera caerulea*, commonly known the blue honeysuckle, honeyberry, or haskap, is a novel fruit crop in North America, but interest as a backyard and commercial crop is rising. Since little agronomic research has been conducted to date, there are few scientifically validated recommendations on propagation, cultivar management, adaptation, and performance. Therefore, horticulturists rely on the experience of individuals as a starting point to propagate, grow, and manage blue honeysuckle taxa in disparate production regions. Four years of horticultural experience with 184 genotypes in British Columbia's Fraser Valley is described.**

## INTRODUCTION

The blue honeysuckle (*Lonicera caerulea*) is an edible, blue fruit borne on a woody perennial shrub in the Caprifoliaceae family (Plekhanova and Sokoleva, 1992). In the wild, it is distributed across most of the arctic and boreal belt of the Northern hemisphere (Rudenberg and Green, 1969). Blue honeysuckle was first bred as a commercial crop in Russia in the 1950s and 60s and separately in Japan in the 1970s (Plekhanova, 2000). Currently, breeding efforts in North America are centered in Saskatchewan, Canada and Oregon, USA. In Saskatchewan, genetic material from Russia (var. *edulis* Turcz. and subsp. *kamtschatica* Sevast.) and the Kuril Islands (uncharacterized subspecies) have been used to produce hybrid commercial cultivars adapted to cold climates similar to the native ranges for these subspecies groups. More recently, genetic material from Canada (subsp. *villosa* Michx.) and Japan (subsp. *emphyllocalyx* Maxim.) has been integrated into these breeding efforts. In Oregon, Japanese genetic material is the primary focus of genetic improvement for more moderate climates when compared with the Russian material (Thompson, 2006b).

The small blue "berries" of the blue honeysuckle are actually multiple accessory fruit. Specifically, the ovaries of the two yellow flowers are enclosed in a copula by four bractlets to form a berry-like accessory fruit (Rehder, 1909). The skin of this fruit is heavily pigmented by anthocyanins; fruit shapes are highly variable, often being oblong, oval or jug-shaped; fruit weight ranges from 0.4 to 2.0 g in taxa from Russia and Japan; and fruit flavor ranges from sweet-sour to sour or even bitter (Plekhanova, 2000; Thompson, 2006b).

Foremost of its attractive features as a crop are: 1) the potential human health benefits of its abundant antioxidants, 2) early fruiting before even strawberries in most environments, 3) unique flavor profile and high acid, and 4) its range of end-uses as a fresh, frozen, or processed product due to its heavy pigmentation. Most genetic resources for this crop are adapted to cold, northern climates such as Siberia, but planting in North America now extends into relatively warmer climates. For example, interest is mounting in planting the blue honeysuckle in the Fraser Valley, British Columbia on the Pacific coast of Canada. Stemming from horticultural experience gained through evaluation of 184 taxa of blue honeysuckle in the Fraser Valley, the following are some general guidelines for propagation, management and crop adaptation that can be of applied to a range of production regions.

## PROPAGATION

In general, the blue honeysuckle is a plant that wants to grow. This statement can be liberally applied to vegetative propagation, growing out in pots and field production. Therefore, conventional wisdom for rooting of cuttings is largely sufficient to propagate the crop and can be used to direct experiments.

As an easy-to-root species, vegetative propagation can be achieved using a broad range of stem types and sizes, with or without application of hormones or wounding. Soft, spring growth can be used to produce stem cuttings within a couple weeks of bud break as long as the tissues are firm enough to remain turgid on the mist bed. As stems begin to harden toward the end of vegetative growth, time to rooting tends to lengthen and rooting percentage begins to drop. Once stems are woody and apical buds have formed, rooting becomes considerably more difficult. As for other ornamental species with providence farther north than their target environment, growth over the longer, warmer summers of lower latitudes tends to result in sun-scalding of leaves and recalcitrance to vegetative propagation. Therefore, it is preferable to take vegetative cuttings before growth cessation and certainly before the cumulative effects of long summer days become noticeable.

Hardwood cuttings are mentioned in the literature as the standard Russian approach to propagating large quantities of blue honeysuckle (Dziedzic, 2008). This consists of harvesting stems from dormant plants, sticking them in sand or soil in an outdoor cold frame and waiting for them to root in the spring. As well, tissue culture is widely used to propagate large numbers of plants, with each nursery and researcher tailoring their protocols to specific cultivars. There are numerous accounts in the literature describing tissue culture experiments, but no comprehensive study or review to this author's knowledge.

## MANAGEMENT

Plant growth habits range from a low-growing dome to an upright, narrow vase, depending on the genetic heritage. No matter the plant shape, planting in perennial rows is the most efficient means of establishment. Spacing at 3-4 ft between plants is recommended, depending on the growth habit of the cultivar. Nine to ten ft between rows is likely as dense a planting as can be achieved while permitting tractor movement within the field. Greater spacing may be required to permit movement of bulky harvesting equipment.

Management of a blue honeysuckle planting can easily be modeled after that of a high-bush blueberry, but is easier to achieve since the crop grows well over a broader soil pH range and has even more vigorous vegetative growth. Generally, fertile soils with adequate drainage are better than mineral and/or poorly drained soils. A raised bed can be used to keep the majority of the roots out of standing water and drip-line irrigation can be used to maintain adequate soil moisture throughout the growing season. A sawdust mulch or weed-mat can be used to effectively limit weed growth around plants within the row. The use of a perennial grass row cover is likely the most efficient means of controlling weeds between the rows, limiting mud and dust and providing a level surface for tractor and foot traffic.

Some accounts indicate that fertilizer application should be limited, but no scientific evidence has been found to support this recommendation. To the contrary, the plants respond well to a generous spring dose of slow-release nitrogen as part of a complete macronutrient and micronutrient fertilizer. Application of comparable amounts of fertilizer to what is recommended for high-bush blueberries of the same size has resulted in no signs of deficiency or excess.

Pruning should be conducted during the dormant season with renewal pruning as the general strategy. Younger wood tends to bear the most fruit, so removal of old branches on a regular basis permits growth from dormant buds at the base or on lower branches. Twiggy growth with short internodes indicate under-pruning and is likely associated with lower fruit production in a mature planting.

Though a small degree of fruit set is observed in the absence of cross-pollinating cultivars, the crop is largely an out-crosser, requiring compatible pollinizers (Plekhanova, 2000; Thompson, 2006a). Appropriate pollinizer cultivars must be determined based on cross-compatibility studies, but also depends on overlapping bloom periods in the target environment. To minimize the risk of poor fruit set, interplanting of multiple cultivars is recommended. Planting more than one cultivar in a single row poses challenges for

management of plant growth habit as well as harvesting. There is no scientific evidence to indicate that different cultivars should be planted in the same row to affect cross-pollination, so these management problems can be avoided.

Several accounts indicate that suitability for low-input or organic production are advantages of the blue honeysuckle. There is no scientific evidence behind this claim and abundant experiential evidence to the contrary. First, it usually takes just a few years for pest and disease issues to arise in an area planted with a novel crop. In the Fraser Valley, pests such as aphids, mites, leaf rollers and voles have been observed to cause considerable damage to blue honeysuckle plants. Likewise, diseases such as powdery mildew and botrytis fruit rot are prevalent. The degree to which these issues are of agronomic importance varies based on the cultivar and production region. Second, it has been observed that low levels of fertilization result in reduced vegetative growth as well as reduced fruit yields. Therefore, management of the blue honeysuckle under a low-input or organic approach should not be assumed as an advantage over other crops.

In the future, experimental validation of each aspect of these horticultural management guidelines should be tailored to key cultivars over a range of production regions. This is because management practices are highly dependent on the interaction between genetics and the environment.

## ADAPTATION

Crop phenological response to a target environment depends largely on how the climate of that environment differs from that of the crop's provenance. The genetic lineage of a particular cultivar is the primary determinant of its adaptation. Across a range of production environments, the Russian cultivars are known to break bud, bloom, and fruit the earliest; the Kuril cultivars have the latest phenology; and the Japanese types are somewhat intermediate. Most types fruit earlier than even strawberries.

Cold hardiness is generally not an issue in temperate climates since most blue honeysuckle types can withstand temperatures of -40°C or lower (Sabitov et al., 2007). On the other hand, when grown in warmer climates than that of their origin, it is the more northern adapted cultivars that tend to sustain winter damage. This is due to active growth during the winter months in response to temperatures that alternate above and below zero.

Similarly, the productivity of blue honeysuckle in warmer climates depends on whether pollinators are active during the bloom period. This is a particular problem for cultivars that are adapted to the coldest environments and, therefore, have the earliest spring phenology. In these cultivars, some fruit will set with little pollinator activity, but optimal yields are dependent on adequate cross-pollination via insects.

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**QUESTIONS AND ANSWERS**

David Cain: Do you know what kind of compatibility there is among the various groups? What about self-incompatibility?

Eric Gerbrandt: It is a gametophytically self-incompatible crop. Beyond that there has been no work on compatibility groups. It is recommended to plant 2-5 cultivars in proximity to one another to obtain adequate fruit set.

Katreen Gradowski: We tried growing just one plant and it did produce fruit.

Eric Gerbrandt: Yes, you will get some fruit set from an individual plant, but to get optimum yields outcrossing will be necessary.

# Growth and Establishment of Pacific Ninebark (*Physocarpus capitatus*) and Atlantic Ninebark (*Physocarpus opulifolius* 'Center Glow') in Rain Gardens in the Pacific Northwest©

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**Low impact development is an emerging concept for treating urban stormwater. Bioretention, an important tool to address this, utilizes the properties of plants, soil media, and microorganisms to infiltrate water and filter pollutants. Rain gardens, a form of bioretention, are shallow depressions in the landscape filled with soil media and plants. Plants are an essential rain-garden component. In order to expand the list of plants recommended for rain gardens in the Pacific Northwest, an Atlantic ninebark (*Physocarpus opulifolius* 'Center Glow') was planted in three rain-garden hydrologic zones: the wetter bottom, the dryer top, and the sloped transition zone. The Pacific ninebark (*P. capitatus*) was planted in the wet zone for comparison. Results after three growing seasons showed rain-garden zone did not affect growth or survival of Atlantic ninebark and there were no differences between the Pacific and Atlantic ninebarks. All plants grew well during the study.**

## INTRODUCTION

Stormwater runoff has traditionally been handled in urban areas with storm sewers. In many cities, these systems are aging and are not viable as the sole means of handling runoff. Urban areas have grown substantially, increasing the area of hardscape that funnels water to the storm sewers, thus increasing problems with volume as well as the level of pollutants in the runoff. Climate change increases the volume of water in single rain events, exacerbating these problems (Gill et al., 2007). The challenge is to develop new and more effective stormwater management techniques for protecting our fresh and marine water systems. The current structural engineering approaches to stormwater management have limitations for fully mitigating the flow and water quality impacts from development. Increasingly, stormwater engineers and designers are exploring and implementing distributed, low-impact development strategies that manage stormwater where it falls and in frequent, small contributing areas (Dietz, 2007). These new strategies use existing natural features and small-scale engineered hydrologic controls to better mimic natural processes allowing water to soak into soils and other pervious surfaces.

A critical tool in the low impact development approach and one of importance to the green industry is bioretention (Dietz, 2007). Bioretention cells, commonly known as rain gardens, are shallow depressions in the landscape filled with soil media and plants. They can be implemented on various scales from small residential lots to large commercial properties. Rain gardens use the biological, physical, and chemical properties of plants, soil media, and microorganisms to infiltrate water and filter pollutants and are intended to be long-term installations.

Plants are an essential component of rain gardens; they absorb nutrients, transpire water, and help maintain favorable soil infiltration and microbiological activity. The moisture

status of plants within a rain garden can vary with season and location. In the Pacific Northwest, plants must tolerate wet winters as well as dry summers, preferably without supplemental irrigation. During wet seasons, rain gardens will have different hydrologic zones, varying from temporarily saturated, oxygen-deprived conditions in low areas to dry conditions in upper areas that merge with the existing landscape. For long-term success, identifying plants that will be healthy and viable under these widely varying conditions is crucial.

Most rain garden research has been done in the eastern USA, which has substantial rainfall in the summer, when evapotranspiration is high. The heavy winter rainfall and summer drought typical of the Northwest provide challenges for survival of rain garden plants and research is needed to evaluate the suitability of different plant species for use in different moisture zones within rain gardens. The purpose of this study was first, to evaluate the growth and survival of 'Center Glow', an Atlantic ninebark cultivar, in all three rain garden hydrologic zones: the wetter bottom, the dryer top, and the sloped zone that transitions between the top and bottom zones and second, to compare the growth of 'Center Glow' and the native Pacific ninebark in the wetter bottom zone.

## MATERIALS AND METHODS

Sixteen identical rain garden cells were installed at the Washington State University Puyallup Research and Extension Center as part of a Low Impact Development stormwater research program partly funded by a Washington Department of Ecology grant (<www.puyallup.wsu.edu/stormwater/>). Each has approximately 256 $ft^2$ of surface area. A bioretention soil mix of 3 sand and 2 recycled yard-waste compost (v/v) was spread to a depth of 18 in. (Hinman, 2005). The cells had a flat bottom area (approximately 10×10 ft) and sloping edges. This created hydrologic zones of varying soil moisture (wetter in the bottom, dryer on the top and transitional on the slopes).

'Center Glow' was grown by the researchers from cuttings donated by Dr. Harold Pellett. The Pacific ninebark was obtained from a local native plant nursery. Both species were grown in #1 containers. Thirty-two 'Center Glow' and eight Pacific ninebark plants were selected for uniformity and transplanted to the rain garden cells using recommended planting procedures (Ophardt and Hummel, 2011). There were 12 'Center Glow' planted in the dry zones, 12 in the transition zones, and 8 in the wet zones. All eight Pacific ninebark were planted in the wet zones. Plants were spaced about 4½ ft on center. All plants were mulched to a depth of 3½ to 4 in. with arborists' wood chips.

All plants were manually irrigated once at transplant in the fall of 2010 and then relied on natural rainfall until the summer of 2011. Drainage of the rain gardens in this study was excellent and no standing water was observed during the winter months. An overhead sprinkler irrigation system was installed and from June to September 2011 all rain gardens were irrigated as needed to prevent plant water stress. After September 2011, no supplemental irrigation was applied to the rain gardens. Precipitation during the time of this experiment was collected by a WSU AgWeatherNet station (<http://weather.wsu.edu/awn.php>) located about one-half mile from the rain gardens.

Plant height and two canopy widths, the widest width and the width perpendicular to the widest, were measured at the end of the 2012 growing season. After the 2013 growing season, plant height and the two canopy widths were measured again. Yearly increase in height and widths was determined. From these data, the yearly plant growth increase was calculated as the incremental shoot growth index (ISGI) using the following formula: ISGI = [(widest width increase + perpendicular width increase)/2 + height increase]/2 (Hummel et al., 2013). In fall 2013 plant survival was evaluated and plant visual quality was rated on a scale from 5 (a superior plant) to 1 (a poor quality plant), with a rating of 3 considered an acceptable landscape plant. Data were subjected to analysis of variance (ANOVA; PROC GLM; SAS 9.1, SAS Institute Inc., Cary, North Carolina) and means separations were done with a protected Tukey's Studentized range test. A Student's t-test was used to compare the two species.

## RESULTS AND DISCUSSION

Recorded rainfall for WSU Puyallup was 0.78 in. in July and 0.34 in. in August of 2011 (Table 1). During that summer, plants were closely monitored and irrigated to prevent water stress. No supplemental irrigation was applied to the rain gardens after September 2011. In the summer of 2012, August and September were extremely dry with no rainfall and 0.01 in., respectively, and some plants exhibited water stress symptoms such as wilting and marginal leaf burn.

Table 1. Monthly precipitation recorded at the WSU Puyallup Research and Extension Center during the rain garden study.

| Month | 2010<br>cm (in.) | 2011<br>cm (in.) | 2012<br>cm (in.) | 2013<br>cm (in.) |
|---|---|---|---|---|
| January | 16.36 (6.44) | 11.07 (4.36) | 12.78 (5.03) | 7.06 (2.78) |
| February | 8.51 (3.35) | 8.13 (3.2) | 7.85 (3.09) | 3.84 (1.51) |
| March | 9.73 (3.83) | 16.97 (6.68) | 15.60 (6.14) | 6.55 (2.58) |
| April | 6.99 (2.75) | 12.12 (4.77) | 7.80 (3.07) | 11.15 (4.39) |
| May | 9.73 (3.83) | 11.18 (4.4) | 6.45 (2.54) | 8.61 (3.39) |
| June | 7.85 (3.09) | 4.06 (1.6) | 5.28 (2.08) | 3.91 (1.54) |
| July | 1.27 (0.5) | 1.98 (0.78) | 3.12 (1.23) | 0.00 (0) |
| August | 1.02 (0.4) | 0.86 (0.34) | 0.00 (0) | 3.71 (1.46) |
| September | 7.32 (2.88) | 2.90 (1.14) | 0.03 (0.01) | 19.20 (7.56) |
| October | 10.26 (4.04) | 9.63 (3.79) | 14.22 (5.6) | 4.06 (1.6) |
| November | 11.25 (4.43) | 13.87 (5.46) | 16.13 (6.35) | 8.76 (3.45) |
| December | 11.66 (4.59) | 6.68 (2.63) | 16.26 (6.4) | 3.61 (1.42) |

Rain garden hydrologic zone had no significant influence on survival, growth or quality of 'Center Glow' ninebark plants measured in the fall of 2013 (Table 2). One of the 12 plants in the transition zone died, but all other plants were surviving in the fall of 2013 and their quality was good to excellent. In Fall 2013, plant heights ranged from 6.1 to 6.9 ft and spreads from 5.6 to 6.4 ft. The Atlantic ninebark hybrid, 'Center Glow' is reported to grow to 6 to 8 ft (1.8 to 2.5 m) in height and spread (U.S. Plant Pat.).

Table 2. Effect of rain garden hydrologic zone on survival, height, width, incremental shoot growth index (ISGI), and quality of *Physocarpus opulifolius* 'Center Glow'.

| Rain garden hydrologic zone | Number of plants | Survival (%) | Height cm (ft) | Width[z] cm (ft) | ISGI[y] cm (ft) | Quality[x] |
|---|---|---|---|---|---|---|
| Dry | 12 | 100 | 185.1 (6.1) | 171.5 (5.6) | 19.6 (0.6) | 5.0 |
| Transition | 12 | 92 | 196.3 (6.4) | 195.3 (6.4) | 29.8 (1.0) | 4.6 |
| Wet | 8 | 100 | 208.9 (6.9) | 186.1 (6.1) | 28.8 (0.9) | 5.0 |
| | | NS[w] | NS | NS | NS | NS |

[z]Width = (widest width + perpendicular width)/2.

[y]ISGI = [(widest width increase + perpendicular width increase)/2 + height increase]/2.

[x]Quality was rated on a scale ranging from 5 (a superior plant) to 1 (a poor quality plant), with a rating of 3 considered an acceptable landscape plant.

[w]NS indicates non-significance at the P=0.05 level using a protected Tukey's Studentized range test.

Atlantic ninebark is native to central and eastern North America where it can be found growing along stream banks and in moist thickets as well as on rocky hillsides and woodland edges (Hoss, 2001; Missouri Botanic Garden, 2014). Hoss (2001) indicated Atlantic ninebark is adaptable to a very wide range of site and soil conditions from moist

to dry, acid to alkaline and gravelly to heavy clay. It was recommended to gardeners as a fast-growing, drought-tolerant plant that can grow in harsh conditions (Missouri Botanic Garden, 2014). In addition to 'Center Glow', there are a number of other *P. opulifolius* cultivars available with varying foliage colors and plant growth habits.

In the rain garden wet zone there was 100% survival of both 'Center Glow' and Pacific ninebark and there were no significant differences between the two species in growth or quality (Table 3). Pacific ninebark is native to Western Washington where it is typically found growing in wet open places along streams, rivers or lakes, in marshlands or along moist forest edges (Pojar and MacKinnon, 1994; Washington Native Plant Society, 2007). Pacific ninebark is a large, erect-to-spreading shrub that can grow to 13 ft (4 m) tall. Pacific ninebark performed similarly to Atlantic ninebark in the rain garden wet zone in this study. While some consider it to have low drought tolerance (USDA NRCS, 2007), others report that it is also occasionally found growing on drier sites (Pojar and MacKinnon, 1994); it is possible that it would have performed similarly to Atlantic ninebark in drier zones of the rain gardens, but that was not examined in this study.

Results of this study indicated the Atlantic ninebark hybrid 'Center Glow' grew and survived in all three rain garden zones. Survival and growth of the Northwest native Pacific ninebark and 'Center Glow' were similar in the wetter bottom zone. Both species survived the dry summer months. Both species grew rapidly from #1-container-sized plants in fall of 2010 to an average height of 6½ ft for 'Center Glow' and 7½ ft for Pacific ninebark, with nearly equal spreads. In the Pacific Northwest, both species could be recommended for use in the wet zones of rain gardens and Atlantic ninebark could be recommended in any rain garden hydrologic zone.

Table 3. Comparison of Pacific ninebark (*Physocarpus capitatus*) and *Physocarpus opulifolius* 'Center Glow' survival, height, width, incremental shoot growth index (ISGI), and quality in the wet rain garden hydrologic zone.

| Species | Number of plants | Survival (%) | Height cm (ft) | Width[z] cm (ft) | ISGI[y] cm (ft) | Quality[x] |
|---|---|---|---|---|---|---|
| Center Glow ninebark | 8 | 100 | 208.9 (6.9) | 186.1 (6.1) | 28.8 (0.9) | 5.0 |
| Pacific ninebark | 8 | 100 NS[w] | 229.1 (7.5) NS | 211.4 (6.9) NS | 25.5 (0.8) NS | 4.6 NS |

[z]Width = (widest width + perpendicular width)/2.

[y]ISGI = [(widest width increase + perpendicular width increase)/2 + height increase]/2.

[x]Quality was rated on a scale ranging from 5 (a superior plant) to 1 (a poor quality plant), with a rating of 3 considered an acceptable landscape plant.

[w]NS indicates non-significance at the P=0.05 level using a Student's t-test.

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**QUESTIONS AND ANSWERS**

Patrick Peterson: Has anyone looked at, particularly in parking lot situations, the influence of pollutants?

Rita Hummel: That work is currently being done. What they're finding is that even though run-off containing hydrocarbons are entering the rain gardens the system still seems to work. Pollutant levels are below what's allowed for organic use of compost. One of the questions being asked is whether edible plants can be grown in a rain garden. Right now, the answer to that question is not known.

Douglas Justice: First questions, when you're establishing the rain gardens are they irrigated in the beginning and/or subsequently? Second, has anyone actually tracked the costs related to the installation and maintenance over those years?

Rita Hummel: There's a relatively old publication I can provide that details installation costs for rain gardens. In our rain garden we irrigated the plants at transplant and the first summer after that. Then we stopped any irrigation. I believe that was a mistake so I currently recommend irrigating plants in a rain garden for two entire growing seasons. We're also recommending to plant lots of plants close together to minimize the need for weeding the rain gardens.

# Propagating Native Milkweeds for Restoring Monarch Butterfly Habitat©

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**The number of monarch butterflies, charismatic nomads of North America, is rapidly declining. Milkweeds (*Asclepias* spp.), which are the sole food source for monarch caterpillars, have also experienced a decline throughout the breeding range of this butterfly. Milkweeds can be grown from seeds or vegetatively from root cuttings or rhizomes. Seed germination is often improved with stratification and plants are easily grown with standard propagation methods. However, some species require adjustments to the substrate to reflect unique soil conditions of their natural habitat. We encourage you to grow and outplant milkweeds to create habitat for monarch butterflies and help restore their populations.**

## THE POPULATION CRASH OF MONARCH BUTTERFLIES

The causes behind the decline in pollinators are many, but most can be related either directly or indirectly to human activity. Habitat loss is always near the top of the list — habitat destruction or fragmentation into small, disperse patches threatens all types of insect pollinators (Mader et al., 2011). Monarch butterflies (*Danaus plexippus*) are, however, an interesting example of pollinator decline because, unlike many other organisms that rely on one specialized habitat, adult monarchs are generalists that thrived all across North America — that is, until recently.

With its large size and striking orange and black coloration, the monarch butterfly has been considered the most well-known butterfly in the world (Commission for Environmental Cooperation, 2008). The monarch is a tropical butterfly that readily recolonizes much of temperate North America through annual migrations. Indeed, their long-distance migrations from breeding areas to overwintering sites in Mexico and California are among the most unique and spectacular biological phenomena in the world (Luna and Dumroese, 2013).

Like many school children, we learned one of our first biology lessons from rearing monarch caterpillars and watching their magical transformation into beautiful butterflies. In fact, in southern Kansas where Tom grew up, monarchs were so common that he remembers wishing he could find some other butterflies to collect for his Boy Scout merit badge. Unfortunately, things have changed. Surveys taken at overwintering sites confirmed our observations that monarch populations have recently experienced a major collapse and, what is more alarming, is how quickly this occurred. Population levels of the eastern and western groups have crashed during the past two decades (Fig. 1). From 1999 through 2010, the eastern monarch group plummeted 81% (Pleasants and Oberhauser, 2013). Similarly, annual surveys of the western group overwintering on the California Coast have revealed a nearly 90% decline during the last decade (Jepsen et al., 2010).

Although adult monarch butterflies are generalists, feeding on nectar from a wide range of flowers, their caterpillars are specialists, requiring tender leaves of milkweed plants (*Asclepias* spp. [*Asclepidaceae*]) to complete that portion of the life cycle. Flockhart et al. (2015) asserted that the loss of milkweeds, especially in the Midwestern United States, is one of the major causes for the decline in monarch butterfly populations. Therefore, growing and outplanting milkweeds is a simple and easy way to assist this beloved butterfly.

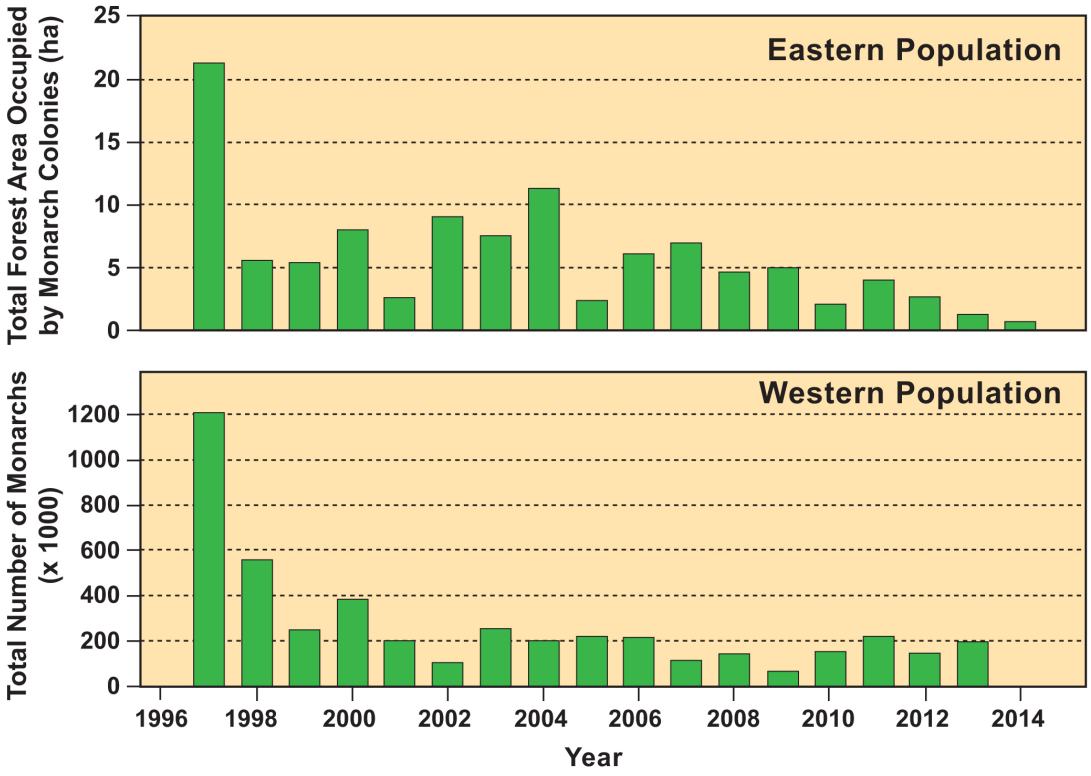


Fig. 1. Although monarchs were among the most common butterflies in the United States, overwintering numbers within the eastern (A) and western (B) populations have declined dramatically during the last two decades. (A) modified from Rendon-Salinas and Tavera-Alonso (2013), (B) modified from Jepsen et al. (2010).

## PROPAGATING NATIVE MILKWEEDS

Milkweed can be propagated sexually (seeds) or asexually (root cuttings or rhizomes), although seedling production is much more common. Propagation protocols for 11 different milkweed species are provided in the Native Plant Network database (for example, Schultz et al., 2001; <http://www.nativeplantnetwork.org>).

### Seed Source and Seed Production Areas

Monarch Watch recognizes 73 species of native milkweeds in the United States, but to date, monarchs are only known to use about 30 of these species as host plants. So, the first step is to determine which of these milkweed host species occur in your area. Helpful state-by-state maps are available on the PLANTS database (<http://plants.usda.gov>); clicking on the state will take you to the county level. A helpful table with all the milkweed species and the states in which they occur is also provided in Appendix 1 of "Milkweeds: A Conservation Practitioner's Guide," that can also be accessed on-line (Borders and Lee-Mäder, 2014).

Forest, conservation, and native-plant nurseries are well acquainted with the concept and importance of seed zones; locally-adapted plants usually perform best. Finding source-identified, locally-adapted milkweed seeds has, however, been a serious obstacle in the past, but efforts are underway to improve this situation. One objective of the Xerces Society's Project Milkweed is to develop local milkweed seed sources (Xerces Society, 2013), and they offer a Milkweed Seed Finder feature on their website: <http://www.xerces.org/milkweed-seed-finder/>. Monarch Watch also has a Milkweed Market that sells seed packets and nursery plants of several species of milkweed (Monarch Watch, 2014). They have developed a milkweed seed zone map for the continental United States (Fig. 2) that is based upon ecoregions (Bailey, 1994). In this map, mountainous areas

are indicated with cross-hatching. For forest trees, elevational seed zones of 500 ft (150 m) are commonly used but nothing is known about the proper seed transfer of milkweeds in mountainous areas. We concur, having noted that showy milkweed (*A. speciosa*) can be found along a 48 km (30 mile) transect from Gold Hill to Hyatt Lake in southern Oregon in which the elevation changes 1220 m (4000 ft). So, when collecting milkweed seeds or rhizomes, try to collect from a similar elevation.

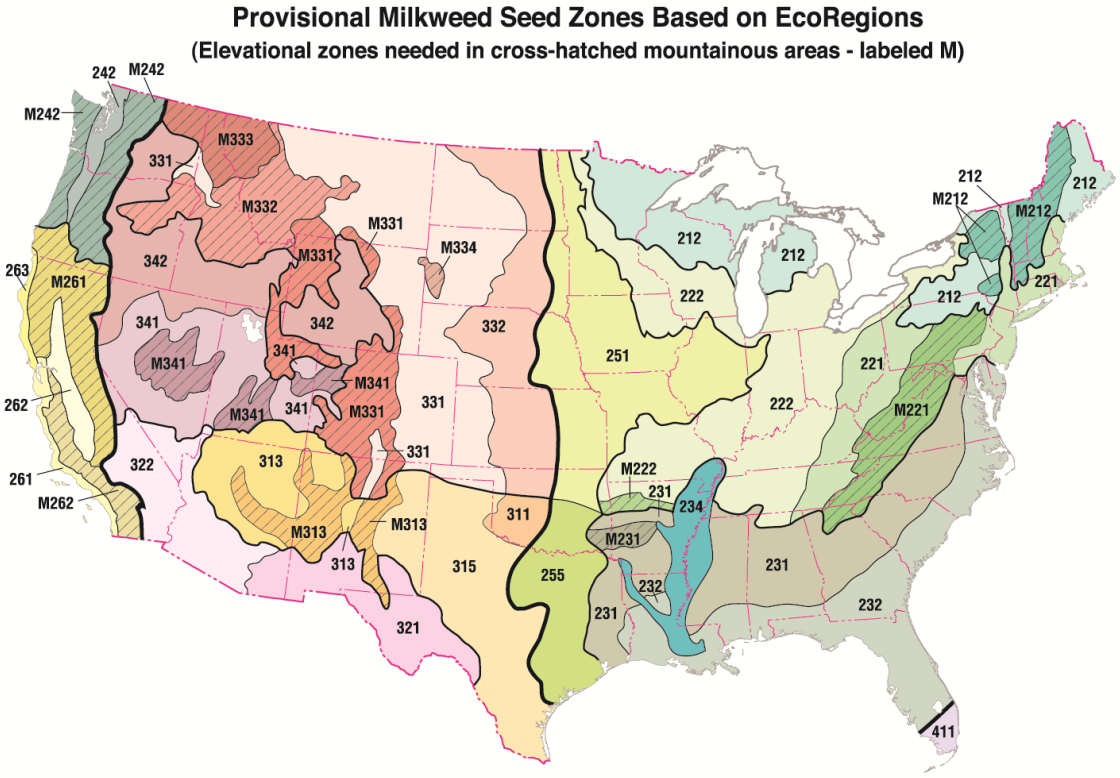


Fig. 2. Provisional milkweed seed zones (Monarch Watch, 2014c) based on ecoregions (Bailey, 1994).

Because milkweed stands could be clones, care should be taken to collect seeds from many scattered stands to ensure genetic diversity and improve seed quality. Research has shown that many milkweeds are genetically self-incompatible (Wyatt and Broyles, 1994), so long distances between individual plants could reduce cross pollination and seriously impair seed quality. When self-pollinations were conducted for common milkweed (*A. syrica*), only 4% of the pollination was successful (Kephart, 1981).

Forest, conservation, and native-plant nurseries could provide a significant service by establishing seed production areas from genetically diverse collections. By partnering with the Xerces Society and Monarch Watch, this would ensure a long-term supply of source-identified, locally adapted milkweed seeds. Useful information on establishing and managing milkweed seed production fields can be found in "Milkweeds: A Conservation Practitioner's Guide" (Borders and Lee-Mäder, 2014).

**Seed Propagation**

Cleaning milkweed seeds of their feathery pappi is relatively easy: gently rub the seeds on a 0.6 cm (0.25 in.) screen and the cleaned seeds will fall through. Be sure to clean seeds outdoors if at all possible because the pappi blow everywhere. Wearing rubber gloves is recommended because some people are sensitive to milkweed. Another less messy technique is to place the uncleaned seeds in a resealable plastic bag containing a small

rubber ball; gently shaking the bag dislodges the pappi and allows the cleaned seeds to fall to the bottom where they can be harvested by clipping the corner off the bag. A range of seed cleaning techniques and equipment for processing small to large collections can be found in Borders and Lee-Mäder (2014).

Many sources of milkweed seeds require stratification (cold, moist treatment) before sowing. In a review of stratification requirements for common milkweed, recommendations varied from as short as 7 days to as long as 11 months at 5°C (41°F) (Luna and Dumroese, 2013). Butterfly milkweed (*A. tuberosa*) germination increased from 29 to 48 to 62% as stratification duration increased from 0 to 30 to 60 days, respectively (Bir, 1986). Our informal natural stratification trial with showy (milkweed) and narrow leaf milkweed (*A. fascicularis*) in southern Oregon revealed that seeds began to germinate after 15 weeks in stratification (Fig. 3A).

Any of the standard seed propagation methods (Landis et al., 1999) are effective with milkweed. Direct sowing of non-stratified seeds during the fall followed by exposure to ambient winter conditions can be effective, but the seeds must be mulched and protected. Cover sown seeds with a thin mulch; research has found that common milkweed seeds germinated better when planted 1 to 2 cm (0.4 to 0.8 in.) deep than when at the soil surface (Jeffery and Robison, 1971). Others have had success sowing seeds without stratification. In early spring, non-stratified showy milkweed seeds that were direct-sown into Ray Leach Cone-tainer Super cells (164 ml [10 $in^3$]; Stuewe & Sons, Tangent, Oregon) filled with Sunshine #1 mix showed 85% germination within 2 weeks under typical greenhouse culture. After 5 months, plants were averaging 13 cm (5 in.) tall (Bartow, 2006). Sowing germinants directly out of stratification has the highest seed efficiency because only live seeds are sown into containers. Growing milkweed in shallow germination trays and then transplanting ("pricking out") the emergents to larger containers is also effective. Fill trays with a well-drained growing medium, press the milkweed seeds gently into the substrate and cover with a very thin layer of peat moss or perlite. The trays should remain "moist, but not wet" by misting as needed, and temperatures should be maintained between 18 and 24°C (65 to 75°F). Transplant young seedlings into larger containers when they have at least one set of true leaves (Kirk and Belt, 2011).


Fig. 3. Propagating milkweeds from seeds is most common, but can have its challenges. Milkweed seed germination can be extremely variable; these showy milkweed seeds germinate after a 15-week stratification treatment (left). Due to their rhizomatous nature, milkweeds do not develop many fibrous roots and their root plugs often fall apart during transplanting (center). Therefore, Jiffy® pellets (right) or containers with other types of stabilized growing media are recommended. Photos by T.D. Landis.

**Vegetative Propagation**

A couple types of vegetative propagation can be used with native milkweeds (Fig. 4). Most milkweed species can be propagated from root cuttings, but the process is much more productive for rhizomatous species, such as common and showy milkweed (Luna and Dumroese, 2013). The best time to collect rhizomes is during the late fall to early spring when the buds are dormant and the rhizomes contain high levels of stored energy. You can locate milkweed plants during the winter by looking for the dried flowering stalks. Rhizomes can be stored by trimming off dead shoots and replanting them outdoors in raised beds or in a large container filled with a well-drained growing medium. Sprouts will form once the weather warms. We have had success propagating from rhizomes during the growing season as long as frequent irrigation is possible (Landis, 2014). Even rhizome sections as short as 5 cm (2 in.) contain buds and can be used as propagules (Easyliving Wildflowers, 2014). When cultured properly, plants propagated from large rhizomes will flower and produce seeds the first year.


Fig. 4. Several species of native milkweeds can be propagated from rhizomes, such as showy milkweed (left). Rhizomes contain dormant buds that develop into shoots under moist and warm conditions (center), and rhizome sections can be used as propagules (right). Photos (left) and (center) by Thomas D. Landis, photo (right) by R. Kasten Dumroese.

**Propagation Challenges of Different Milkweeds**

Three species of milkweeds are found in southwestern Oregon (Borders, 2012). The seed and vegetative propagation methods discussed in the previous sections have worked well for narrowleaf and showy milkweeds, but heartleaf milkweed (*A. cordifolia*) has been more challenging (Table 1). Heartleaf milkweed is much less common than the others and in southern Oregon is restricted to rocky soils in the foothills and mountains. Seed germination of this species has been very low, less than 5% in our experience. This may be a function of poor seed quality caused by self-incompatibility of isolated clones, so we will be planting heartleaf milkweed from different local clones together in a seed production area to foster cross-pollination to, hopefully, improve seed quality.

Table 1. Propagation success for milkweed species of southern Oregon.

| Common name | Scientific name | Seed propagation | Vegetative propagation |
|---|---|---|---|
| Narrowleaf milkweed | *Asclepias fascicularis* | Yes | Yes |
| Showy milkweed | *Asclepias speciosa* | Yes | Yes |
| Heartleaf milkweed | *Asclepias cordifolia* | A few | No |

Our first-year trials with heartleaf milkweed found that this species grows poorly in standard peat-based growing media. Soon after germination, most seedlings succumbed to root rot and the same root disease problems occurred when rhizomes were planted in peat-based growing media. Based on a recommendation from a local grower, we transplanted young heartleaf milkweed plants into a commercial growing media composed of bark, perlite, and sand, which is pH adjusted with dolomitic limestone. Subsequent growth was much improved and one plant even bloomed.

*Asclepias* species grow in a wide range of environmental conditions with one species (*A. perennis*) growing in wetlands and another species (*A. solanoana*) restricted to serpentine soils (USDA NRCS, 2014). Therefore, growers should take local environmental conditions into consideration when deciding how to propagate specific milkweeds.

## MANAGING MILKWEEDS IN YOUR GARDEN

Once established, milkweeds can spread aggressively if you do not manage them. Some things that have worked for us:

### Grow in Raised Beds

Milkweeds spread rapidly by means of rhizomes so planting them in confined spaces, such as raised beds, is recommended. By the second year after establishment, the narrowleaf milkweeds in our raised beds had completely dominated the space and formed a thick canopy.

### Prune to Extend Flowering Period

Like many ornamental plants, pruning flowers soon after they have withered will result in new flower buds. Because milkweed is such a good nectar plant, clipping old flowers will prolong the availability of nectar for monarchs and other pollinators. Narrowleaf milkweeds in a local park that had been mowed several times flowered well into September, more than 6 weeks longer than non-mowed plants.

### Control Unwanted Seed Dispersal

Milkweeds produce seeds at a prolific rate and the fluffy seeds quickly blow all over, which can be a nuisance in a flower garden. Clipping off immature follicles will prevent seed formation and allow growers to better manage their pollinator gardens. If, however, you plan to save seeds from your plants, collect them early or apply a rubberband around the ripening follicles to prevent seed dispersal until harvest (Borders and Lee-Mäder, 2014).

Milkweed and nectar plants are the food elements of monarch waystations, which are specialized pollinator gardens that provide critical habitat for monarchs and other pollinators. Please see Landis (2014) and Landis et al. (2014) for more details on creating a monarch waystation.

## CONCLUSION

Depending on the species, milkweeds can be readily grown from seeds or cuttings. Care should be taken to obtain source-identified, locally-adapted materials. Nurseries can provide a valuable public service by growing milkweed, establishing monarch waystations, and sharing new techniques and insights into propagation of more *Asclepias* species. The plight of monarch butterflies has been widely publicized and efforts to create monarch

habitat are very popular. Tom has been giving "milkweeds and monarchs" workshops in southern Oregon and the positive public response has been amazing. After a recent newspaper article that featured his monarch waystations, he received more than 150 requests for milkweed seeds. Milkweed gardens could also be used for seed production areas that would provide source-identified, locally adapted seeds for local communities. So, planting native milkweeds and creating monarch waystations is a "white hat" activity that can only reflect positively on your nursery and may create other marketing opportunities.

To those of us who care deeply about the environment, it is nice to have a project where we can truly make a difference. So many times, we end up thinking "but, what can one person do?" Growing milkweeds and establishing pollinator gardens is a simple, but effective way to do something positive for our world.

"I have to believe that we can have an impact if we get the gardeners in this country to help us out by planting milkweed and putting in native plants to stabilize native pollinator communities." — Chip Taylor as quoted in Conniff (2013)

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**QUESTIONS AND ANSWERS**

Kerry Beane: You cautioned against the purchase of commercial seeds so where would you suggest we obtain high-quality milkweed seed?

Tom Landis: I suggest going to MonarchWatch.org. That website has a list of seed sources.

Douglas Justice: With those seed balls, are you using seed that have been stratified?

Tom Landis: We will make-up the seed balls this fall and put them in the ground and naturally stratify them.

Mike Evans: Could you comment on the four generations of butterflies one more time?

Tom Landis: The first generation comes off the western U.S. coast and flies into the California foothills. The second generation in May or June fly inland and north and that's when we begin to see them in Oregon. The third generation probably goes a little farther north and a little higher elevation, but we're not sure since the tagging research is still in progress. And, finally, the fourth generation shows up in the Rogue Valley at this time of year (October). This generation goes back to California, over-winters and then starts it up again the following year.

Mike Evans: A generation is about how long?

Tom Landis: The summer generations are about 6 weeks to 2 months while the winter generations are 6-7 months. They are the elite athletes of the Monarch world; they fly all that way, over-winter without eating and mate and start all over the following year.

Ray Maleike: Is there a list of other plants that the adults feed on besides milkweeds?

Tom Landis: Yes, there is and I can get that for you. Or, if you conduct a web search for "nectar plants" you'll find long lists of plants. The butterfly bush is one of the best ones since it blooms for a long time and late into the year.

# An Irrigation Evolution©

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Saunders Brothers, Inc. is a third-generation family farm in central Virginia. The nursery portion of the business was started in 1947 by my father as a 4-H project working with his science teacher propagating *Buxus*. The first greenhouse was built in 1980. Since then, 400 more have been constructed and many new products have been added to our mix.

For many years our system of irrigating our container plants was by manually opening a below-ground valve. Later, the valve would have to be manually shut. As technology changed, solenoid valves were installed and soon Rainbird controllers turned the valves on and off. Because the nursery was terraced and greenhouse sizes were not consistent, the need was apparent for a program that allowed us to maximize our pump capacities and schedule the irrigation to take place as late as possible in the morning hours with a finish time prior to the work day beginning. This Dbase system could tell us the vertical inches of water delivered during the irrigation time and also allowed us to do cyclic irrigation and evaporative cooling of plants. Based on when a controller finished, we could have another starting to maximize our pump usage and finish as quickly as possible. Daily weather changes meant daily changes in scheduling which was determined by management with field staff entering controller changes. It was a 24/7 process and it went on for 15 years. We knew there had to be a better way.

Rolling the clock forward to the IPPS Southern Region meeting in Charlotte in 2010, I heard a talk on evapotranspiration-based (ET-based) irrigation in row crops. The technology was being trialed by the University of Florida, but not on a commercial nursery. It was at that time that we made a commitment to trial it for 5 years.

Year 1 we had an intern spend a summer doing ET-based research on several crops that we were growing. The purpose of the work was to help formulate data that could be used to determine maximum irrigation requirements for plants on our nursery under the summer growing conditions. Table 1 shows some of the data that was discovered.

Table 1. Data collected from the Davis weather station.

| Zone | Name | Plant | Sched. | Time | ET (in.) | CF | IU (%) | Irrigation rate (in./h) |
|---|---|---|---|---|---|---|---|---|
| 1 | 15-18 | Azaleas | daily | 01:45:00 | 0.21 | 1.1 | 100 | 0.4 |
| 2 | 28-30 | *Ilex* | daily | 01:45:00 | 0.24 | 1.1 | 100 | 0.3 |
| 3 | BB Lower | Flowering shrubs | daily | 01:45:00 | 0.27 | 1.0 | 100 | 0.5 |
| 4 | 503-505 | Junipers | daily | 01:45:00 | 0.24 | 1.0 | 100 | 0.4 |
| 9 | BB Upper | Flowering shrubs | daily | 01:45:00 | 0.22 | 1.0 | 100 | 0.5 |
| 8 | 9.11.13 | Azaleas | daily | 01:45:00 | 0.14 | 1.0 | 100 | 0.4 |
| 7 | AA Fx | Flowering shrubs | daily | 01:45:00 | 0.22 | 1.0 | 100 | 0.5 |
| 6 | 19-21 | Azaleas | daily | 01:45:00 | 0.21 | 1.1 | 100 | 0.4 |
| 5 | 8.10.12.14 | Azaleas | daily | 01:45:00 | 0.13 | 1.0 | 100 | 0.4 |
| Solar radiation: | | 129.2 W/m$^2$ | 11.1 MJ/m$^2$ | | | | | |
| Min temperature: | | 65.4°F | 18.5°C | | | | | |
| Max temperature: | | 76.7°F | 24.8°C | | | | | |
| Rainfall: | | 0.00 inches | 0.00 cm | | | | | |

Abbreviations: Sched.=scheduled, ET= evapotranspiration, CF= Capture Factor, IU=irrigation uniformity.

Year 2 we spent focusing on leachate fraction-based (LF-based) irrigation. The testing taught us that we had been over irrigating our crops. When we reduced irrigation to the desired leachate fraction, we also learned that we had to cut fertilizer rates on most of our crops. During this year and the year following, some crop losses were higher than we were accustomed to because of high EC levels since we were fertilizing as in the past. We determined that we could grow the same crops at a higher quality with less fertilizer and less water. We also noticed our herbicides lasted longer. To target a desired LF, a formula is used that incorporates the current LF and the irrigation run time. The formula is the following:

$$\text{New Irrigation Time} = \text{Current Irrigation Time} \times (1 - \text{Current LF}) \times (1 + \text{Desired LF}) \quad (1)$$

In Year 3 we installed a Davis weather system that could remotely monitor the four most important weather variables that dictate the ET levels for the particular crops. Those four variables were: solar radiation, temperature, relative humidity, and wind. Knowing these, the University of Florida professors, Tom Yeager and Jeff Million, tweaked their Cirrig program (Container Irrigation Module) and wirelessly irrigated three crops on our nursery next to three that we irrigated based on a desired leachate fraction. For their continued production of the Cirrig system, some crop information was added on regular intervals including container size, canopy cover, spacing, and whether the crop was under plastic or shade fabric. In order for them to have access to the weather station and solenoid control, Fralo Control Systems built two controllers that bypassed our normal controllers. The exercise proved successful. Table 2 shows some crops and irrigation times based on daily conditions.

The next step was for us to control zones wirelessly. For this initial in house run, irrigation times were determined through continued LF testing and downloaded through a PC directly to the controllers. Plants were grouped based on similar characteristics, pot sizes, and planting dates. They were also prioritized based on irrigation header capacities and whether the plant would be affected (from a disease standpoint) from the earlier irrigation start times which were normally around 4-5 AM during the longest and hottest days of the summer.

During this initial phase of running zones without field manual input, the UF zones continued to run based on the ET rate of the plants. There were hiccups in the early stages; the early transmitting radios proved to be unacceptable as well as other glitches. Nevertheless, we liked what we saw and soon had Fralo integrate the systems so that a daily weather download takes place and wirelessly sends the run times to the individual solenoid. These times are based on the weather information and the crop information that is input. We liked what we saw so much that the entire woody division of the nursery was converted to being irrigated wirelessly based on the ET needs of the plants in a period of less than a year.

Figure 1 shows the water savings since we implemented a portion or all of the new irrigation practice. It also touches on the fertilizer savings and improved weed control. Figure 2 shows the costs savings.

Continued tweaking of the system is taking place daily at our nursery and includes establishing LFs for different plants and irrigating some based on a saturation threshold. Recently we even had Fralo change all times to the tenths of a minute. This is not a big deal on a 20-min run time crop. On a drip system that is run for 3 min., it is.

Table 2. Data collected from our ET-based irrigation system.

| Plant | Plant week | Date of max. ET | Max ET (in.) | Max. temp (°F) | From weather station Radiation (in Lydians) | From AgMaster (in.) Evaporation | Space (in.) | Sun | Shade | Container size (pot #) | Capture factor | LAI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y – 1047: *Rhododendron* 'Chinoides' | 12 | 14-Jul | 0.18 | 80 | 769 | 0.27 | C-C | | x | 300 | 1.563 | 2.35 |
| L – L6: *Buxus sinica* var. *insularis* 'Nana' | | 22-Jun | 0.22 | 90 | 818 | 0.28 | 3.87 | | x | 1000 | 0.763 | 6.92 |
| I – 5021: *Rosa* 'Meigalpio', Red Drift® groundcover rose | 22 | 29-Jun | 0.25 | 90 | 777 | 0.28 | C-C | x | | 1000 | 0.586 | 5.89 |
| K – L3: *Buxus* 'Green Velvet' | | 15-Jun | 0.27 | 79 | 817 | 0.24 | 3.00 | | x | 1000 | 1.220 | 6.82 |
| H – 5005: *Ilex crenata* 'Hoogendorn' | | 29-Jun | 0.23 | 90 | 777 | 0.28 | C-C | x | | 1200 | 1.160 | 7.36 |
| CC – 602: *Euonymus* | | 4-Aug | 0.28 | 91 | N/A | 0.26 | 2.13 | x | | 1200 | 0.838 | |
| D – 1003: *Rhododendron* 'Yaku Princess' | | 26-May | 0.33 | 80 | 801 | 0.29 | 7.60 | | x | 1200 | 0.910 | 3.18 |
| Q – 404: *Nandina domestica* 'Gulf Stream' | | 7-Jul | 0.35 | 92 | 741 | 0.27 | 5.07 | | x | 1200 | 0.772 | 4.37 |
| E – 1002: *Rhododendron* 'Chinoides' | | 26-May | 0.37 | 80 | 801 | 0.29 | 4.86 | x | | 1200 | 1.330 | 3.57 |
| F – BB1: *Buddleja* 'Adonis Blue' | 17 | 21-Jun | 0.38 | 92 | 690 | 0.26 | C-C | x | | 1200 | 0.849 | N/A |
| O – 1029: *Vaccinium corymbosum* 'Bluecrop' | | 7-Jul | 0.39 | 92 | 741 | 0.27 | 6.73 | x | | 1200 | 0.699 | 3.06 |
| G – 5023: *Buddleja* 'Adonis Blue' | 24 | 29-Jun | 0.40 | 90 | 777 | 0.28 | C-C | x | | 1200 | 0.676 | N/A |
| S – 5022: *Spiraea japonica* 'Neon Flash' | 24 | 12-Jul | 0.41 | 99 | 734 | 0.31 | C-C | x | | 1200 | 1.027 | 2.63 |
| M – T4: *Cornus florida* 'Comco No. 1', Cherokee Brave® dogwood | | 30-Jun | 0.55 | 86 | 775 | 0.26 | 20.73 | x | | 2800 | N/A | N/A |
| R – 940: *Rhododendron* 'Chinoides' | | 7-Jul | 0.82 | 92 | 741 | 0.27 | 12.87 | x | | 2800 | 1.273 | 5.67 |
| V – 53: *Rhododendron* 'Blaauw's Pink' | | 26-Jul | 0.91 | 91 | 712 | 0.27 | 10.40 | x | | 2800 | 1.349 | 5.33 |
| X – CC1: *Cupressus* × *leylandii* | | 26-Jul | 0.92 | 91 | 712 | 0.27 | 12.27 | x | | 2800 | 2.061 | N/A |
| DD – 51: *Ilex glabra* 'Shamrock' | | 9-Aug | 1.05 | 88 | N/A | 0.25 | 15.27 | x | | 2800 | 2.429 | |

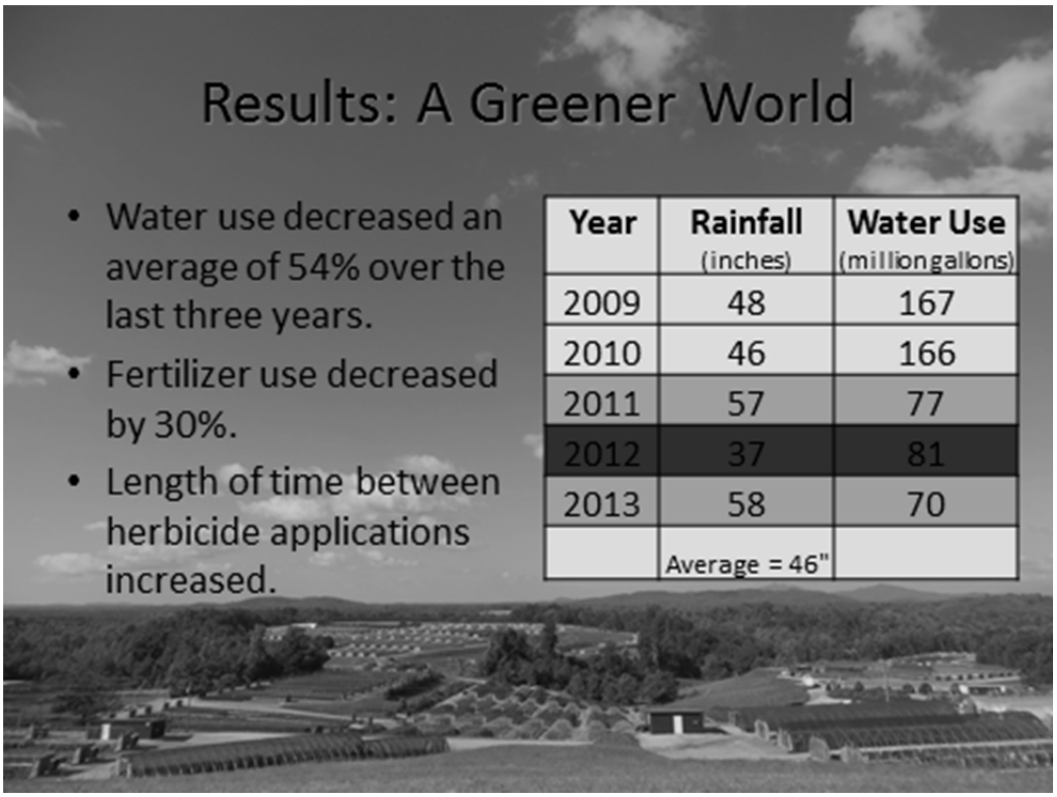


Fig. 1. Water, fertilizer and energy savings using an irrigation based on leaching fraction.

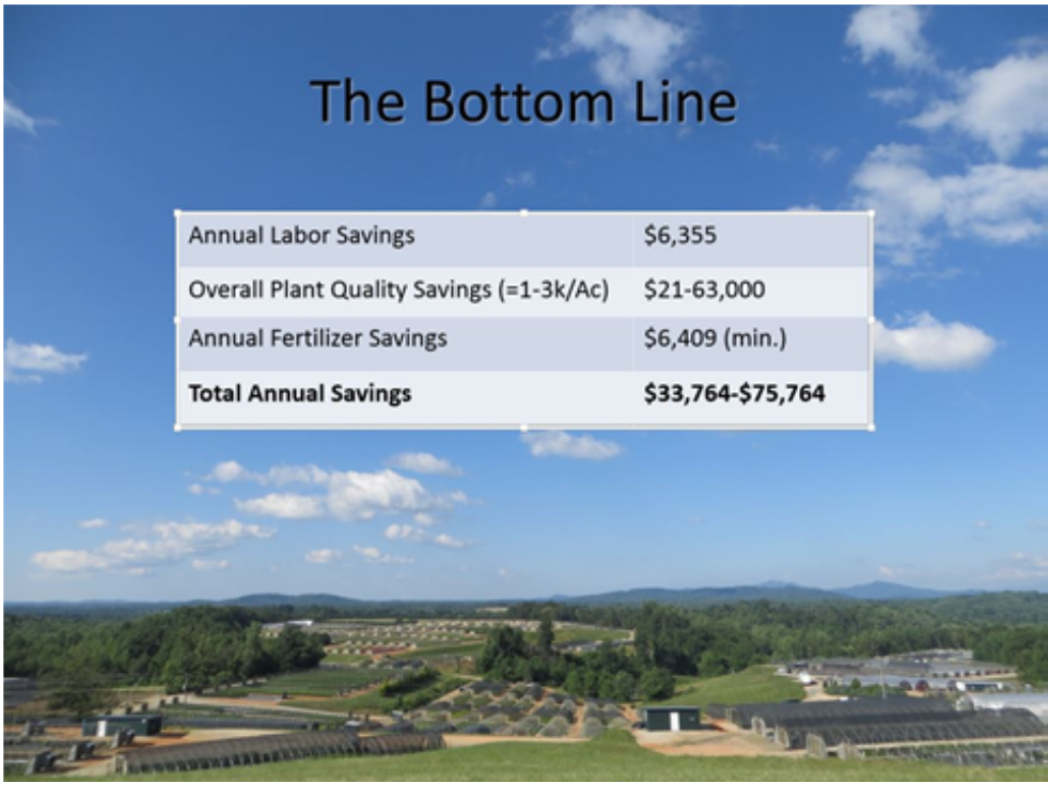


Fig. 2. Cost savings when using an irrigation system based on leaching fraction.

The Cirrig module was originally developed to be a system used during the growing season. In Florida, that season is certainly longer than it is in Virginia. We have some crops that can stay covered for half the calendar year. Because of that, the continued expansion of the system includes determining light and temperature differentials under winter-covered plastic houses. The differential between inside and outside temperature and light would then be used to determine plant water needs until the plastic was removed.

In my 30-plus years of producing plants, this type of technology is as industry changing as any that I have seen. Many may believe that they have too many types of plants and the system will not work. We are growing 400 products and have no sensors. I hope in time others will consider irrigating in this manner.

**QUESTIONS AND ANSWERS**

Diego Martinez: We used a similar ET-based irrigation system. How do you know what the crop coefficients are to put into the formula?

Tom Saunders: We used our leachate fraction data to help establish ET crop coefficients along with actual observations of how wet the soil was in the containers for our crops. We also took growth measurements to help fine tune things.

Todd Jones: What software did you use to run the system?

Tom Saunders: The software was developed by the University of Florida. Fralo Systems was responsible for integrating our irrigation system hardware and the software.

# Market Invaders: Invasive Plants on the Propagation Radar©

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## INTRODUCTION

The Government of Canada, in its publication *An Invasive Alien Species Strategy for Canada*, defines invasive species as alien plants, animals (fish included), fungi, and microorganisms introduced by man into areas outside of their natural range or distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species (Environment Canada, 2004).

The topic of invasive species is one of global concern. It is well-known that invasive organisms are second only to habitat loss and degradation in endangering native plants and negatively impacting our environment, society, and economy (Voller and McNay, 2007).

Invasive species are usually circulated via human-based pathways and are spread by a wide array of vectors (Voller and McNay, 2007). They can significantly compromise natural ecosystems as well as man-made systems by adversely altering biodiversity, food sources, species at risk, crop integrity, and may threaten human and/or animal health and introduce foreign parasites and disease. These negative effects often result in increased management costs and lost resource productivity (Invasive Species Council of BC, 2012). Finding both short and long-term, practical and effective solutions to prevent the introduction and spread of invasive species is often overwhelming and challenging. Prevention by education is critical to halting invasive spread. An important step to making a difference in preventing invasive spread is to provide the necessary education and tools to help businesses and the public understand the widespread impact of invasive species.

Invasive plants make up only a small subset of introduced plants on a global scale. Regardless, the damage done by invasive plants is tremendous. Such invaders are successful due to the fact they have few or no natural population controls outside of their native range. In addition, these plants tend to maintain effective and diverse reproductive strategies that allow them to establish aggressively and out-compete non-invasive species. Once established, invasive plants can cause large-scale environmental, social and/or economic damage which is often irreversible. Management and/or eradication efforts are often costly and difficult. In British Columbia (BC) alone, the damage costs associated with just six invasive plants far outweigh the cost of management. It is projected that by 2020, damage costs may reach $140 million (Fridd et al., 2009; Coulatti et al., 2006).

## INVASIVE SPECIES COUNCIL OF BC (ISCBC)

The Invasive Species Council of British Columbia (ISCBC) is an action-oriented, non-profit organization whose members are involved in all aspects of invasive species management. The ISCBC works to reduce the negative impact of invasive species in British Columbia. Through province-wide coordination and collaboration with those invested in making a difference, ISCBC provides effective prevention and management programs. Education and awareness are keys for implementing many of these programs. To streamline its programs, ISCBC follows the *Invasive Species Strategy for British Columbia*, a multiyear, strategic framework for improved invasive species management in BC.

## THE HORTICULTURAL TRADE: PATHWAY OF INVASIVE PLANT SPREAD

The horticulture industry has been identified as a key pathway of invasive plant spread. Nearly 60% of invasive plants were intentionally introduced to Canada as agriculture crops, landscape plants, ornamentals, or for medicinal and/or research purposes (CFIA,

2008). Invasive plants are being spread in rural and urban communities, orchards, crops, gardens, vineyards, aquatic areas, and wild lands. In addition, global trade of plants has allowed for movement of plants around the world at a rate, volume, and diversity not seen in geologic times past. The result is an increase in the promotion, propagation, selling, purchasing, trading, gifting, and relocating and improper disposal of invasive plants.

## PLANTWISE: AN EFFECTIVE SOLUTION FOR CHANGE

To mitigate the growing threat of horticulturally invasive plants in BC, ISCBC partnered with the BC Landscape and Nursery Association, and the Horticulture Advisory Board (HAC) to create a powerful solution — PlantWise. The HAC consists of plant scientists, horticulturists, provincial invasive plant committees and council members, landscapers and landscape architects, nursery owners among others, who voluntarily contributed their time and expertise toward the development and production of the program.

Being a prevention-based program specifically designed to work with both the horticulture industry and consumers, the PlantWise program bases its success, not only on conveying a positive and realistic message, but also by integrating the power of community-based social marketing (CBSM). The latter is an effective way to encourage and motivate the horticulture industry and plant enthusiasts to commit to making a long-term change in their behavior. The desired behavior for people is to utilize only non-invasive plants instead of plants deemed invasive in their region. If increasingly more consumers decide to choose and purchase only non-invasive plants, the greater will be the decrease in supply of invasive plants. Over time, this change may cause a significant, positive impact on halting invasive plant spread.

Around the world similar programs are in action: “PlantWise”, Vermont; “PlantRight”, California, “Grow Me Instead”, Australia; “Be PlantWise”, United Kingdom; and “GardenSmart”, Oregon and Colorado.

### Invasive Species Council of BC’s Grow Me Instead Resource

The Grow Me Instead (GMI) is a valuable resource tool that complements the PlantWise program. It illustrates 26 of horticulture’s most “unwanted” invasive plants commonly circulated throughout BC. These “unwanted” plants are sold at garden centers and other outlets, and are used by landscapers and landscape architects in their designs. The invasive plants included in this resource were chosen by the HAC. Each plant is pictorially listed along with a map showing current provincial distribution. Also included is a profile of the plant as well as a list of suitable, functional and equally beautiful, non-invasive plant alternatives (native and exotic) that work well for a range of growing zones and conditions in BC. In combination with ISCBC’s Grow Me Instead Resource, the PlantWise message encourages responsible behavior in both the horticulture industry (supply) and the general public (demand).

### PlantWise and the Horticulture Industry

The PlantWise program relates well to plant growers, wholesalers, and retailers. The program offers free PlantWise certification, an easy-to-follow Code of Conduct, in-store Grow Me Instead resources, staff training as well as community and provincial recognition to those businesses willing to promote and utilize only regionally non-invasive plants. In exchange, the program encourages horticulture businesses to voluntarily phase out or halt selling plants deemed invasive in their region and, instead, grow and/or sell only non-invasive alternatives. Horticulture business owners and/or managers can make a significant difference in their community — becoming a trusted source for offering a wide variety of safe plants and providing in-store and/or online invasive plant education to their customers.

### PlantWise and Consumers

Consumers, such as landscapers and gardeners, are often drawn to the beauty and functionality of invasive plants without questioning whether or not a particular plant is

invasive in the region. Without having widespread meaningful awareness and understanding of invasive plants, preventing their introduction and spread may not be possible. One effective solution is providing consumers with relevant and factual information about the potential threats that invasive plants pose and offer them safer non-invasive alternatives. The Grow Me Instead resources are key tools used to help consumers make informed decisions about the types of plants they purchase.

The PlantWise message and Grow Me Instead Resources are positive and motivating; they encourage consumers to connect with the issue and take action to prevent the problem of invasive plant spread in their region. In the past 2 years the program has helped inspire many people to want to commit to choosing and utilizing only safe, alternative non-invasive plants instead of invasive ones. By committing to making a simple change in behavior, consumers can drive change in market supply. In so doing, consumers can make a measurable difference in reducing the spread of invasive plants. In addition, consumers can build trust with local garden suppliers, are able to select from and use a greater diversity of regionally safe plants, and can have peace of mind knowing they are avoiding negative and often costly consequences that come with invasive plant infestation.

**The PlantWise Ambassador Program: Provincial and Regional Collaboration**

In collaboration with Plant Wise Ambassadors, such as the Master Gardeners Association of BC (MGABC), British Columbia Communities in Bloom (BCCIB) and numerous regionally-based invasive species committees in the province, the PlantWise message is now being disseminated and associated resources circulated to businesses and the general public throughout BC.

## 2014 SNAPSHOT OF HORTICULTURE-BASED INVASIVE PLANT USE IN BC

In the spring of 2014, ISCBC contracted Mario Lanthier of CropHealth Advising & Research based out of Kelowna, BC, to carry out a number of spring visits to garden centers in the Lower Mainland and Southern Interior of BC. The areas selected represent the horticulture hub of BC. Stores selected include chain stores, independent seasonal, and independent year-round. The purpose of store visits was to determine horticultural business purchasing patterns and the number and kind of GMI listed invasive plants being sold.

Out of a total of 83 garden centers visited, 45% sold one or more invasive plants. Of those selling invasive plants, approximately 40% sold only one type of invasive. Of all stores visited in the spring, only a fraction of total sales were derived from selling invasive plants. Garden center visits also revealed that only six GMI listed, regionally invasive plants were regularly being sold in the spring (Table 1).

Table 1. List of six commonly sold invasive plants in British Columbia, Canada.

| Common name | Latin name |
|---|---|
| Common periwinkle | *Vinca minor* |
| Yellow archangel | *Lamium galeobdolon* |
| Mountain bluet | *Centaurea montana* |
| Spurges | *Euphorbia esula*, *E. myrsinites*, *E. cyparissias* |
| Russian olive | *Elaeagnus angustifolia* |
| English ivy | *Hedera helix* |

## CONCLUSIONS OF THE SURVEY

Preliminary findings of this snapshot survey shows that at least six invasive plants were commonly sold in the BC horticulture trade and many were sold in regions where these plants are regionally invasive. Also, less than 20% of sellers provide only one type of

invasive plants. Due to the narrow margin of monetary gain derived from the sale of these plants it is conceivable that garden centers can afford to either phase out or entirely halt the sale of many of these plants in regions where they are invasive. Notable exceptions are *Vinca minor* and *Hedera helix*, which may be more difficult to remove from the trade because demand is strong, therefore supply is strong. It was suggested that in order to effectively convince garden centers to sell only non-invasive alternatives, a different approach must be taken depending on store type (e.g., chain store, independent seasonal, or independent year-round store).

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**QUESTIONS AND ANSWERS**

Larry Rupp: Several of the plants you listed are not invasive where I come from. Should a wholesale nursery continue to grow and ship a plant where it is not invasive or if it's invasive in their area they should stop growing it so they don't run the risk of it escaping?

Evan Rafuse: It can be challenging for a wholesale nursery and other suppliers, even retailers, to be mindful of and practice not selling plants to and/or within regions where they are proven invasive. If a plant is not invasive in area but it is in another, then clearly it is okay to grow it and ship it where it is not invasive. By growing and shipping plants to areas where they are invasive however, is consistently catalyzing further introduction and spread and thus associated damages and management costs in that area. There are many safe, alternative plants that can be utilized across the country and businesses can make a profit on these while providing invasive plant education to their customers. We simply encourage suppliers, growers, and wholesalers to adopt the PlantWise mindset or like-mindsets already prevalent in many regions of the world and become community stewards exercising responsible behavior. Remember, if you grow, send or sell it, trusting consumers will buy it. It takes both consumers and industry to work together to first become aware of the problem, then to care enough about it to make a concerted, beneficial change.

# Performance of Biodegradable Nursery Containers©

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## INTRODUCTION

Consumer demand for environmentally conscious products and business practices is on the rise (Behe et al., 2013) and consumers are willing to pay more for eco-friendly products, such as plants grown in biodegradable containers. Biodegradable containers or biocontainers are made from plant-based materials and degrade quickly in the environment. Two recent online surveys found that consumers are willing to pay $0.23 to $0.29 (Yue et al., 2010) and $0.61 to $0.82 (Hall et al., 2010) more for plants grown in biocontainers. Besides the market opportunities, nursery growers are interested in biocontainers due to their environmental conscience and interest to reduce transplanting costs. Plantable biocontainers can reduce transplanting time by 17% relative to traditional plastic containers that must be removed when planted (Nambuthiri and Ingram, 2014). In response to industry's interest in biocontainers, a broad range of products are commercially available (Table 1) and others are in development (Evans and Hensley, 2004; Helgeson et al., 2010; Schrader et al., 2013).

Despite consumer interest in biocontainers, the nursery sector has been slow to adopt them. In 2009, less than 25% of greenhouse and nursery growers in the USA used biocontainers and fewer than 15% planned to adopt them in the next 1 to 3 years (Dennis et al., 2010). There are a variety of reasons why growers are reluctant to use biocontainers, which includes premature breakdown and higher cost. This paper summarizes the findings of recent research that compares the performance of a variety of biocontainers to traditional petroleum-based plastic containers. This information will assist growers to select an appropriate biocontainer to meet their needs.

Table 1. The different biocontainers that were used in the studies cited in this paper.

| Types of biocontainers | Product names | Manufacturer |
|---|---|---|
| Bioplastic | SoilWrap® sleeves | Ball Horticultural Co. |
| | TerraShell™ ($OP_{47}$) | Summit Plastics Company |
| Coconut fiber | Coir pots | Myers Industries Inc. |
| | | Dillen Products |
| Manure | CowPots™ | CowPot Co. |
| Paper | Ellepots | Ellegaard A/S |
| | Fiber grow products | Myers Industries Inc. |
| Peat | Jiffy pots® | Jiffy® |
| Rice hull | NetPot™ and rice pots | Summit Plastics Company |
| Rice straw | Straw Pot™ | Ivy Acres |
| Wood fiber | Fertil pots | Fertil USA |
| | Moulded fiber pots | Western Pulp Products |

## COMPARING THE PERFORMANCE OF BIOCONTAINERS WITH TRADITIONAL PLASTIC CONTAINERS

### Strength and Compatibility with Automation

A few studies have measured the strength of biocontainers (Beeks and Evans, 2013b; Evans et al., 2010; Koeser et al., 2013a). In general, the strength of water-permeable

biocontainers drops significantly after a few weeks in production (Beeks and Evans, 2013b; Evans et al., 2010). Beeks and Evans (2013b) measured the strength of nine biocontainers after 15 weeks of production of *Cyclamen persicum* 'Rainier Purple' using subirrigation. At the end of the trial, the tensile strengths of peat, manure, wood fiber, and rice straw containers were significantly less than plastic containers. In fact, the peat and manure containers broke during production. Similar findings were reported by Evans et al. (2010). They concluded that bioplastic, coconut fiber, rice hull, rice straw, and paper containers had adequate strength (i.e., at least 2 kg wet vertical and punch strength), while wood fiber, manure, and peat containers did not.

Koeser et al. (2013a) tested how seven biocontainers held up to mechanical filling with a gravity-fed potting machine and shipping the biocontainers in shuttle trays placed on rolling carts in a box truck. All of the biocontainers performed well in the mechanical filling trial. Container damage never exceeded 1.5% and there was no difference in the proportion of biocontainers successfully filled. However, it was noted the manure, peat and rice straw containers were slower to fill because they were difficult to separate. In the shipping trial, 27 and 35% of the manure and peat containers, respectively, sustained damage. The paper and wood fiber containers sustained no damage during shipping and outperformed the bioplastic (8.3% damage), coconut fiber (8.3%), plastic (1.7% damage), and rice straw (6.7%) containers. Based on these findings, growers should be cautious when using manure, peat and, to a lesser degree, wood fiber containers due to their relative fragility.

**Plant Growth**

Biocontainers must not compromise plant growth or quality to be accepted by industry. Several recent studies have evaluated plant growth in biocontainers. Lopez and Camberato (2011) measured the quality and marketability of *Euphorbia pulcherrima* grown in six biocontainers. After 14 weeks of growth, they concluded that plant quality was not negatively impacted by any of the containers. Kuehny et al. (2011) conducted an extensive study on the growth of three bedding plants in eight biocontainers at three trial sites. Although there was variation in plant growth between the containers types, Kuehny et al. (2011) stated that all of the biocontainers produced marketable plants. In addition, Koeser et al. (2013a) found no variation in leaf area, shoot dry weight and above ground plant volume of *Solenostemon* 'Florida Sun Jade' when grown in seven biocontainers for 7 weeks. Likewise, Beeks and Evans (2013a) found *C. persicum* grown in 10 biocontainers to have significantly higher shoot dry weight, with the exception of wood fiber containers, and equal to or higher root dry weight relative to plastic containers. These findings provide evidence that biocontainers do not negatively impact plant growth.

**Water Use of Crops**

Biocontainers can have a very significant effect on water use. Containers that are water-permeable have been shown to require shorter irrigation intervals and a significantly greater volume of total irrigation to produce a crop (Beeks and Evans, 2013b; Evans et al., 2010; Koeser et al., 2013b). Crops grown in water-permeable biocontainers can require almost twice as much irrigation as impervious containers (Koeser et al., 2013b). Based on the results of Koeser et al. (2013b), biocontainers can be divided into three categories based on water use (Table 2) that are representative of the results of Evans et al. (2010) and Beeks and Evans (2013b). Koeser et al. (2013b) did not include paper biocontainers in their water use study. Based on the findings of Evans et al. (2010) and Beeks and Evans (2013b), paper biocontainers have low to medium water use.

Table 2. Segregation of biocontainers into water use categories based on the total amount of irrigation required to produce a 5-week-old crop of *Petunia* × *hybrida* 'Yellow Madness' (adapted from Koeser et al., 2013b).

| Water use category[z] | Type of biocontainer |
|---|---|
| Low | Bioplastic, rice hull (solid) |
| Medium | Coconut fiber, peat, rice hull (slotted) |
| High | Manure, rice straw, wood fiber |

[z]The low, medium and high categories used 2.0-2.5 L, 2.5-3.0 L and >3.0 L of irrigation, respectively.

**Algal and Fungal Growth on Containers**

The growth of algae, fungi, and other organisms on the walls of biocontainers can be a serious problem. Manure, peat, and wood fiber biocontainers are most susceptible to the growth of algae and fungi (Table 3) (Beeks and Evans, 2013b; Evans et al., 2010).

Table 3. Results from two studies that measured the growth of algae and fungi on the outer walls of biocontainers.

| Biocontainer | Algae and fungi coverage[z] (%) | |
|---|---|---|
| | Beeks and Evans, 2013b[y] | Evans et al., 2010[x] |
| Peat | 85 | 47 |
| Wood fiber | 80 | 26 |
| Manure | 60 | 2-4 |
| Rice straw | 20 | 2-4 |
| Paper | 10 | 2-4 |
| Coconut fiber | 10 | 0 |
| Bioplastic | 0 | 0 |
| Rice hull | 0 | 0 |

[z] Expressed as a percentage of the total surface area of the container walls that were covered with algae and fungal growth.

[y] Results were recorded after 15 weeks of greenhouse production.

[x] Results were recorded after 6 weeks of greenhouse production.

**Degradation of Plantable Biocontainers in the Field**

A significant advantage of some biocontainers is the ability to plant them without removing the container. This only applies to biocontainers that are classed as plantable; compostable biocontainers do not breakdown readily in the soil and should be removed at planting. The rate of degradation in the soil does vary for different biocontainers (Table 4), but does not seem to negatively impact transplant growth. For instance, Kuehny et al. (2011) observed no reduction in shoot dry weight of *Catharanthus roseus* 'Grape Cooler', *Impatiens walleriana* 'Dazzler Lilac Splash', and *Pelargonium* 'Score Red' when transplanted to landscape beds in coconut fiber, manure, peat, rice straw, and wood fiber containers, with the exception of impatiens grown in manure containers. Nambuthiri and Ingram (2014) found similar results for plants grown in Ellepots and bioplastic sleeves. The lone exception in this study was peat containers. *Ajuga reptans* grown in bioplastic sleeves, plastic, and Ellepot containers covered 26-35% more ground after 15 weeks than in peat containers. Similarly, *Lamium galeobdolon* produced in bioplastic sleeves, plastic, and Ellepot containers, respectively, covered 2.6, 2.4, and 1.9 times more soil surface than in peat containers. Nambuthiri and Ingram (2014) pointed to slow degradation of peat containers as the reason for poor plant growth in that treatment. Although, they also suggested the water wicking nature of peat containers may have contributed to their poor performance, especially since the trial was conducted during a hot and dry summer.

Table 4. The decomposition of five biocontainers 8 weeks post-transplanting at trial sites in Pennsylvania and Louisiana (Evans et al., 2010).

| | Decomposition (%) | |
|---|---|---|
| | Pennsylvania | Louisiana |
| Manure | 62 | 48 |
| Peat | 32 | 10 |
| Rice straw | 28 | 9 |
| Wood fiber | 24 | 2 |
| Coconut fiber | 4 | 1.5 |

**SUMMARY**
Today, a wide range of biocontainers are commercially available for use by nursery growers. Research has shown that there are differences in the performance of biocontainers, which must be taken into account when selecting and using them. The shortcomings of some biocontainers are premature breakdown, higher water use, and unsightly growth of algae and fungi on the container walls. Cost is another drawback of biocontainers but was not reviewed in this paper. Some shortcomings may be resolved by adjusting production practices. For instance, using plastic shuttle trays and a less porous growing medium may reduce water use of permeable pots (Koeser et al., 2013). Research continues to develop new containers, which will result in more innovative biocontainers being commercialized in the future.

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**QUESTIONS AND ANSWERS**

Diego Martinez: Our experience with rice hull pots is they are heavy (about 20% more than conventional, plastic pots) and somewhat brittle.
David Woodske: Thanks for bringing that up. The cost of some of the biocontainers is also an issue.
Jim Conner: Were the peat pots mentioned Jiffypots® or some other type of peat pot?
David Woodske: All of the studies summarized here used Jiffypots.

# Organic Matter in Horticulture — a Report from Scientific Meetings©

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Scientists working in their respective disciplines will meet on a regular basis to exchange notes, report on current projects, and raise questions for future research. These meetings, although technical in nature, are open for all to attend. It is a good place to catch up on the latest thinking from the people most involved on any given topic.

This presentation covers three scientific meetings attended by our company in the past two years. All events were sponsored by the International Society of Horticulture. By coincidence, the common thread was soils and management of organic matter. For this report, an emphasis is placed on information most useful for practical use in horticulture, especially nursery production of trees and shrubs and greenhouse production of vegetables.

## SECOND INTERNATIONAL SYMPOSIUM OF ORGANIC MATTER MANAGEMENT AND COMPOST USE

This event was held in October, 2013 in Santiago, Chile. Attendance was 120 persons from 18 different countries, the largest contingent being from the host country. The four-day symposium included 12 keynote presentations, 58 technical talks, 12 posters, a small trade show and a full day of visits to organic farms using compost.

Composting is the biological decomposition of organic substances under controlled conditions. The large molecules are broken down into simple molecules that can be utilized for plant growth. The finished product is a biologically stable, humus-like product that is rich in microbial flora.

### How Much Compost to Use?

For short-term research projects, scientists apply compost at 20 to 50 dry metric tons per hectare of soil (10 to 25 short tons per acre), incorporated 20-cm deep in the soil profile. On sites where compost is applied repeatedly over many years, application rate of 5 to 10 dry metric tons per hectare (Mg/ha) are sufficient. “Dry” refers to moisture content below 40% by volume.

If used on a volume basis, plant residue compost can be applied 2.5 to 5.0 cm-deep, equivalent to 250 to 510 $m^3 \cdot ha^{-1}$ (or, a 1 to 2-in. layer is equivalent to 135 to 270 cubic yd per acre or 3 to 6 $yd^3$ per 1000 $ft^2$). Lower rates (170 $m^3 \cdot ha^{-1}$) are used where soil quality is good and higher rates (up to 750 $m^3 \cdot ha^{-1}$) on soils with a high content of sand or clay.

Compost made from animal manure should be applied at lower rates as soluble salts (EC) may exceed 1.25 $dS \cdot m^{-1}$ and be injurious when placed in direct contact with plant roots.

Of note, the USA Compost Council suggest aiming for 5% organic matter in the soil to derive most of the benefits (see: <http://compostingcouncil.org/strive-for-5/>).

### Quality Standards for Compost Products

A laboratory program was established in 1998 at Colorado State University to evaluate the precision in laboratory methods for testing of compost. Three times every year, participating laboratories are sent compost materials for testing. Results are compiled and accuracy determined as 95% confidence limit of the median for all lab results.

The “Compost Analysis Program” (CAP) is under the umbrella of the US Composting Council (see: <http://compostingcouncil.org/compost-analysis-proficiency-program/>).

Results indicate the best inter-lab proficiency (measures most reliable) are:

- For inorganic methods: dry matter, total organic carbon, phosphorus, potassium and zinc.

- For biological methods: seed germination, seedling vigor, respirometry.

Results indicate the worst inter-lab proficiency (measures least reliable) are:

- For inorganic methods: EC (an excellent test, but variable from lab to lab), $NO_3$ and $NH_4$.
- For biological method: pathogens (an excellent test, but no standard to measure amounts).

Carbon to nitrogen ratio (C:N) is a useful measure of finished compost quality, but there is variation across laboratories, thus a result of 15 could mean anywhere from 12 to 20.

**Using Soil Microbes for Decontamination of Soil with Hydrocarbons**

Near Mexico City, Mexico, a refinery complex was closed in 1988 after 70 years of operation. Pemex, the largest oil company in the country, was responsible for decontamination of petroleum residues in the soil.

One method of soil remediation was the use of *Pseudomonas putida*, a bacterium with the ability to degrade organic solvents. The bacterium produces natural surfactants which increase the solubility of the pollutants and allow their desorption from the soil. Coffee grains were used as bulking agents as this *Pseudomonas* species can live on pure caffeine and break it into inert components.

Compared to untreated soils, the use of *P. putida* removed 41% of the petroleum hydrocarbons when used alone and up to 61% when used in combination with nitrogen and phosphorus nutrients.

The 55-ha site was opened in 2010 as the Bicentenario Park. A technical paper is found at: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3833165/pdf/bjm-44-595.pdf>.

**Food Safety and Organic Amendments**

Waste products from animals or humans may contain pathogens, such as *Escherichia coli* and *Salmonella*, with a potential to cause human illness. These waste products include animal manure, biosolids, leftovers from meat and fish processing, etc.

Studies indicate high variations in the risk of infection. At one farm, some animals are more susceptible to infection and may shed more pathogens in their waste. Also, virulence varies within a pathogen population. Thus, a problem at one farm may not be a problem under similar conditions at another farm.

Methods to minimize the risks of human pathogens in organic waste include:

- Strict sanitation at the farm, for example, discarding animals identified with infection.
- Compost the materials with hot temperatures, then store 50 to 60 days before using.
- Test the waste products using a large sample size to find spot infection locations.

More information available at: <http://www.ugacfs.org/faculty/erickson.html>.

## 2nd INTERNATIONAL SYMPOSIUM ON ORGANIC GREENHOUSE HORTICULTURE

The event was held in October, 2013 in Avignon, France. About 120 persons attended, including six from Canada.

Soil management is important in organic production. Soiless media, the standard growing medium in conventional greenhouses, is not accepted by many organic certifying agencies. Organic greenhouse production has to be "in natural soil."

**Soil Fertility Management in Organic Greenhouse Crops**

Organic farming is about "feeding the soil not the plant." The goal is to reach equilibrium between the soil capacity and other production factors. Thus, the goal is not to maximize the yields, but higher yields are necessary to recoup the financial investment.

Organic growers need to improve plant fertilization. Incorporation of excess compost at planting is inappropriate as it may result in high salts (EC) near plant roots. Top-dressing after planting is effective if the material is mineralizing rapidly, but may lead to leaching of nutrients in the soil profile.

The answer may be to fine tune the nutrient supply-and-demand via irrigation

scheduling. The grower can use liquid fertilization (compost applied as a liquid after planting) or fertigation (application of fertilizers via the irrigation system).

**Composts to Improve Soil Fertility and Plant Health**
Soil steaming is a fumigation method used in organic production to clean the soil of pathogens. Steaming creates a void in soil biology that may lead to a rapid recolonization by plant pathogens. The problem can be prevented by using compost immediately after steaming, which will recolonize the soil with the beneficial microbes found in the compost.

However, not all composts are created equal. Some composts immobilize nitrogen while others release nitrogen. Composts can also differ in their salt content and some have high pH, leading to iron deficiency in the plant tissue.

**Managing Root-Knot Nematodes in Organic Greenhouses**
In Southern France, 40% of farms are damaged by root-knot nematodes (*Meloidogyne* spp.). Plants most affected are salad winter crops, cucurbits, and spring solonaceous crops. Usual methods to decrease nematode numbers include soil sterilization or steaming, green manure, selection of resistant cultivars, or use of non-host crops.

In controlled trials, solarization plus green manure (sorghum-Sudangrass) lowered the number of root-knot nematodes, but the soil was recolonized by nematodes surviving in deeper soil depths, or in untreated borders, or multiplying after sowing a sensitive crop.

**Influences of Vermicompost as Growth Medium for Seedlings**
Vermicompost is a by-product of specialized worms digesting plant and food residue. It can be used as an alternative growing media in seedling production as it increases water-holding and is rich in NPK compared to peat or field soil.

Trials done in Turkey in organic greenhouse cucumber production found the highest yields and longest plant lengths in growing media made of 2 vermicompost and 3 peat moss (v/v). Second best was a 20:80 mixture of vermicompost and peat moss, compared to the control of 100% peat moss.

**1st WORLD CONGRESS ON THE USE OF BIOSTIMULANTS IN AGRICULTURE**
The event was held in November, 2012 in Strasbourg, France. It was attended by 705 people from 50 countries, a large audience that reflects the growing importance of this topic for academics, growers, manufacturers, and fund investors (looking for upstart companies).

The word "biostimulant" is relatively new. It is meant as a classification for products that regulate and enhance plant physiological processes:

- Biostimulants are not fertilizers, but they improve plant nutrition.
- They are not pesticides, but they protect from disease infection.
- They are not growth regulators, but they stimulate plant growth.

Research on biostimulants is fairly new and the science is not fully developed. Under controlled conditions, the impact is most obvious when the plant is under stress, but it is unclear the products are useful under optimized growing conditions.

**What Are Biostimulants?**
The products are usually derived from natural sources such as seaweed extracts, humic acid, amino acids, plant extracts, soil microorganisms, silicates, trace elements, or manure fermentation. They are complex molecules that may contain plant hormones, leading to multiple and synergestic effects. They are applied in small quantities to influence plant respiration, photosynthesis, nucleic acid synthesis, and nutrient ion uptake.

A report was prepared in 2012 looking at 250 publications in peer-reviewed scientific journals. The author concluded: "Biostimulants are defined more by what they do than by what they are, since the category includes a diversity of substances. They stimulate

growth, but they do much more. Stress tolerance is perhaps the most important benefit". See: <http://ec.europa.eu/enterprise/sectors/chemicals/files/fertilizers/final_report_bio_2012_en.pdf>

**The Science of Biostimulants**

Generally, plants recognize a pathogen attack with a genetic response that leads to production of proteins to increase cell wall thickness, act as antibiotics or physically isolate the pathogen. Commercial products of biostimulants try to mimic one of these pathways.

The effects from biostimulants may not be seen until 4 to 6 weeks after application. There is a drawback: if the plant defense system is activated in absence of stress, too many resources may go to production of defense proteins at the expense of food production.

Biostimulants can be effective in the lab but not in the field. This is because of genetic variability in the host plant, the pathogen adapting rapidly to a modified host, or different environmental conditions. For a grower to adopt a commercial product, it is important the supporting research be based on field experiments.

**Seaweed Extracts as Biostimulants**

Dr. B. Prithiviraj is based at Dalhousie University in Nova Scotia. He is recognized as "the most reputable researcher on the topic" in the world. His work was done with the brown seaweed *Ascophyllum nodosum*. Results published in scientific journals indicate that:

- Seaweed improved growth and vigour of barley seedlings.
- Seaweed induced tolerance to frost stress and salinity stress in the plant *Arabidopsis*.
- Seaweed protected against oxidative and thermal stress in spinach.

**QUESTIONS AND ANSWERS**

Diego Martinez: How much compost do you recommend to be used in making a potting mix? And, since the compost is coming from plant residues, is there a risk of spreading pathogens?

Mario Lanthier: As a general rule, most research work shows that having 25% plant-residue compost in a potting mix is satisfactory. However, there are variations to this that can work depending on the situation. Compost comes in different grades and qualities so making specific recommendations is a challenge. For compost that includes animal manures, the recommended rate goes down to 10 to 15%. With regard to plant pathogens, if the compost is not processed sufficiently, meaning temperatures in the compost pile did not reach the temperature threshold to kill pathogenic microorganisms, you may find viable pathogens in the compost.

# Urban Agriculture: Is it a Fad or the Future?©

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What's the world's biggest crisis?

If you said "energy" you wouldn't necessarily be wrong. Our civilization is built on a supply of cheap and plentiful oil that is no longer cheap or plentiful.

Or, you could have chosen "global warming." Climate change may threaten the very ecosystem on which we rely, yet as political leaders fail to take significant action, our situation seems increasingly bleak.

But, ask the same question on a worldwide basis and a large number would answer differently. The more than 800 million people who are hungry and the 1.4 billion who are overweight and at risk of eating-related diseases, would more than likely have answered that our main problem is "food" (FAO, 2014; WHO, 2014). Even here in Canada, close to 850,000 people are assisted each month by food banks (FBC).

Urban agriculture has emerged in the public eye as a potential antidote to all three of these crises or, at least, a positive step in the campaign to overcome them and guide us onto a greener path. Media accounts feature glowing depictions of the earnest practitioners driving this trend along with their supporters crowding farmers' markets. But media popularity and trendiness are no guarantees for longevity or success. Does urban agriculture really have a major role to play?

In one sense, it already does. Growing crops and raising animals around human dwellings has continued throughout the 10,000-year history of agriculture. Food was integrated into cities from their origin about 5,000 years ago. Only with the rise of industrial agriculture in the 20th Century have large numbers of us been cut off from the presence of growing food. The urban-rural divide in post-war North America, in particular, seemed to turn farming into a remote, little understood and much under-appreciated task. Although it should be mentioned that even while urban centers in North America grew, there were always working farmers in them who continued to grow crops out of the limelight. Urban farming may be trendy but it is hardly new.

Urban agriculture now represents a relatively small portion of the global food market — 15-20%, according to the Resource Centres on Urban Agriculture and Food Security (RUAF). Although we may take some comfort in learning that there are 800 million urban farmers, and that these numbers are growing, it's still a daunting task to integrate local city food into a global food system that seems well-entrenched.

One way to answer the question of whether urban agriculture is relevant is to say that it must be — because the situation is so dire that any addition to our food supply is necessary. The notion that we may never be far away from famine seems all the more daunting with the disruptions in the weather patterns we've learned to rely on to grow crops for generations. A Spanish proverb says, "Civilization and anarchy are only seven meals apart". Climate change may increase these pressures by putting 49 million additional people at risk of hunger by 2020 and 132 million by 2050 (IFAD).

In 2008 when prices of staple foods rose beyond the ability of the poorest to pay, riots broke out in more than twenty countries. Soldiers in the Philippines were called out to guard rice paddies and in Egypt the army was put to work baking bread.

Curiously, this happened during a time of record grain harvests and massive stockpiles. Later, the role of Wall Street speculators was revealed in driving up the price of staples for profit. Certainly big food corporations reaped huge benefits. Even as the United Nations declared "The Year of the Global Food Crisis", the Wall Street Journal reported food giant Cargill's profits rising 86% while pesticide and seed seller Monsanto doubled its earnings (WSJ, 2008). If this all reads like a vague memory at best, it could be because 2008 later became better known as the year of the financial crisis when huge banks and

corporations seemed about to collapse under the weight of their own greed. Somehow political leaders swiftly agreed to solve that crisis.

Against the backdrop of what could be looming global breaking points, new urban farmers are joining the ranks of those determined to grow food in cities for personal use, community enrichment, or as livelihood.

Examples abound of people, many new to farming, who are bucking convention in building a new food system in which much of our produce is produced and consumed in the cities where we live. Those with an optimistic outlook may be encouraged to see this response. It suggests we as a people, even if removed a generation or two from the farm, still know how to grow food. Skills we may have thought were lost forever are being rediscovered and re-invented as more growers and consumers search for alternatives to a flawed industrial food system.

The good news may be that cities can save agriculture. Of course, this is usually put the other way around. Rural farms have fed urban areas for ten thousand years. Perhaps now it's time to repay the favor. Consider the influence cities now wield. The power of the urban consumer is multiplied by millions. The way we shop and eat — and, of course, grow — has a powerful effect all down the food chain. Producers and consumers are already getting together through self-generated strategies such as farmers' markets that bypass the corporate food system. If city folks can understand and embrace a network of farmers growing food that's good for people and for the planet, the tide will turn.

And when it does, city dwellers will start paying back a legacy of support to surrounding rural farms which will, after all, still be needed. Cities can grow a lot more food but not all of it. Nor will they need to if they're in a mutually supportive relationship with their adjacent countryside.

Rural communities in many parts of the world today are in difficult circumstances, abandoned by young people as the industrial model sucks the life out of the traditional family farm. Urban agriculture could help by inspiring innovations in rural farming, including ecologically-sound organic growing techniques. Cities might even supply the workers: traditional farmers are an aging demographic, so the rise of urban nonprofit groups, academic institutions, and individuals training to grow for the future are positive signs.

Why is urban agriculture a key feature of a better, cleaner, greener Earth?

Advantages include:

- Stronger local economies with more local jobs.
- Fresher and more nutritious food.
- Reduced use of fossil fuels.
- Creation of beautiful spaces.
- More citizens reconnecting with their food.
- More effective responses to climate change and emergencies.
- Healthier food that tastes better.

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# Inventory Management©

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Inventory management, while not necessarily a fun topic, is a crucial element in determining a nursery's profitability. If a nursery cannot make a profit, it will soon cease to be able to produce more plants. Therefore, inventory management is very important for our industry.

There are many perils associated with inventory planning. If we make too many of an item, there are extra costs involved. If we make too few of an item, there is lost sales revenue. If the wrong kind of inventory is produced, that is very difficult because producing plants for no market is a very quick path to bankruptcy. There are several methods of determining what and how much to produce, most of which involve guessing (crystal ball, throwing dice, etc).

Our goal at Van Belle Nursery is to get the highest sales AND the highest sell through. These are somewhat contradictory goals. The conflict comes when deciding how many plants to produce. Produce one plant more than you can sell, and that equals waste — wasted resources, time, space, etc. If we could have sold at least one more of an item than we produced, that represents lost opportunity — greater revenue, lower per unit overhead, etc., as well as the possibility your customer could look elsewhere. Often these opposing goals are championed by different silos in an organization, typically production versus sales.

At Van Belle Nursery, we are trying to align the teams with a common goal, and that is profit. Profit is greatest when the maximum sales are achieved AND the highest sell through occurs. Achieving both is a win-win for everyone.

We meet as a sales group to decide the goals, based on history, discussions with customers, and any other marketplace knowledge we have. The principle is to have the decision made as close to the ground as possible. Then, the production teams review it for feasibility. Each division has a cross-section of groups that meet weekly to discuss any problems as well as opportunities. We have a schedule that we follow each year, making any adjustments as we go. With liner sales, we review goals monthly and in containers, at least three times per year — September, January, and June.

Philosophically, we are trying to improve our management through several strategies:

- Produce in as short a time as possible. Turning crops over quickly is good for business.
- Multiple production times, staggered potting cycles so the crop is always fresh.
- Try to pre-sell as much as possible. Since forecasting demand is difficult, knowing demand ahead of planting is very beneficial.
- Outsource where it makes sense. No longer are we trying to make it all ourselves. We are also able to offer so much more than we can produce if we offer other nurseries' material too. Strategic, mutually profitable partnerships are a key element in being able to offer a wide range of products.
- Always have a contingency plan, a "Plan B" for each crop. If we don't have a plan B then we don't produce that crop. The idea is to minimize risk.

# Light-Emitting Diode Lighting for Forest Nursery Seedling Production©

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## INTRODUCTION

Crop lighting is an energy-intensive necessity for nursery production of high-quality native plants and forest tree seedlings. During the winter months (especially in northern USA latitudes) or overcast or cloudy days, the amount of solar radiation reaching greenhouse crops is insufficient resulting in growth cessation, early terminal bud formation, and failure of seedlings to reach target height for outplanting (Tinus, 1995; Lopez and Runkle, 2008). In light of this, nursery growers have added supplemental lighting to increase the daily light integral (DLI), defined as the photosynthetic light received over the course of the day for seedling production (Torres and Lopez, 2010). A wide range of supplemental light sources are used in nurseries to control plant development and manipulate plant quality (Tinus, 1995; Bourget, 2008). However, the problem with most lighting systems, such as high-pressure sodium (HPS) lamps, is that they do not provide the light spectrum that is most efficient for photosynthesis in plants. In addition, because of the huge amount of electrical energy required, using HPS as supplemental lighting, for most reforestation and native plant nurseries, is economically impractical.

The light-emitting diode (LED) is key to improving energy utilization for greenhouse lighting. Light-emitting diodes are solid-state, robust, very long-lived, and are designed to produce the exact light quality that plants can utilize for photosynthesis while using only a fraction of the electricity used by HPS, the current industry standard (Bourget, 2008). Thus, any new lighting technology that significantly reduces electricity consumption for crop lighting while producing top quality seedlings for ecological restoration and conservation efforts has significant benefits to society. The objective of the current study was to examine the effect of supplemental lighting provided by LED and HPS on growth and chlorophyll concentrations of Douglas fir (DF, *Pseudotsuga menziesii)* and Engelmann spruce (ES, *Picea engelmannii*) seedlings from British Columbia, Idaho, and New Mexico (northern, central, and southern populations, respectively).

## MATERIALS AND METHODS

### Plant Materials, Culture, and Growing Conditions

*Pseudotsuga menziesii* (Douglas fir, DF) and *Picea engelmannii* (Engelmann spruce, ES) seeds from three latitudinal sources: 1) British Columbia (BC), 2) Idaho (ID), and 3) New Mexico (NM), were sown in Ray Leach™ pine cells filled with a 1:1 (by volume) of sphagnum peat moss and vermiculite growing medium (40-50% peat, vermiculite, and bark, Sunshine Custom Blend #1, Sun Gro Horticulture, Bellevue, Washington, USA). Each tray held 200 cells and each cell measured 2.5×16 cm (66 cc). Osmocote (15N-9P-12K) 5-6 month controlled release fertilizer (The Scotts Company, Marysville, Ohio, USA) was incorporated into the media, with each seedling receiving 76.23 mg of N. Filled containers were placed onto greenhouse tables (8×3.5 ft) inside a fully-automated, thin-wall, polycarbonate greenhouse at the USDA Forest Service Rocky Mountain Research Station, Moscow, Idaho. The greenhouse air temperature set point was a constant 24°C and average relative humidity (RH) of 65±10%.

The seedlings were grown for 1.5 weeks prior to the supplemental lighting treatment. On 7 Feb. 2014, RL trays with germinated seedlings were assigned at random to eight tables and were comprised of four replications of 200 seedlings of each species growing under a 18-h photoperiod (0600 to 2400 HR) consisting of natural day lengths with

supplemental lighting from LED containing 15% B and 85% R (GreenPower DR/W LED 120-110V, Philips, Texas, USA) and HPS lamps (400 W, Sunlight Supply, Inc. Vancouver, Washington) that delivered a photosynthetic photon flux (PPF) of 70-80 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at plant height as measured with a quantum sensor (LI-COR Biosciences, Lincoln, Nebraska). To avoid light pollution between lighting treatments, one layer of 6-mil-thick black polyethylene plastic (Hummert International, Topeka, Kansas), between two layers of white plastic (curtains) were hung from the upper frame of the greenhouse structure. Irrigation scheduling was determined by gravimetric water content (GWC) and seedlings were irrigated when GWC reached 75% of field capacity.

**Measurements and Data Analysis**

Seedling growth (height and root collar diameter, RCD), shoot and root dry mass (DM) were measured 17 weeks ($n$=12) after supplemental lighting treatment began. Tissue dry mass was obtained after oven-drying at 70°C for 72 h. Total chlorophyll (chl) content ($n$= 12) was measured according to the methods described by Islam et al. (2008). Power use for both HPS lamps and LED lights was measured using a plug power meter (P440Kill A Watt; P3 International, New York, New York). Analysis of variance (ANOVA) was used to examine the effects of light source and seed sources on the measured response variables for each species separately ($\alpha$=0.05) (SAS 9.1 Institute Inc., Cary, North Carolina).

**RESULTS AND DISCUSSION**

Significant differences in seedling height ($P<0.001$), RCD ($P<0.001$), shoot ($P<0.001$) and root ($P<0.001$) DM between supplemental light sources were observed at the end of the experimental period (17 weeks). Seedlings grown under LED had significantly greater growth compared to HPS (Fig. 1). The magnitude of increase in seedling growth and tissue DM to LED was greater in ES compared to DF (Fig. 1).

As expected, the northern (BC) and southern (NM) seed sources of DF and ES were the most and least sensitive to supplemental lighting, respectively. The DF from BC showed the highest growth among the seed sources after the final, 17$^{th}$ week of supplemental lighting. For example, LED lighting caused 15.4, 15.0, and 3.2% increase in height compared with HPS in BC, ID, and NM, respectively at the end of the supplemental lighting period.

Of the studied seed sources (Fig. 1), overall LED-grown seedlings from BC had the greatest growth and tissue DM followed by ID and NM populations. At the end of the experiment, light-emitting diode-grown ES showed 31-35% increase in height for both BC and ID and 15% increase in height for NM than was observed in HPS-grown seedlings. Within the DF and ES, seedling growth and tissue DM decreased latitudinally from BC, through ID, and NM seed sources. Our study reveals the presence of seed sources variation for seedling growth and physiology in response to supplemental light source, which could be interpreted as an adaptive response to the length of the growing season (Clapham et al., 1998).

By the end of the treatment period (Week 17), total chlorophyll (chl, $P<0.0001$) was significantly affected by light source. Light-emitting diode-grown DF and ES seedlings from NM had 28 and 30% increase in total chl compared with DF seedlings grown under HPS, respectively (Fig. 1).

In forest nurseries, provision of light during natural short photoperiods is a common practice for several conifers to prevent seedling dormancy and maintain growth rates to meet target size specifications for outplanting (Landis et al., 1992; Tinus, 1995). The greater growth measures and DM production of the LED-grown plants compared with the HPS-grown seedlings observed in our study correlates with enhanced gas exchange measures (data not shown) and chlorophyll contents. This is in accordance with the findings of Currey and Lopez (2013), where LED treatments containing 85:15 red:blue (similar to the spectral ratio we used in our present study) led to a significantly higher accumulation of DM in *Petunia* compared with HPS lamps.

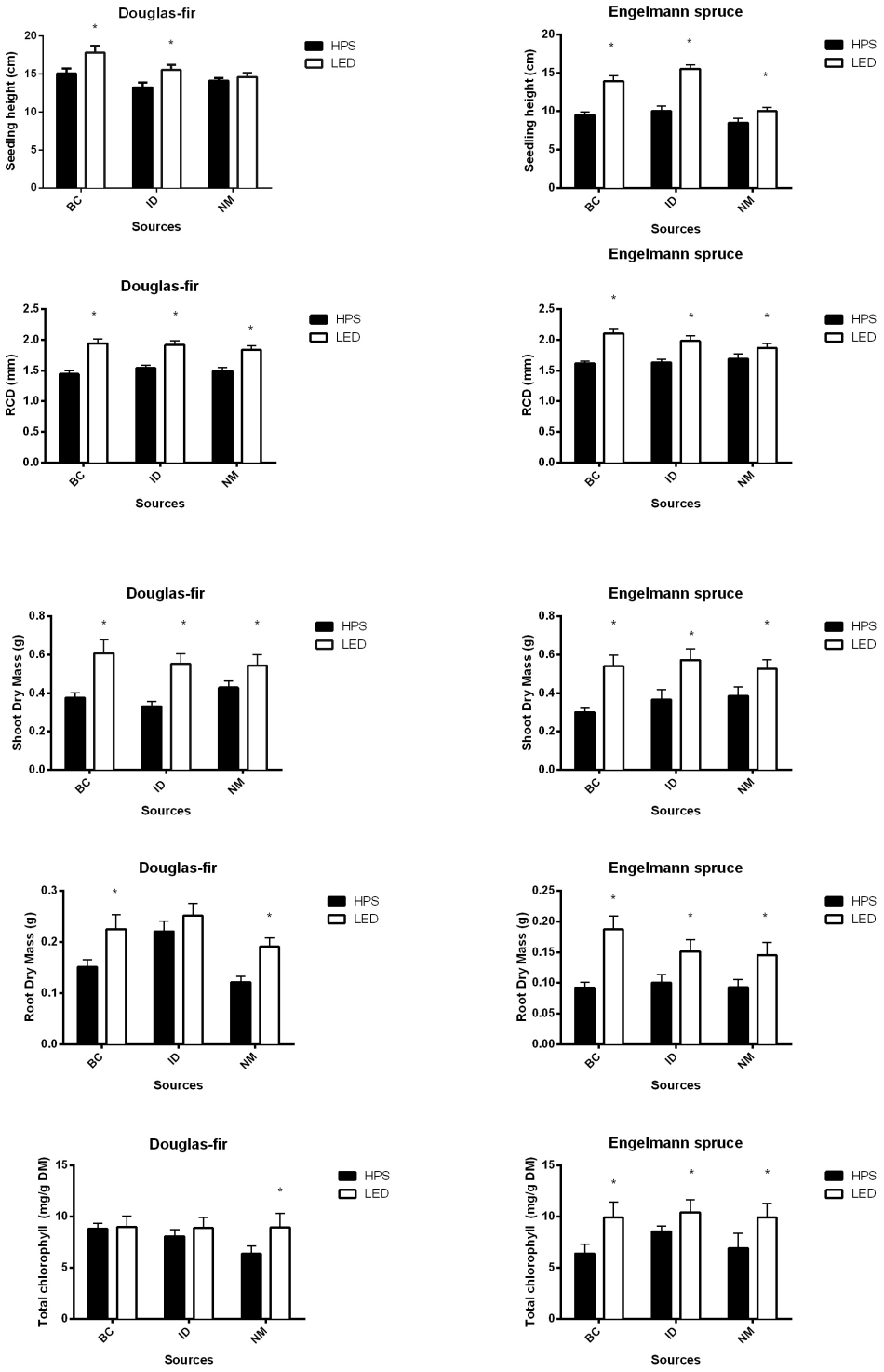


Fig. 1. Seedling height, root collar diameter, tissue DM and total chlorophyll content of LED and HPS-grown DF and ES seedlings from three latitudinal sources. Each data point represents mean ($n$=12) ± SE. LED bars marked with an asterisk above indicate a significant difference from the HPS at P<0.05. Only pairs of means (HPS and LED) at each source are being compared with each other.

In our study, the energy consumption metrics indicated 70% energy savings using LED supplemental lighting technology relative to HPS lamps. Currey and Lopez (2013) demonstrated a 35-40% reduction for LED-grown annual bedding plants (*Impatiens*, *Pelargonium*, and *Petunia*) compared with HPS lamps whereas, Gomez et al. (2013) reported 75% energy savings for tomato (*Solanum lycopersicum*) crops grown under LED lighting.

The significant increase in seedling growth and chlorophyll measures and energy savings in LED compared with HPS highlights the promise of using LED for container seedling production in the northern latitudes particularly during light-limited times of year.

**ACKNOWLEDGEMENT**

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**QUESTIONS AND ANSWERS**

Dharma Sharma: What was the distance from the lights to the crop?

Kent Apostol: Since we had to match the light intensity to the HPS, we kept the lights about 2 ft above the canopy of the crop.

Robert Boada: Was the light bar we saw in the pictures a traveling boom? What is your experience with it?

Kent Apostol: Actually, the growers don't really like the travelling boom. When installed

they work well, but over time they are not very reliable.

Katarzyna Gradowsky: Do you think there is a demand for the design of customized light systems for crops?

Kent Apostol: Yes. When you talk to manufacturers they'll ask you about what kind of quality you want to achieve for your crops and the light intensity you'll want. There are many ways you can customize the light system.

Diego Martinez: How do you determine relative amount of red and blue wavelengths?

Kent Apostol: When we planned this study we found in the literature that 10% of the blue wavelengths are needed for stomatal opening with the rest being used for photosynthesis which is in the red region. There is some flexibility with the relative amounts of red and blue wavelengths needed and this depends on the plant in question.

# Production of Northwest Washington Heirloom Dry Beans (*Phaseolus vulgaris*)©

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Dry bean (*Phaseolus vulgaris*) is a pulse crop that is relatively easy to grow throughout Washington and benefits vegetable crop rotation by breaking disease cycles and providing nitrogen for the following crop. Consumer demand for regionally produced staple crops has opened a market opportunity for dry bean production and niche market cultivars (colored, patterned beans) are sold at local farmers markets for $6-$14 per pound. Small-scale growers have been successfully growing dry beans in northwest Washington for over 100 years; however, it is not clear if these cultivars are suitable for production on a larger scale. The objective for this study was to compare heirloom dry bean cultivars that have been grown in northwest Washington for 20-130 years with standard cultivars (seed grown outside the region) to determine which are more productive in the region. This study was initiated in 2013 and will be repeated in 2014. In May, 14 northwest heirloom dry bean cultivars and 11 standard cultivars were seeded in a replicated field trial at Washington State University Mount Vernon Research Center. Plots were 10-ft long, four rows wide with four replications in a randomized complete block design. Plots were not irrigated, following common practices in the area. Plots were hand harvested 1 Sept. through 1 Oct. In 2013, yield and days to maturity differed significantly among cultivars ($P<.0001$ and $P=0.003$, respectively). Average yield for northwestern heirloom cultivars was 2330 lbs/acre and average days to maturity was 109 days after seeding. In comparison, average yield for standard cultivars was 2298 lbs/acre and the average days to maturity was 114 days. Highest yielding cultivars were 'Eclipse' (standard black, 3094 lbs/acre), 'Lariat' (standard pinto, 3008 lbs/acre), and 'Ireland Creek Annie' (Standard) (standard yellow, 2747 lbs/acre). Northwest heirloom cultivars that were next highest yielding were 'Youngquist' (brown, 2612 lbs/acre), 'Bale' (cranberry, 2617 lbs/acre), and 'Ireland Creek Annie' (NW) (yellow, 2595 lbs/acre). Cultivars with the shortest days to maturity included five northwestern heirloom cultivars: 'Black Coco' (101 days), 'Decker' (101 days), 'Ireland Creek Annie' (NW, 101 days), 'Francis Kring' cranberry (104 days), and 'Rockwell' (107 days). One standard cultivar, 'Ireland Creek Annie' (Standard), also matured early (104 days), while all other entries matured from 101-124 days of seeding. [Editors note: there are two forms of 'Ireland Creek Annie': seeds produced in the northwestern Washington (NW) region and 'Ireland Creek Annie' seeds from seed companies.] Growers in northwestern Washington would benefit most from dry bean cultivars that are early to mature as the onset of rains by late September makes harvest difficult.

# Root Knot Nematodes of the Low Desert Bell Pepper Production©

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The presence and population density of root-knot nematode (*Meloidogyne* spp.) infestation in southern California bell pepper (*Capsicum annuum*) fields was determined by collecting and analyzing soil and root samples at varying periods of bell pepper growth. The earlier samples were virtually free of root-knot nematodes, but the later samples all contained, sometimes very high numbers. Nematodes were all identified as *M. incognita*. A nematode population from one of the fields was multiplied in a greenhouse and used as inoculum for two repeated pot experiments with three susceptible and two resistant bell pepper cultivars. Fruit yields of the susceptible pepper cultivars decreased while that of the resistant peppers was not affected as a result of nematode inoculation. Nematode-induced root galling and nematode multiplication was low, but different between the two resistant cultivars. Root galling and nematode reproduction was much higher on the three susceptible cultivars. One of the susceptible cultivars exhibited tolerance, as yields were not affected by the nematodes, but nematode multiplication was high. It was concluded that *M. incognita* is common in southern California bell pepper production and that resistant cultivars may provide a useful tool in a non-chemical management strategy.

# Late-Fall Propagation of Native Woody Plants in Utah Using Nearing Frames©

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The selection and propagation of superior native plants for use in landscaping has potential for water conservation in the Intermountain West. We examined the use of a Nearing frame system for cutting propagation as a simpler, more economical alternative to a greenhouse system. The rooting of three species [*Cercocarpus ledifolius* var. *intricatus* USU-CLI-3 (CerLed), *Shepherdia* × *utahensis* 'Torrey' (SheUta), and *Berberis aquifolium* var. *repens* (MahRep)] was evaluated in both Nearing frames and a glass greenhouse. Greenhouse conditions were 18/15.5°C D/N, bottom heat 22°C, and natural lighting (85% of ambient PPF at solar noon). Nearing frames were 104 $cm^2$ and 46 cm deep with a plastic-film cover and oriented with the open side facing north. Frames had bottom heat set at 22°C with unheated air temperatures as low as 5°C, and natural lighting (2% of ambient under the plastic).

The MahRep cuttings were selected from a group of seedling source plants while the other two were clonal materials. During the period 30 Oct. to 4 Nov. 2013, 130 terminal hardwood cuttings of each species were collected, sorted for uniformity, wounded with a 1-cm basal scrape, and treated with either 0.1% IBA as Hormodin® 1 (CerLed and SheUta) or 2000 ppm IBA/1000 ppm NAA as Dip'N® Grow (MahRep). Cuttings were stuck in Turface® calcined clay in individual containers (6.5×6.5×8.9 cm) and randomly assigned to one of two greenhouse benches or Nearing frames. Nearing frame cuttings were irrigated daily until Nov. 23 when irrigation was changed to every second day. Greenhouse cuttings were irrigated identically and also misted during the day using a targeted VPD accumulation value of 60 as determined by a Phytotronics® Water Plus VPD mist controller.

On 17 Dec. 2013, cuttings were evaluated for percent rooting, roots per cutting, and length of longest root. The cuttings of CerLed and SheUta had 95 and 98% rooting in the greenhouse with 5 and 11% rooting in the Nearing frame, respectively. Rooting of cuttings of MahRep was much more variable and did not show significant differences between the greenhouse (71%) and the Nearing frame (56%). All species showed significantly increased numbers of roots per rooted cutting in the greenhouse as compared to the Nearing frame (MahRep: 16.1 versus 3.3; CerLed: 10.8 versus 1.7; SheUta: 7.7 versus 2.5). Average length of longest roots (mm) per rooted cutting was (MahRep: 81.6 versus 24.8; CerLed: 83.8 versus 1.5; SheUta: 100.5 versus 12.1). The results indicate that *Cercocarpus* and *Shepherdia* (both of which are full-sun requiring plants) were not well-adapted to Nearing frame propagation system in the fall. In contrast, it appeared that *M. repens*, a more shade-adapted plant, may have potential for propagation in a Nearing frame system.

# Public Horticulture Public Gardens: Is there a Career for You?©

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The poster was prepared to advertise an experimental course on Public Horticulture and Public Gardens. In three sections (Public horticulture sites, Public Gardens, and Turf Management), images of sample landscapes were represented by photographs. Public horticulture sites included such venues as Disney World, Sea World, a shopping mall, an airport garden, college campus, Singapore's Gardens by the Bay, and hotel grounds. Public gardens included the San Francisco Botanical Garden, Longwood Gardens, Fairchild Gardens. Turf sites included baseball and football fields, parks, a golf course, and the sports fields at ESPN — Disney's Wide World of Sports in Orlando, Florida. Examples of careers in these kinds of settings were listed.

# Alerting University Students to Careers in Public Horticulture and Public Gardens©

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With more than 600 public gardens in the USA, career opportunities abound in a diverse range of occupations, from groundskeeper/gardener to horticulturist, arborist, pest management specialist, and fund-raisers, education and interpretation, visitor services, publicist, collections management, librarian, and many levels of administration. Public horticulture opportunities are found in managing the design, installation, and maintenance of landscapes in theme parks; hotel, resort, and municipal grounds; shopping malls; convention centers; cemeteries and memorial parks; sports facilities, golf courses, and parks and recreation facilities. University students are often unaware of these career opportunities because their majors do not shine spotlights on them. The poster illustrated a number of sites where interesting careers can be found under the headings Public Gardens, Public Horticulture, and Turf Management.

# Comparison of Extraction Methods for Testing pH and Electrical Conductivity of Substrates Amended with Different Phosphorus Sources Used to Grow Marigolds©

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Phosphorus (P) is one of the major elements essential for plant growth. Commercial P fertilizers are typically derived from phosphate rock, but the world's supply of mined phosphate is limited. Biosolids and animal manures are rich in P that can be reclaimed to produce struvite (magnesium ammonium phosphate hexahydrate). Struvite has the potential to replace mined fertilizer P in the soilless substrates used for container plant production. Utilizing struvite from wastewater could enhance nutrient use efficiency and sustainability of container production systems.

Electrical conductivity (EC), a measure of soluble salt levels, and pH are two important chemical properties of plant growth substrates that influence plant nutrition and growth. Substrate pH and EC should be tested prior to planting. In order to measure pH and EC, liquid must be extracted from container substrates. There are several commonly used extraction methods and they typically give different results. Using one substrate amended with different P sources, we compared three common methods for liquid extraction: the saturated media extract (SME) method and the 1:2 and the 1:5 dilution by volume methods. There were four replicate samples of each method. This comparison will provide useful information for interpreting pH and EC results.

The container growth substrate was made by thoroughly mixing peat, perlite, and vermiculite (2:1:1, by vol.) along with 1.75 lb/yd$^3$ (1.04 kg·m$^{-3}$) Micromax micronutrient mix and 8 lb/yd$^3$ (4.75 kg·m$^{-3}$) dolomite. This was the no pre-plant P mix (NoP). The other two mixes with pre-plant P were made by incorporating either triple superphosphate [TSP, (0-45-0)] at a rate of 1 lb/yd$^3$ (0.59 kg·m$^{-3}$) or struvite at an equivalent rate into the substrate. Struvite (0-25.4-0) was obtained from the Yakima, Washington municipal wastewater treatment plant (http://www.multiformharvest.com/). In spring 2014, uniform marigold (*Tagetes patula* 'Little Hero Flame') seedlings were transplanted into 0.75 qt (0.7 L) square containers. After transplant, liquid fertilizers containing 200 ppm nitrogen (N) and 200 ppm potassium (K) were applied twice weekly at two rates of P: no P or 100 ppm P. All plants received same amount of N and K. Stem height and the widest and narrowest canopy width were measured. Shoot visual quality was rated.

Results indicated ECs of substrates extracted with the SME method were approximately twice that of the 1:2 dilution method. The 1:2 method ECs were about twice that of the 1:5 dilution method. Measured pH of substrates extracted with the SME was somewhat higher by 0.3 to 0.7 units than pH of the 1:2 or 1:5 methods. Struvite produced marigolds similar to the TSP-incorporated controls in shoot growth and visual quality. The addition of liquid fertilizer with P did not improve plant growth and quality in the struvite and TSP amended substrates. In the NoP substrate post-plant addition of P in liquid form significantly increased growth and quality of the marigold plants. Leaves of marigolds in the NoP substrate without liquid P developed the purple coloration associated with P deficiency in some species. These plants were not salable. Results indicated struvite can be a suitable TSP replacement for container-grown greenhouse plants.

# Economic Profitability of Producing Tomato and Lettuce in Western Washington under Open-Field and High-Tunnel Production Systems©

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Lettuce and tomato are popular warm-season, fresh market vegetable crops grown in western Washington and both are produced in open-field and high-tunnel production systems. The objectives of this study were to examine the economic feasibility of growing lettuce and tomato under both production systems by comparing their economic potential and identifying the main factors affecting profitability within each production system. Data for this study were collected through focus groups of experienced tomato and lettuce growers in western Washington. Costs of production varied by crop and production system. The findings indicated that it was five times more costly to grow lettuce and eight times more costly to grow tomato in a high-tunnel than in the open-field system in western Washington. Labor per square foot of growing area was found to be greater in a high-tunnel operation than in the open field. Total labor cost comprised more than 50% of the total production costs of lettuce and tomato in both the high-tunnel and open-field systems. As a percentage of total production cost, total labor cost was similar in both the high-tunnel and open-field production of lettuce, but higher in high-tunnel tomato production than in open-field tomato production. Tunnel-grown lettuce and tomato had three and four times greater marketable yield compared to field-grown, respectively. Given the base crop yield and average price, it was 43% more profitable to grow lettuce in the open-field than in the high-tunnel system, while in contrast, high-tunnel-grown tomato was three times more profitable than open-field tomato production.

# Cost Estimation of Establishing a Cider Apple Orchard in Western Washington©

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Cider apple production is increasing in Washington State where an estimated 204 acres were produced in 2010 and 256 acres in 2011. Growers are seeking trees to establish new orchards and need information to help determine potential cider orchard profitability and scale of production. Common cider apple cultivars grown include 'Kingston Black', 'Yarlington Mill', 'Brown Snout', 'Dabinett', 'Porter's Perfection', among others. Fewer pesticide inputs are used for cider apples than for dessert apples, as minor surface blemishes are tolerated if yield and internal fruit quality are not affected. In western Washington, cider apple production is not limited by environmentally induced diseases (e.g., scab) which otherwise limit apple production and yields. The objective of this study was to provide information on: 1) The costs of equipment, materials, supplies, and labor required to establish and produce a cider apple orchard in western Washington; and 2) The ranges of price and yield levels at which cider apple production would be a profitable enterprise. The study outlined baseline production assumptions for a 10-acre cider apple orchard based on input from producers, including a productive orchard life of 25 year, with 4 years of establishment and 21 year of full production and crop yield of 5 bins/acre, 12 bins/acre, and 46 bins/acre during Years 3, 4, and thereafter, respectively. Furthermore, the baseline price received for a 900-lb bin of cider apples was $315 ($0.35/lb). Study findings indicated that a producer will start to receive positive net returns after 4 years. For a fully established cider apple orchard, a producer would expect about $1570/acre of net returns based on a yield of 46 bins/acre at $315/bin and the total cost break-even return was estimated at $281/bin ($0.31/lb). The investment in the orchard was estimated to be recovered in about 6.40 years. When changing the price of cider apples while holding all other variables constant, the investment would not be recovered within the productive life of the orchard if the price received for cider apples was $242/bin ($0.27/lb). At higher prices of $270/bin ($0.30/lb), $360/bin ($0.40/lb), and $405/bin ($0.45/lb), the estimated payback periods were 17.83 years, 10.51 years, and 9.1 years, respectively. On the other hand, if crop yields were 10% lower than the base, holding all other variables constant, the cash cost investment would be recovered at 15.88 years. If crop yields were 10% higher than the base, the estimated payback period was 11.09 years. Given the baseline yield, price and production costs, study results showed that it would be economically feasible to produce cider apples in western Washington.

# Evaluating Baby-Leaf Salad Greens for Spring and Fall Production in Northwest Washington©

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Leafy green crops such as lettuce (*Lactuca sativa*), kale (*Brassica oleracea*), arugula (*Eruca vesicaria* syn. *E. sativa*), and mustard greens (*Brassica juncea*) thrive in the cool, humid climate of the maritime Pacific Northwest, particularly in the spring and fall seasons when farmers in the region experience decreased income relative to the main summer growing season. Thus, baby-leaf salad greens are a popular direct-market crop for producers in northwest Washington. To identify salad greens best-suited for shoulder-season production, 10 leafy green salad greens were grown in replicated trials in a randomized-complete-block, split-plot design with three replications at two locations in the fall and spring for 2 years in northwest Washington. Salad greens were evaluated for marketable yield, leaf length, days to harvest, and associated weed pressure. Results from Fall 2012, Spring 2013, and Fall 2013 reveal that brassica crops have a higher yield: days-to-maturity ratio than lettuce, spinach, or beet crops ($P=0.0234$), suggesting that leafy green brassica crops are better suited for baby-leaf salad green cultivation in northwest Washington than lettuce, beet, and spinach. Weed pressure was significantly higher in spring than in fall ($P<0.0001$). The ratio of grams marketable yield per grams weeds harvested differed by taxon in the spring ($P<0.0001$), with komatsuna and bekana mustard greens, joi choi pac choi, 'El Real' spinach, and winter red kale having the lowest weed weight per gram of marketable yield. The ratio of grams marketable yield per grams weeds harvested did not differ between salad green type in the fall. These results suggest that weed management and plant selection for weed competitiveness is more important for spring production of baby-leaf salad greens in northwest Washington than for fall production. In an adjacent study bed flaming was assessed as an organic weed management option for baby-leaf salad greens production. Beds of arugula were planted and assigned randomly to one of three treatments: 1) pre-seeding flaming, 2) post-seeding flaming, and 3) control (no flaming). Stand counts and weed density were recorded for each plot 2 weeks after planting. Flaming was found to significantly decrease the number of weeds in the beds of arugula ($P<0.0001$) and the timing of bed flaming (before seeding and after seeding) did not significantly affect arugula stand counts ($P=0.9956$), indicating that exposure to a flaming treatment did not affect the crop's germination.

# iPhone and iPad Apps for Extension©

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Smartphones and tablets are increasingly being used to supplement or replace laptops and desktop computers. Horticulture-related applications (apps) for extension are becoming more available. These apps deal with such topics as:

- Food safety
- Geographic information systems
- Image enhancement
- Hydroponics
- Insect scouting
- Turfgrass and weed management
- Plant growth regulator calculations
- Creating and scanning QR (quick response) codes
- House plants
- Landscape design
- Plant and tree identification
- Whiteboard
- Agricultural retailers
- Crop protection product information
- Industry trade publications.

Finding apps can be done in several ways:

- Search for apps on a specified subject in the itunes App Store
- Do Internet searches for apps
- Use apps, such as appadvice, Appsfire, apps: Free!, Free App Tracker, FREE appz, and Apps Gone Free, to find apps.

To get apps, downloaded them to a smartphone or tablet, or to a computer and then transfer them to mobile devices. Apps can be downloaded from Apple's App Store using the app called App Store. Or, use the Mac App Store on a Macintosh computer. For my extension work, I have used the app, Zapd, to create mobile web sites. Mobile websites can also be created using Google Sites. E-books are easily created with the app Book Creator. I have given extension talks on QR code generator apps to produce QR codes and using QR code reader apps. News-aggregator apps and RSS Feed apps are used to help find articles, websites, and videos about cutting-edge technological developments in horticulture, which are then distributed to clientele. In conclusion, apps for mobile devices provide horticulturists with useful tools for their work.

# Light Source Effects on Hydroponically Grown Miniature 'Little Gem' Lettuce©

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There is growing concern about food safety, environmental impact, and efficient energy usage in agricultural production systems. Producing lettuce under artificial lighting can be a solution addressing these concerns. Light-emitting diodes (LEDs) offer the advantage of a narrow light spectrum, low power consumption, and little heat production. Light emitting plasma offer high light intensity, sun-like full spectrum, and long life. The objective of this study was to determine the effects of different light sources on the growth of miniature 'Little Gem' romaine lettuce in a non-circulating hydroponic system. Lettuce seedlings were started in Oasis® cubes that were transferred to net pots and put in 1.9-L containers containing a hydroponic nutrient solution. The solution was Hydro-Gardens' Hobby Formula 10-8-22 hydroponic fertilizer with added magnesium sulfate (9.8% Mg). The lettuce was grown in a lab under different light treatments: red plus blue plus white LEDs, light emitting plasma (LEP), and high-output T-5 fluorescent lights. The light level was 253.7 $\mu mol \cdot m^{-2} \cdot s^{-1}$ with an air temperature of 20.9°C. At the end of the study, the fluorescent lights resulted in significantly greater plant height than the LED and LEP treatments. There was no significant difference in plant height between the LED and LEP treatments. Percent partitioning of dry weight to roots was greater with the LEP treatment than the fluorescent lights treatment. There was no significant difference in percent partitioning of dry weight to roots between the LEP and the LED treatments and between the LED and the fluorescent lights treatments. There were no significant differences in shoot dry weight, root dry weight, total dry weight, and percent partitioning or dry weight to shoots among the treatments. In conclusion, LEDs and LEP may provide alternative lighting sources for miniature lettuce.

# Evaluation of Watermelon Rootstocks for Resistance to Verticillium Wilt in Northwestern Washington, USA©

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Watermelon (*Citrullus lanatus*) grafting is common in areas of the world where production is affected by soil-borne diseases. One serious disease is verticillium wilt. The pathogen, *Verticillium dahliae*, has a wide host range and produces microsclerotia (long-lived resting structures). Verticillium wilt has the potential to become increasingly problematic for watermelon growers because watermelon does not have known resistance and chemical control options are limited. This study investigated the reactions of 11 non-grafted, commercially available watermelon rootstocks and 14 non-grafted, potential watermelon rootstocks to *V. dahliae* in a field naturally infested with the pathogen. Entries were obtained from various seed companies as well as the U.S. National Plant Germplasm System (NPGS). One grafted entry was also included, as well as two non-grafted watermelon cultivars that served as controls. The experiment was arranged as a Randomized Complete Block design with three replications. Plants were rated visually for verticillium wilt severity using classic symptomology including chlorosis, necrosis (in the form of V-shaped lesions) and wilting. Ratings began in August and continued through September of 2013. Severity was reported as the percentage of each plot displaying verticillium wilt symptoms and was plotted over time so that the area under disease progress curve (AUDPC) value could be calculated. Due to staggered planting dates among entries, the AUDPC values were converted to relative area under disease progress curve (RAUDPC) values. All entries displayed at least some verticillium wilt severity. The mean of all RAUDPC values was 6.56 and there was a significant difference among entries (P=0.0001). The non-grafted watermelon controls 'Sugar Baby' and 'Crimson Sweet' had the highest RAUDPC values (26.80 and 15.62, respectively), but did not differ significantly from 'Marvel', PI 642045 'Speckled Swan' or PI 368638 'Mesna'. 'Crimson Sweet' grafted onto 'Shintoza' and PI 419060 had the lowest RAUDPC values (1.46 and 2.03, respectively), but did not differ significantly from eight other entries. There was no significant difference between the RAUDPC values of germplasm accessions and commercial rootstock cultivars. At season's end, entries were assayed for the presence or absence of *Verticillium* spp. *Verticillium* spp. were observed on all but two entries (PI 181913 and 'Crimson Sweet' grafted onto 'Shintoza') and isolated from 18 entries. Eight isolates were sent to a lab for species identification. Three of the isolates were identified a *V. dahliae*, while the other five were identified as *V. isaacii*. Results from this study show that the rootstocks have greater tolerance to Verticillium wilt than watermelon, suggesting that grafting may be used as a successful management strategy for controlling verticillium wilt in Washington State.

# Effect of a Soil Conditioner FFC-Ace© on Growth of Sugarcane and Quality of Soil Penetration Water©

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## INTRODUCTION

Since 1984, at Akatsuka Garden Company we have focused our attention on the behavior of certain ions, especially the iron ions in water and interactions of water molecules with them. We have continued research on various solutions to not only accelerate plant growth but also activate physiological functions of plants. Based on this research, we have developed FFC materials such as "FFC-Ceramics" (a water improvement device), "FFC-Ace" (a soil conditioner) and others. In addition, many agricultural producers in Japan have been utilizing FFC materials to rejuvenate plants and increase profits. Those producers have also explored many other original methods for using FFC materials, and consequently found good ways to fit them into their actual production sites. As a result, they have obtained many advantages over years of use, such as, productivity enhancement, cost reduction, decreased amount of agricultural chemicals required among others. In addition, it has been reported that "FFC-Ace" enhances the growth of plants under laboratory conditions while improving disease resistance, and drought and salt stress tolerance of plants (Ichikawa et al., 2013; Fujita et al., 2010; Hasegawa et al., 2006; Konkol et al., 2012; Shiraishi et al., 2010; Toyoda et al., 2010). In this short paper, we will report on a portion of the results on the effectiveness of FFC-Ace applied to agricultural products under field conditions.

We researched the effects of FFC-Ace on growth and yield of sugar cane in Miyakojima city, Okinawa Prefecture. In addition, Miyakojima City has a major eutrophication problem that groundwater is polluted mainly by chemical fertilizer and livestock manure. Therefore we also examined the influence of the FFC-Ace on leaching of nitrate nitrogen, which is in fertilizer, from soil.

## MATERIALS AND METHODS

### Field Experiments on Growth of Sugarcane

The examination was carried out over approximately 14 months in a sugarcane field (cultivar: Ni21) from 10 Oct. 2009 to 26 Jan. 2011. The size of a test plot was 56 $m^2$ (5.6×10.0 m). Details of the examination are shown in Table 1. The cultivation method, such as fertilizer and pesticide application, and weeding followed the precedent. Ten plants were randomly sampled from each test plot to measure the growth and the yield of the sugarcane.

Table 1. Test plot name and application amounts on research of growth and the yield of sugarcane.

| Test plot | Application amounts |
|---|---|
| Control | Standard amount of chemical fertilizer only |
| FFC-Ace | Standard amount of chemical fertilizer and 150 kg per 10 a of FFC-Ace |

**Research of Soil Penetration Water**

The size of a test plot was 56 $m^2$ (5.6×10.0 m). Details of the examination were shown in Table 2. Soil penetration water was collected into a polyethylene tank through a pipe connected to the Rohto type lysimeter (0.98 $m^2$ in area: 0.7×1.4 m, no wall) buried to 60 cm in depth from ground level (Figs. 1 and 2). We measured the amount of penetration water, cation and anion concentration, electric conductivity, pH, and also measured concentration of inorganic nitrogen in the water.

Table 2. Test plot name and application amounts on research of soil penetration water.

| Test plot | Application amounts |
|---|---|
| Control | 4 tons per 10 acres of compost and standard amount of chemical fertilizer |
| FFC-Ace | 4 tons per 10 acres of compost, standard amount of chemical fertilizer and 150 kg per 10 a of FFC-Ace |

Fig. 1. The Rohto-type lysimeter was buried 60 cm depth in the sugarcane field.

Fig. 2. Polyethylene tanks along the sugarcane field to collect soil penetration water.

**RESULTS AND DISCUSSION**

The crop index of FFC-Ace plots, which multiplied Brix sugar content by a unit area yield (t/10 acres), was compared with that of the controls to evaluate profitability of the FFC-Ace application. The crop index of the FFC-Ace plot section increased approximately 1.3 times from that of the control plot (Fig. 3). It compared the ratio of the amount of nitrate nitrogen in soil penetration water collected from the FFC-Ace plot with that of the control. The ratio of nitrate nitrogen in the FFC-Ace plot was 21.1%, and that of the control was 34.82%. There was clearly a lower ratio of nitrate nitrogen in the FFC-Ace plot than that of the control. The results show that the application of FFC-Ace to sugarcane cultivation is effective for increasing profit and restraint of elution of fertilizer components. In an area, such as Miyakojima, where eutrophication by nitrate nitrogen derived from agriculture is one of the environmental problems, it demonstrates that the application of FFC-Ace enables both an increase in crop productivity and reduction of environmental load.

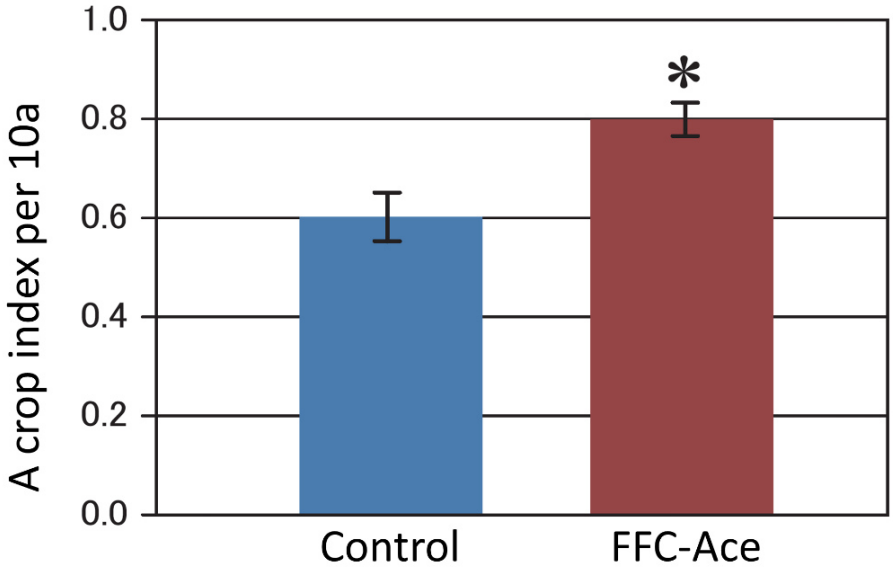


Fig. 3. Comparison of a crop index (multiplied sugar content in sugarcane by the yield). *$p<0.05$.

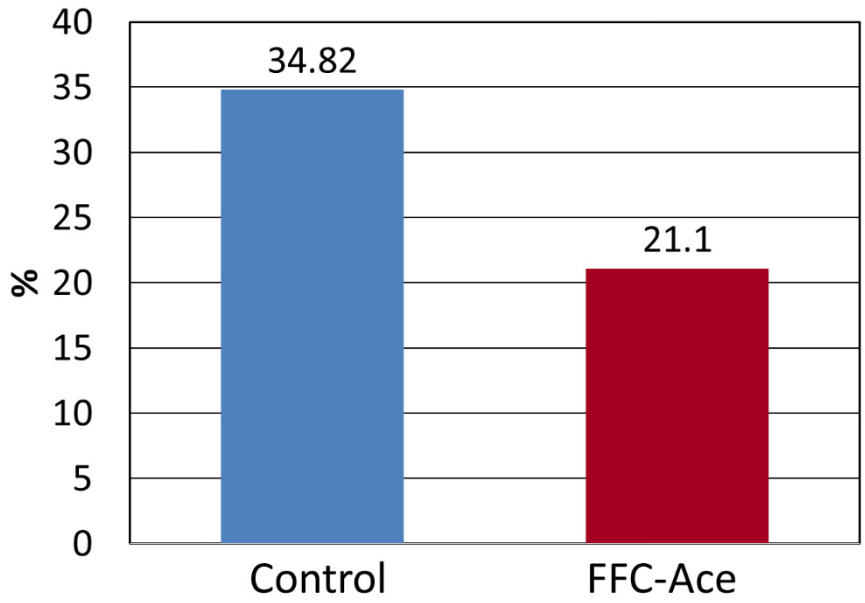


Fig. 4. A ratio of nitrate nitrogen volume in soil penetration water to total nitrogen volume of applied fertilizer.

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# Rooting of Cuttings and Growth of Nursery Stocks of MKR1, a Dwarfing Rootstock for Kaki©

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## INTRODUCTION

Miyazaki Kaki Rootstock No. 1 (MKR1), formerly named Rootstock-b and OD-1, are promising dwarfing rootstock for kaki (*Diospyros kaki* Thunb.). We previously showed the results of cutting propagation of MKR1 and growth of 'Fuyu' and 'Hiratanenashi' trees grafted on MKR1 (Tetsumura et al., 2011, 2012, 2013). In Japan an evaluation test of kaki rootstocks is planned and 17 prefectural research stations will participate in the test. In the test, other promising kaki dwarfing rootstocks such as 'Shizukadai 1 gou', 'Shizukadai 2 gou', and SH-1 will be provided as well as MKR1. However, timing of rooting of MKR1 cuttings and growth of MKR1 nursery stocks soon after grafting have not been reported yet. Hence, the objective of this study is to investigate the above-mentioned characteristics of MKR1 and to discuss future experiments which are necessary for commercial use of the kaki dwarfing rootstocks.

## MATERIALS AND METHODS

### Rooting of Cuttings

Root-suckers of MKR1, Rootstock-a, KD-3, and 'Jiro', and shoots of MKR1 hedges were collected on mid-June in 2012, 2013, and 2014. Single-node stem cuttings with one leaf and one bud were prepared from the root-suckers and the shoots, 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 D.C.), and then placed under a vaporized aluminum netting in a propagation frame covered with plastic film. The propagation frame was intermittently misted (30-s mist and 15-min stop in the daytime) and was ventilated with fans when the ambient air reached 38°C. A data logger (TR-72i, T&D Corporation, Japan) measured the temperature in the frame. Twenty-four cuttings per cutting source were used. When the roots were visible at the bottom of the pot, 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). The pots were filled with Metro-Mix® 360 and were placed in a propagation frame covered with plastic film but opened at the sides. The percentages of survival of rooted cuttings were investigated in April of the following year.

### Growth of Nursery Stocks

Both the rooted MKR1 cuttings and seedlings of 'Yamagaki' (*D. kaki*) which grew for one growing season were planted singly in a plastic pot (CSM-180 L, 3.5l, Minamide Inc., Japan) which was filled with a mixture of Andosol (volcanic tephra) and Boratsuchi (volcanic tuff) (1:1, v/v). On 21 Mar. 2013, 'Fuyu', 'Hiratanenashi', and 'Taishuu' were veneer-grafted on the 1-year-old rootstocks. The percentages of graft establishment and the growth of nursery stocks were investigated. Eight MKR rootstocks and four seedling rootstocks per cultivar were used.

## RESULTS AND DISCUSSION

### Rooting of Cuttings

In 2012, some of the cuttings from MKR1 root-suckers started rooting from 1 month after the planting and all of the cuttings had rooted by the end of 2 month after the planting (Fig. 1). Similar tendencies were observed in 2013 and 2014. The cuttings from root suckers of Rootstock-a, KD-3, and 'Jiro' rooted well and the terminations of rooting were between 2 and 3 months after the planting. Although the rooting speed of the cuttings from MKR1 hedges was slower than that from MKR1 root-suckers, rooting of the cuttings from MKR1 hedges occurred even when the average daily temperature in the propagation frame decreased 20°C. Such root growth might relate to earlier bud break of the young kaki trees grafted on MKR1 rootstocks in spring than that on *D. kaki* seedlings. The survival percentages of the rooted cuttings from MKR1 hedges were lower (2013, 41%; 2014, 35%), whereas those from the root suckers were higher (MKR1, 100 and 96%; Rootstock-a, 90 and 71%; KD-3, 91 and 60%; 'Jiro', 100 and 90%). These results were the same as the previous ones, which suggested that the cuttings should be collected from root-suckers (Tetsumura et al., 2011).

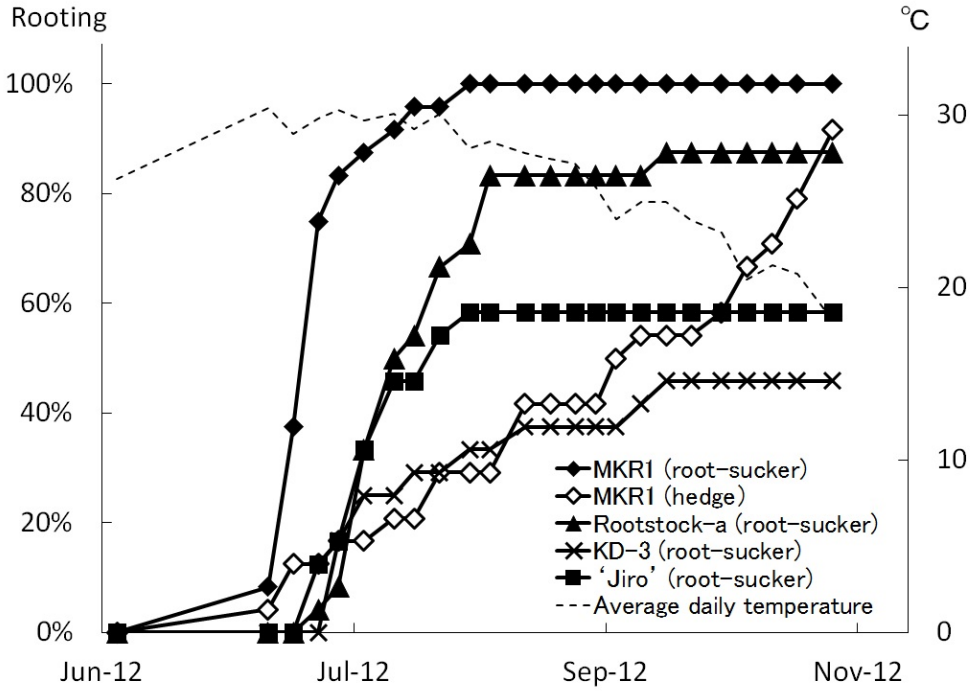


Fig. 1. Rooting percentages of the cuttings and average daily temperature in the propagation frame in 2012.

### Growth of Nursery Stocks

The greatest difference in the percentage of graft establishment between the rootstocks was observed in 'Taishuu' (Table 1). Although 60% of the shoots of 'Taishuu' on MKR1 showed secondary growth like 'Fuyu' and 'Hiratanenashi' on MKR1, the total shoot length of 'Taishuu' on MKR1 was almost the same as 'Taishuu' on seedlings, which showed that only 25% of the shoots occurred as secondary growth. These results imply that there is a graft-incompatibility between 'Taishuu' and MKR1. However, the quality of the fruit produced by 6-year-old 'Taishuu' trees on MKR1, which were dwarfed, was as well or better than that on seedling (Tetsumura et al., pers. commun.). Moreover, the yield efficiency, such as yield per canopy volume, of 'Taishuu' trees on MKR1 was the same as that on seedling. Hence, productivity of dwarfed 'Taishuu' trees seemed not to relate to the

graft-incompatibility. The growth of nursery stocks of 'Fuyu' and 'Hiratanenashi' on MKR1 was better than that on seedling (Table 1), although the growth of trees of both cultivars on MKR1 are expected to be dwarfed (Tetsumura et al., 2010). In conclusion, the growth characteristics of kaki trees on MKR1 varied with the scion cultivar and will varied with age. Hence, like dwarfing rootstocks of other fruit trees, the long-term field evaluation of MKR1 rootstocks will be needed in each combination of scion cultivar.

**ACKNOWLEDGEMENTS**
This work was partly conducted under the "educational grant aid for Miyazaki-oriented" by University of Miyazaki for fiscal 2014 in "Center of Community (COC) Project" supported by the Ministry of Education, Culture, Sports, Science & Technology in Japan.

Table 1. Graft establishment and growth of 'Fuyu', 'Hiratanenashi', and 'Taishuu' nursery stocks on rootstocks of *Diospyros kaki* seedling and MKR1.

| Cultivar | Rootstock | Graft establishment (%) | Total shoot length (cm) | Leaves (no) | Rate of secondary shoot occurrence (%) |
|---|---|---|---|---|---|
| Fuyu | Seedling | 75 | 17.3 | 8.0 | 0 |
| | MKR1 | 75 | 38.3 | 13.5 | 67 |
| Jiro | Seedling | 75 | 19.3 | 8.0 | 0 |
| | MKR1 | 88 | 34.1 | 16.3 | 57 |
| Taishuu | Seedling | 100 | 17.3 | 6.3 | 25 |
| | MKR1 | 63 | 14.6 | 5.5 | 60 |

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# Effects of Plant Growth Regulators on the Vegetative Growth of Pitaya Cladodes©

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## INTRODUCTION

Pitaya (*Hylocereus undatus* Britt & Rose) is a climbing cactus that is cultivated across a range of countries, including Vietnam and Nicaragua (Merten, 2003). In the Japanese archipelago, pitaya cultivation has been largely concentrated in the subtropical landscape of Okinawa Prefecture. However, many forms grown in the domestic warm region are cold tolerant and do not require greenhouse heating to prevent frost damage. Fumuro et al. (2007) and Fumuro and Sakurai (2013) reported that pitaya cultivation was possible on the Kinki University experiment farm located in Yuasa-cho, Wakayama Prefecture where daily minimum temperatures fell to about -4°C on four or five occasions during winter.

Pitaya forms flower buds on the cladodes **(**flattened leaf-like stems) when plants stop growing, but not during the period of elongation. Cladodes grow vigorously when young; if their growth is suppressed, flowering and yield increase incrementally. However, the cladode elongation rate declines during aging and yields are reduced in consequence.

Cultivated tree vigor is frequently controlled by application of plant growth regulators. Paclobutrazol, daminozide, and other agents are used as dwarfing agents, while gibberellin and other bioactive molecules are applied to promote growth. Little is known of the effects of these regulators on the vegetative growth of pitaya. Consequently, this study was conducted to measure the effects of growth regulators on pitaya cladode growth either through spraying plants or by application to the soil medium.

## MATERIALS AND METHODS

Experiments were performed in 2006 and 2007 using rooted cuttings growing in pots (13.5 cm in diameter, 11 cm in height) held in a greenhouse located on the Kinki University experimental farm. The cladode cuttings were collected from 4- and 5-year-old plants growing in a greenhouse. Each cutting was trimmed to a 12-cm length, sprayed with a solution of 500 ppm benomyl and 150 ppm streptomycin, and placed in a shaded, well-ventilated location for 48 h to allow healing of the wound. The bases of cuttings were dipped into a 2000 ppm solution of NAA (1-naphtaleneacetic acid; Wako Pure Chemical Industries, Osaka, Japan) for 10 s to promote rooting. Each cutting was planted to a depth of 4 cm in a polyethylene pot (10.5 cm in diameter, 9.0 cm in height) filled with a soil mixture (2 mountain sand, 1 peat moss, and 1 vermiculite (by volume) and held them in a greenhouse under 50% light shading. The plants were watered once a day and applied 150 ml of liquid fertilizer ($N:P_2O_5:K$ in concentrations of 120:200:100 ppm) to each cutting once per month.

### Experiment 1. The Effects of Gibberellin Solution Spraying on Cladode Growth

Cladode plants were used 3 months after initial potting when growth had begun. Ten plants were sprayed with a 10 ppm gibberellin (GA) solution (Gibberellin, Kyowa-Funmatsu, Kyowa-Hakko-Bio, Tokyo, Japan) three times (1 Sept., 10 Sept., and 20 Sept.). Ten untreated plants were used as controls.

The lengths of new cladodes were measured each month, and recorded their weights on 14 Feb.

### Experiment 2. The Effects of Ethephon and Paclobutrazol Solution Spraying on Cladode Growth

Rooted cuttings with new elongating cladodes were used 2 months after the initial potting. New cladodes were hand sprayed twice with 500 or 1000 ppm solutions of ethephon (Nissan-Esureru 10; Nissan Chemical Industries, Tokyo, Japan) combined with 1000 or

2000 ppm solutions of paclobutrazol (Bonzai-Furoaburu, Syngenta Japan, Tokyo, Japan) on 23 July and 23 Aug. 15 replicate plants were used in the treatments and controls.

The lengths of new and old cladodes were measured on 10 Nov. and then separated them into new cladodes, old cladodes, and roots; then their fresh weights were measured before drying to constant dry weight in an oven at 75 $^{o}$C. The weights were measured after drying. The summed lengths and weights of new cladodes produced by each plant were obtained.

**Experiment 3. The Effect on Cladode Growth of a Natural-Type Abscisic Acid (ABA) Applied to the Soil**

Rooted cuttings with no new cladodes were used 2 months after the initial potting. An 120 ml solution of 1, 10, or 100 ppm of the natural-type (S)-(+)-abscisic acid (Miyobi; Baru-Kikaku, Ichinomiya, Japan) were applied to the soil in each pot on five occasions (23 July, 7 Aug., 1 Sept., 3 Oct., and 6 Nov.). Untreated controls were also established. Controls and treatments were replicated 15 fold. The numbers and lengths of new cladodes were measured each month.

**Experiment 4. The Effect on Cladode Growth of CPPU, BA, NAA, and Daminozide Applied to the Soil**

Rooted cuttings with elongating new cladodes were used 6 months after the initial potting. An 120-ml solution containing 2 ppm CPPU [N-(2-Chloro-4-pyridyl) -N-phenylurea] (Fulmet; Kyowa-Hakko-Bio, Tokyo, Japan), 200 ppm BA (6-benzylaminopurine; Wako Pure Chemical Industries, Osaka, Japan), and 200 ppm NAA, or 500 ppm daminozide (Bi-Nain-Suiyozai 80; Nisso Green, Tokyo, Japan) were applied to the soil of each pot on five occasions (28 April, 28 May, 28 June, 30 July and 28 Aug.). Untreated controls were also established. Controls and treatments were replicated 12-fold.

All response variables (variables were identical to those in Expt. 2) were measured on 25 Nov.

## RESULTS AND DISCUSSION

**Experiment 1. The Effects of Gibberellin Solution Spraying on Cladode Growth**

Gibberellin is registered as an agricultural chemical that maintains vigor in satsuma mandarin and other fruit trees, and promotes growth in some vegetables (Food and Agricultural Materials Inspection Center, Japan. 2014). Gibberellin spraying promoted elongation of new cladodes (Fig. 1), but did not influence their fresh weights (Fig. 2), suggesting that the treatment did not affect the thickening of cladode.

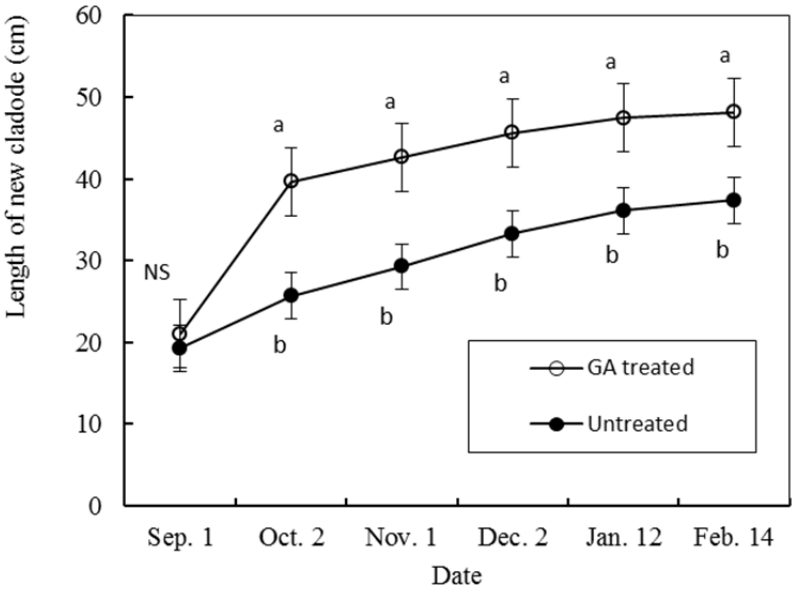


Fig. 1. The effect of spraying with gibberellin solution on the elongation of new cladodes. Vertical bars represent ± SE. Values followed by same letter and NS are not significantly different ($P$<0.05; $t$-test).

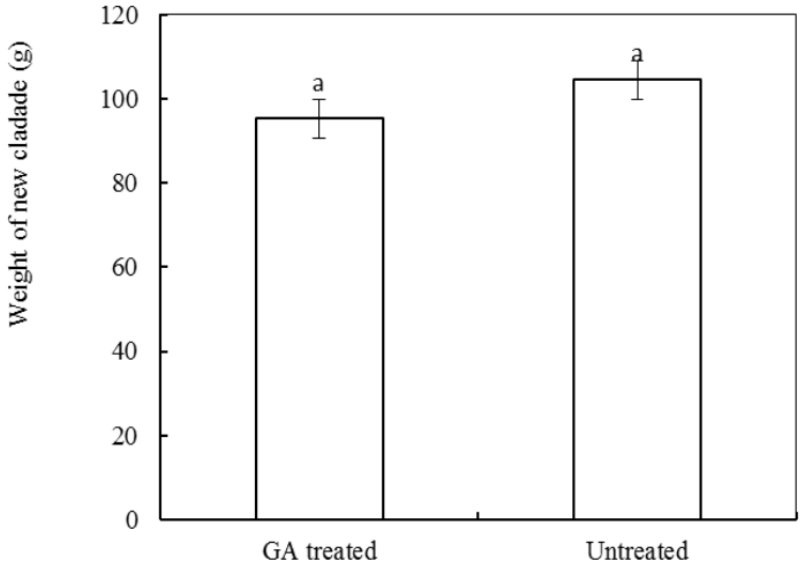


Fig. 2. The effect of spraying with gibberellin solution on the fresh weights of new cladodes. Vertical bars represent ± SE. Values followed by the same letter is not significantly different ($P$<0.05; $t$-test).

**Experiment 2. The Effects of Ethephon and Paclobutrazol Solution Spraying on Cladode Growth**

The lengths of new cladodes and the fresh and dry weights of new cladodes and roots were reduced in ethephon-treated plants in comparison with controls (Fig. 3, Table 1). No spray concentration effects were detected. Paclobutrazol had no significant effects on any of the response variables.

Ethephon is registered as an agricultural chemical that inhibits internode elongation in barley and wheat, and prevents excessive flower and berry abscission in 'Kyoho' grapes through inhibition of shoot elongation. Pacrobutrazol is registered as a chemical that

inhibits shoot elongation in fruit trees, such as peach. Although expected effects of ethephon in our experiment were observed, this was not the case for pacrobutrazol. This disparity should be examined in future trials.

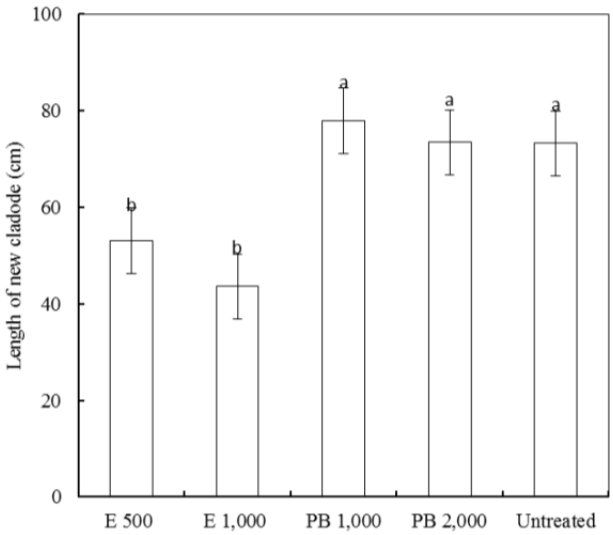


Fig. 3. The effect of spraying with ethephon and paclobutrazol solution on the elongation of new cladodes. Vertical bars represent ± SE. Values followed by the same letter are not significantly different ($P$<0.05; Tukey-Kramer multiple range test).

Table 1. The effect of spraying new cladodes with ethephon and paclobutrazol solution on the lengths of new cladodes.

| | Flesh weight (g) | | | | Dry weight (g) | | | |
|---|---|---|---|---|---|---|---|---|
| | Old cladode | New cladode | Root | Total | Old cladode | New cladode | Root | Total |
| E 500 | 51.7 a[z] | 88.2 b | 3.0 b | 142.9 b | 5.7 a | 8.8 bc | 0.6 b | 15.1 b |
| E 1000 | 64.1 a | 77.5 b | 2.9 b | 144.5 b | 7.0 a | 7.0 c | 0.6 b | 14.6 b |
| PB 1000 | 62.8 a | 122.1 a | 4.0 a | 188.9 a | 6.4 a | 12.2 a | 0.8 a | 19.4 a |
| PB 2000 | 50.8 a | 111.9 a | 3.7 ab | 166.4 ab | 5.5 a | 10.4 ab | 0.8 a | 16.7 ab |
| Untreated | 62.9 a | 121.5 a | 4.2 a | 188.6 a | 7.0 a | 12.0 a | 0.9 a | 19.9 a |

[z]Values followed by same letter indicate not significantly differ ($P$<0.05) according to the Tukey-Kramer's multiple range test.

**Experiment 3. The Effect on Cladode Growth of a Natural Type Abscisic Acid (ABA) Applied to the Soil**

The effect of ABA on cladode growth in pitaya was examined because this phytohormone promotes rooting of strawberry runners (Saito et al., 2008). ABA did not affect the elongation of new cladodes (data not shown), but the higher the concentration of ABA the sprouting rate of new cladodes tended to reduce 1 month after the first soil application (Fig. 4). New cladode sprouting occurred on all plants with or without treatment 2 months after of the first soil application.

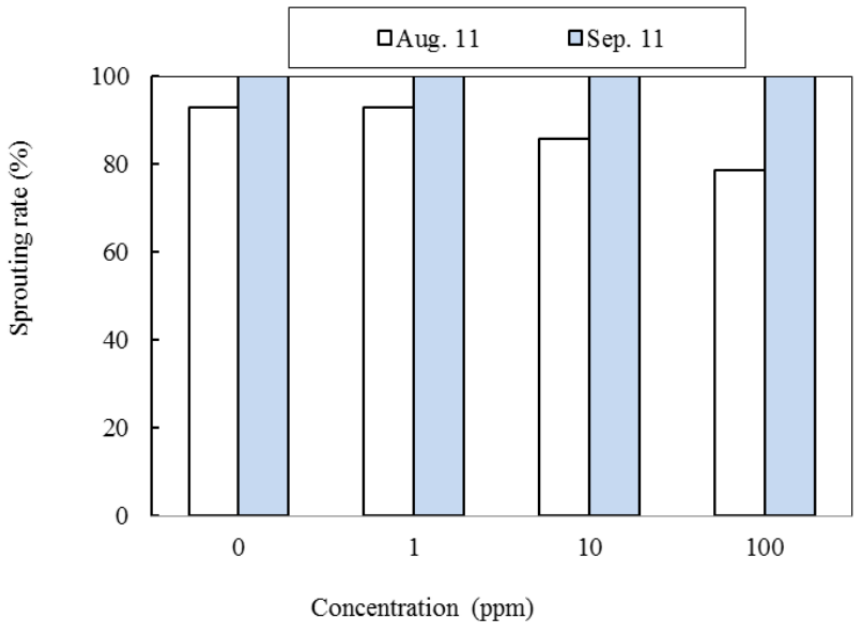


Fig. 4. The effect of treatment of soil with abscisic acid on cladode sprouting growth.

**Experiment 4. The Effect on Cladode Growth of CPPU, BA, NAA, and Daminozide Applied to the Soil**

The application of NAA to the soil reduced the lengths and fresh and dry weights of new cladodes (Fig. 5, Table 2). Effects on roots were not clear. CPPU, BA, and daminozide applications to the soil did not affect cladode growth.

NAA is one of the plant growth regulators with auxin-like activity; it also functions as a fruit-thinning agent for satsuma mandarin and other fruit trees. It is registered as an elongation inhibitor of summer and autumn shoots. Our experimental results were consistant with these general effects.

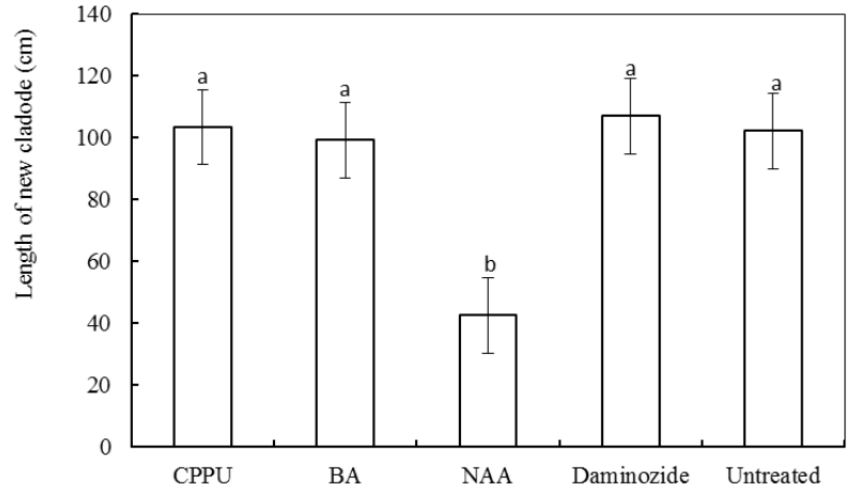


Fig. 5. The effect of treatment of soil with CPPU, BA, NAA and daminozide on the elongation of new cladodes. Vertical bars represent ± SE. Values followed by the same letter are not significantly different ($P$<0.05; Tukey-Kramer multiple range test).

Table 2. The effect of treating soil with CPPU, BA, NAA and daminozide on cladode growth.

| | Flesh weight (g) | | | | Dry weight (g) | | | |
|---|---|---|---|---|---|---|---|---|
| | Old cladode | New cladode | Root | Total | Old cladode | New cladode | Root | Total |
| CPPU | 44.5 b[z] | 228.6 a | 18.2 a | 291.3 b | 8.2 a | 34.3 a | 3.7 a | 46.2 a |
| BA | 51.1 ab | 260.8 a | 16.5 a | 328.4 ab | 9.2 a | 37.7 a | 3.3 a | 50.2 a |
| NAA | 63.8 a | 143.3 b | 10.3 b | 217.4 c | 9.9 a | 21.0 b | 2.1 b | 33.0 b |
| Daminozide | 60.0 a | 262.5 a | 19.4 a | 341.9 a | 10.3 a | 36.3 a | 4.0 a | 50.6 a |
| Untreated | 49.9 ab | 234.3 a | 11.9 ab | 296.1 ab | 8.0 a | 33.0 a | 2.4 ab | 43.4 a |

[z]Values followed by same letter indicate not significantly differ ($P$<0.05) according to the Tukey-Kramer's multiple range test.

Abbreviations note: NAA = 1-naphtaleneacetic acid, BA = 6-benzylaminopurine, CPPU = N-(2-Chloro-4-pyridyl)-N-phenylurea.

Daminozide is registered as an internode elongation inhibitor for chrysanthemum and other species, but no effects were detected on pitaya.

Appropriate management of pitaya cultivation practices should reduce labor inputs and make the species better suited to general amateur gardeners who would be able to harvest year-round and enjoy the large, white, night-blooming flowers. Although cactuses are supplied in pots by retailers, it is not considered suitable for pot cultivation because of the excessive growth vigor of the cladodes in pitaya. However, soil application of NAA suppresses cladode growth and may facilitate the production and sale of potted plants.

## CONCLUSION

Spraying cladode with ethephon and applying NAA to the soil inhibited cladode growth; conversely, gibberellin spraying of cladode promoted cladode growth. Other growth regulators tested had no observable effects.

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# Adventitious Shoots Formation by Flower Bud Culture of *Primula veris*, *Primula vulgaris*, and *Primula juliae*©

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Selections of *Primula* × *polyantha* hort. are important pot flowers in Japan, which are complex hybrids of *P. elatior* (L.) Hill, *P. veris* L., and *P. vulgaris* Hudson, commonly called polyanthus. In addition, hybrids of polyanthus and *P. juliae* Kusnetsow were called Juliana hybrid or Julian, and they were produced as well as polyanthus. Homogeneous seed production is difficult because they are allogamous plant.

Callus induction and regeneration from vegetative organs has not been successful in polyanthus and Julian types, although in *P. juliae* callus was induce easily and a few adventitious shoots were abtained from flower bud culture.

In this study, we studied the induction of adventitious shoot formation by flower bud culture of *P. veris*, *P. vulgaris*, and *P. juliae*. *Primula veris*, *P. vulgaris*, and *P. juliae* plants were divided into into explants containing 2-3 buds, and planted in plastic pots (diameter 9 cm) containing pumice for growing (called "kanuma" soil), in the autumn of the year before flower bud culture. These were placed on subirrigation trays in February, and the flower buds (length: 10-15 mm) were harvested in late March to early in April.

These picked flower buds were dipping in sodium hypochlorite solution (1% available chlorine) for about 8 min and rinsed by sterilized water. Basal medium for flower bud culture was MS medium (Murashige and Skoog, 1962) supplemented with 30 $g \cdot L^{-1}$ sucrose and 2.5 $g \cdot L^{-1}$ gellan gum (Wako pure Chemical Industries, Ltd., Japan), and supplemented with six combinations of 1-naphthyl acetic acid (NAA) and 6-benzylaminopurine (BA) as plant growth regulators (PGR), and hormone-free as control (Table 1). The surface sterilized flower buds were put individually on medium (10 ml) in test tubes (25 mm diameters; 120 mm height), later on measured length of flower buds, divided into S (6-10 mm), M (11-13 mm) and L (14-17 mm).

These were incubated under 20±2°C, 16 h/day with white fluorescent lamp illumination (about 2,000 Lux) conditions, and then observed for callus formation and organogenesis by external observation at 45 and 100 days after inoculation.

Induced callus was cut and divided into approximately 5-mm squares and inoculated on the same fresh medium with *P. veris* and *P. vulgaris*, but *P. juliae* was inoculated on a different PGR combination (Table 2). At 2 and 4 months after inoculation callus formation and organogenesis were recorded by external observation.

Cultured flower buds developed callus in all species, especially in *P. juliae* which showed vigorous callus formation (Fig. 1). However, a relation between callus amount, size of flower buds and, plant growth regulators combinations was not observed. At 100 days after inoculation, adventitious shoots appeared on callus of *P. juliae*, but only one each on two combination of PGR that contained NAA and BA with 1 or 5 $mg \cdot L^{-1}$ each (Table 1) .

Two months after subculture, callus of *P. juliae* showed a high survival rate and vigorous callus proliferation; however, *P. veris* and *P. vulgaris* showed poor callus proliferation (Table 2). However, an adventitious shoot differentiated on callus of *P. vulgaris* for the first time and also on *P. juliae*.

In this study, flower buds of the three species formed callus with differentiated adventitious shoots on callus of only *P. juliae* and *P. vulgaris*. In conclusion, it was shown that those two species have plant regeneration ability. In the future, if the frequency of adventitious shoot formation on these parent species can be improved, it may be possible to establish a regeneration system for polyanthus and Julian primroses.

Table 1. Effects of plant growth regulators to organogenesis on flower bud culture of *Primula juliae*, *P. veris* and *P. vulgaris*, at 45 and 100 days after inoculation (DAI).

| Combination of plant growth regulators (mg/L) | *Primula juliae* | | | | | *Primula veris* | | | | | *Primula vulgaris* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of flower buds | Rate of adventitious roots formation (%) | | Rate of adventitious shoots formation (%) | | No. of flower buds | Rate of adventitious roots formation (%) | | Rate of adventitious shoots formation (%) | | No. of flower buds | Rate of adventitious roots formation (%) | | Rate of adventitious shoots formation (%) | |
| NAA:BA | | 45 DAI | 100 DAI | 45 DAI | 100 DAI | | 45 DAI | 100 DAI | 45 DAI | 100 DAI | | 45 DAI | 100 DAI | 45 DAI | 100 DAI |
| 0:0 | 20 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 |
| 1:1 | 24 | 0 | 20.8 | 0 | 4.2 | 9 | 0 | 22.2 | 0 | 0 | 24 | 0 | 0 | 0 | 0 |
| 1:3 | 25 | 0 | 0 | 0 | 0 | 12 | 8.3 | 25.0 | 0 | 0 | 25 | 0 | 0 | 0 | 0 |
| 1:5 | 24 | 0 | 4.2 | 0 | 0 | 12 | 0 | 8.3 | 0 | 0 | 24 | 0 | 0 | 0 | 0 |
| 5:1 | 24 | 8.3 | 20.8 | 0 | 0 | 12 | 8.3 | 8.3 | 0 | 0 | 25 | 0 | 34.8 | 0 | 0 |
| 5:3 | 23 | 0 | 4.4 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 24 | 0 | 17.4 | 0 | 0 |
| 5:5 | 24 | 0 | 0 | 0 | 4.2 | 11 | 0 | 0 | 0 | 0 | 24 | 0 | 4.2 | 0 | 0 |

Table 2. Effects of plant growth regulators to callus increase and organogenesis on subculture from flower bud culture of *Primula juliae*, *P. veris*, and *P. vulgaris*, at 2 months after subculture.

| Combination of NAA:BA (mg/L) | | *Primula juliae* | | | | | *Primula veris* | | | | | *Primula vulgaris* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. of callus segments | Callus | | Rate of organogenesis (%) | | No. of callus segments | Callus | | Rate of organogenesis (%) | | No. of callus segments | Callus | | Rate of organogenesis (%) | |
| Primary culture | Sub-culture | | Survival rate (%) | Magnification of increase | Adventitious roots | Adventitious shoots | | Survival rate (%) | Magnification of increase | Adventitious roots | Adventitious shoots | | Survival rate (%) | Magnification of increase | Adventitious roots | Adventitious shoots |
| 1:1 | 1:1 | 125 | 34.7 | 3.1 | 2.4 | 0 | 19 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| | 2:1 | 86 | 60.3 | 2.9 | 1.2 | 0 | — | — | — | — | — | — | — | — | — | — |
| 1:2.5 | 1:3 | 255 | 37.3 | 2.8 | 1.6 | 0 | 30 | 0 | 0 | 0 | 0 | 4 | 25.0 | 1.0 | 0 | 25.0 |
| | 1:5 | 64 | 32.8 | 2.9 | 0 | 0 | — | — | — | — | — | — | — | — | — | — |
| 1:5 | 1:5 | 85 | 51.3 | 2.9 | 3.5 | 2.4 | 88 | 2.4 | 2.5 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| | 1:3 | 199 | 39.2 | 2.7 | 2.5 | 0.5 | — | — | — | — | — | — | — | — | — | — |
| 5:1 | 5:1 | 99 | 66.3 | 3.6 | 3.0 | 0 | 6 | 0 | 0 | 0 | 0 | 58 | 29.2 | 2.1 | 0 | 0 |
| | 5:3 | 99 | 50.0 | 3.1 | 3.0 | 0 | — | — | — | — | — | — | — | — | — | — |
| 5:2.5 | 5:3 | 294 | 60.7 | 3.5 | 3.1 | 0 | 1 | 0 | 0 | 0 | 0 | 49 | 7.9 | 3.0 | 2.0 | 0 |
| 5:5 | 5:5 | 254 | 39.6 | 3.4 | 0.8 | 0 | - | - | - | - | - | 53 | 0 | 0 | 0 | 0 |

Survival rate (%) = 100 × Number of survival callus/Number of inoculated callus.
Magnification of increase = Volume of callus at 2 monthes after/Volume of callus at inoculation by external observation.
Rate of organogenesis (%) = 100 × Number of callus with organogenesis/Number of inoculated callus.

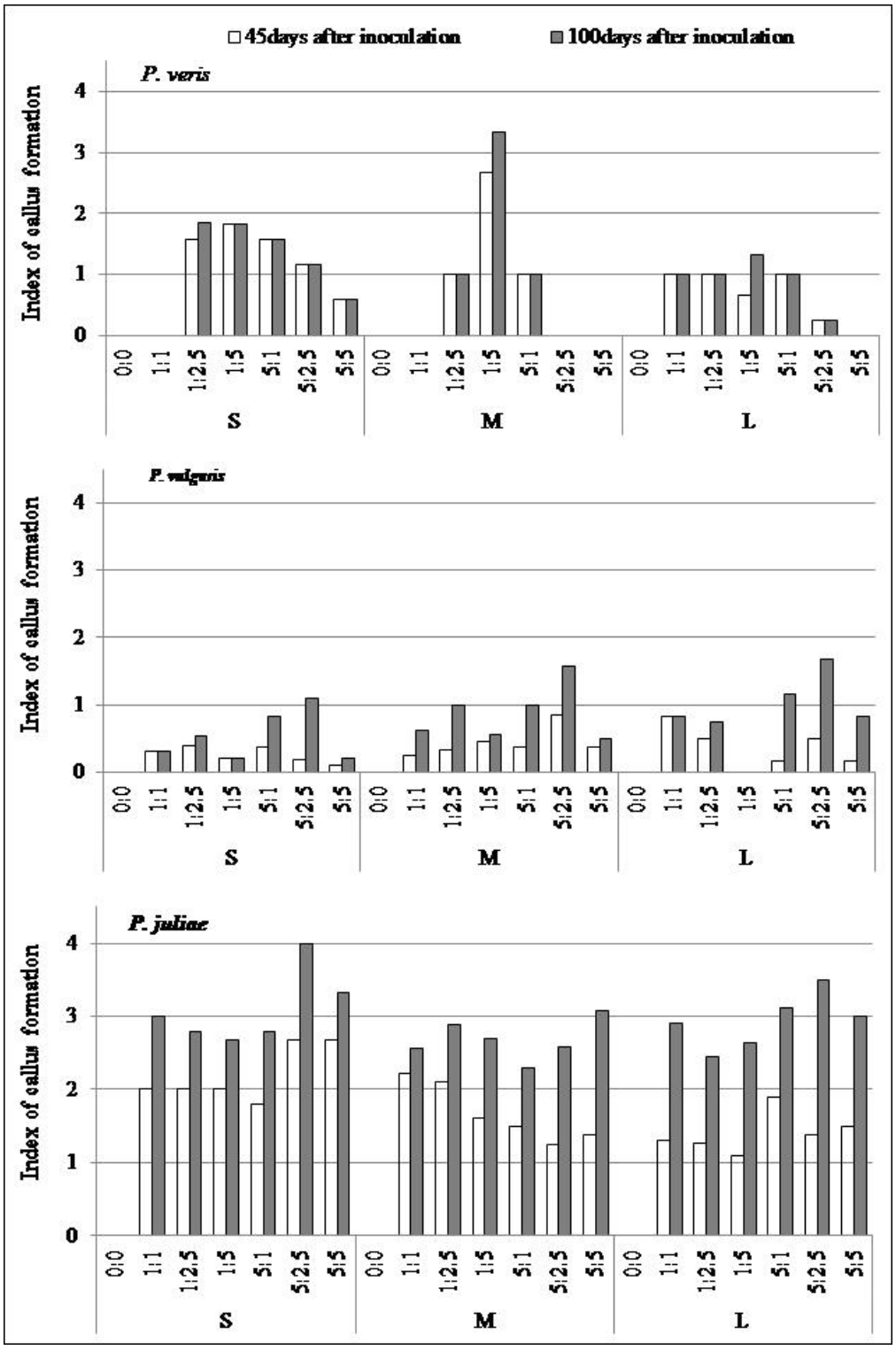


Fig. 1. Callus formation by external observation at 45 and 100 days after inoculation on flower bud culture of *Primula veris*, *P. vulgaris*, and *P. juliae*, each flower bud size. The horizonal axis shows combinations of 1-naphthylacetic acid and 6-benzylaminopurine combination ($mg \cdot L^{-1}$) and flower bud sizes were S (6-10 mm), M (11-13 mm) and L (14-17 mm). The vertical axis shows average callus formation index by external observation, valued 0 to 4.

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# Effects of Various Conditions on Root and Emergent Shoot Growth during Propagation by Cuttings in the Amenity Plant *Hardenbergia violacea*©

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**To develop a mass propagation method for *Hardenbergia violacea* L., new shoots were prepared and used to compare the effects of rooting medium, temperature, photoperiod and concentrations of IBA (3-indolebutyric acid) and surfactant on rooting. The upper nodes of one-node cuttings bearing two leaves were cut half and placed in 16 ppm IBA solution for 1 h. The cuttings were then placed in rockwool cubes and maintained under 16-h photoperiod at 20°C on 4 weeks from the time of cutting to assess the extent of root formation. High percentages of rooting were observed, with the highest observed in the solution containing IBA and 0.05% surfactant.**

## INTRODUCTION

In open spaces and parks, and in public and private grounds, flowers, and other greenery are being grown to produce a congenial environment for human activities. Flowering plants reared for such purposes are know as amenity flowers (Imanishi, 2000). Recently, these have also been called amenity plants. In today's overcrowded cities where urban landscaping counts, beautification of the environment and the creation of amenity values has become an important consideration.

Amenity plants and flowers not only provide a sense of peace, naturalness, and pleasant along with greenery but also create amenities and urban landscaping. As such, the role of amenity plants should continue to grow in importance.

One promising candidate for an amenity plant is *Hardenbergia violacea* L., an evergreen vine in the legume family originating from Eastern Australia (Australian Native Plants Society, 2012). This plant has thick elongated triangular leaves of dark green. Each flower spike contains tens of florets. It is easy to cultivate and has fairly good cold resistance, making it suitable as an amenity plant.

Flowering plants can be propagated by vegetative propagation methods that take advantage of the ability of the plant organs to regenerate. This produces new plants with the same trait as the parent. Among these, cutting propagation is a promising method where cuttings can be taken from leaves, stems, and roots, and placed in a suitable soil medium to obtain new plants from adventitious shoots and roots (Imanishi, 2000). It does not need any advanced technology, the propagation rate is quite high, and the method is easy to incorporate into existing cultivation methods.

In this experiment our laboratory tested some simple but promising cuttings propagation methods for propagating *H. violacea* with various conditions. The purpose was to contribute towards amenity planting with *H. violacea*.

## MATERIALS AND METHODS

Three-year-old *H. violacea* stock was used for this experiment. The experiment was run from 5 April to 5 May. Forty fully grown plants were used. Branches from the current year were collected, and cuttings were taken from sections of the upper shoots to the lower part of a leaf pair. They were made up of a section of stem about 5 cm.

All cuttings except those used for experiments on rooting acceleration agents were soaked for 60 min with 16 ppm indole-3-butyric acid (IBA) in Oxyberon solution (Bayer Crop Science Co. Ltd.), then planted in seeding boxes (length 42 cm, width 32 cm, depth 8 cm) at intervals of 10 cm.

For all experiments except those testing the effect of photoperiod, the plants were

maintained in an incubator (MIR-553, Sanyo Electrical Co. Ltd) at a constant temperature and under LD 16:8 conditions with 15W fluorescent lighting (10 μmol·$m^{-2}$·$s^{-1}$). Twenty samples were used for each experimental group. Four weeks after cuttings were taken; the rate of rooting, the numbers of roots per rooted shoot, the shoot lengths and the number of nodes were recorded.

**The Effect of Growing Media on Root Development and Shoot Lengths**
The media tested were: mixture of sand, peat moss, and akadama soil (conventional soil) (2:2:1, by vol.); rock wool (40×35×35 mm, Nitto Boseki Co. Ltd.); or perlite. The cuttings were cultivated at a constant temperature of 20°C under 16 h light. Four weeks after the cuttings were taken; the rate of rooting, the numbers of roots per rooted shoot, the shoot lengths, and the number of nodes were recorded.

**The Effect of Temperature on Root Development and Shoot Lengths**
Cuttings were cultivated in rock wool and kept in an incubator at temperatures of 10, 15, and 20°C under LD 16:8 conditions.

**The Effect of Photoperiod on Root Development and Shoot Lengths**
Cuttings were cultivated in rock wool and kept in an incubator at a constant temperature of 20°C and photoperiods of 10, 12, and 16 h light under a fluorescent light (10 μmol·$m^{-2}$·$s^{-1}$).

**The Effect of Different Concentrations of Rooting Accelerant on Root Development and Shoot Lengths**
Cuttings were immersed in Oxyberon solution at concentrations of 0, 8, 16, 40, and 80 ppm IBA, and the cuttings were cultured in rock wool at 20°C and LD 16:8.

**The Effect of Rooting Accelerant and Surfactants on Root Development and Shoot Lengths.** Cuttings were immersed in 16 ppm IBA Oxyberon solution combined with 0-0.3% of the surfactant Tween 20 (Kanto Chemical Co. Ltd). The cuttings were cultivated in rock wool, at 20°C and LD 16:8.

## RESULTS AND DISCUSSION

**The Effect of Growing Media on Root Development and Shoot Lengths**
Adventitious roots were observed 10 days after cuttings were taken, regardless of the growing medium. The rate of rooting was 100% in the conventional soil, rock wool, and perlite (Table 1). The number of roots was higher in the rock wool than the other two media. No difference in shoot length or number of nodes with growing media was observed.

**The Effect of Temperature on Root Development and Shoot Lengths**
Maximum root development was observed at 20°C, followed by the 15°C treatment. No root development was observed at 10°C (Table 2). The number of roots, shoot lengths, and number of nodes were significantly higher under the 20°C treatment.

**The Effect of Photoperiod on Root Development and Shoot Lengths**
The rate of rooting was higher under LD 16:8 than under LD 10:14 or LD 12:12. The number of roots per rooted shoot was highest under LD 16:8 conditions. The shoot length and number of nodes were both highest under LD 16:8 conditions (Table 3).

Table 1. Effect of rooting medium on rooting and shoot growth of cutting in *Hardenbergia violacea* L.

| Medium | Rate of rooting (%) | No. of roots per rooted shoots[z] | Length of the shoot (cm) | No. of nodes |
|---|---|---|---|---|
| Soil | 100a | 8.0c[y] | 5.3a | 3.3a |
| Rockwool | 100a | 10.0a | 5.5a | 2.9a |
| Perlite | 100a | 9.2b | 5.2a | 3.0a |

After cutting, plants were subjected to 16-h photoperiod in a growth chamber kept at 20°C. Observations were carried out 4 weeks after cutting. 20 cuttings were used in each treatment.
[z]More than 1 mm in length.
[y]Mean separation within the column by Tukey's HSD test, 5% level of significance.

Table 2. Effect of temperature on rooting and shoot growth of cutting in *Hardenbergia violacea* L.

| Temperature (°C) | Rate of rooting (%) | No. of roots per rooted shoots[z] | Length of the shoot (cm) | No. of nodes |
|---|---|---|---|---|
| 10 | 0c | - | - | - |
| 15 | 80b | 8.2b[y] | 5.0b | 2.9b |
| 20 | 100a | 9.8a | 5.5a | 3.2a |

After cutting, plants were subjected to 16-h photoperiod in a growth chamber kept at various temperature. Observations were carried out 4 weeks after cutting. 20 cuttings were used in each treatment.
[z]More than 1 mm in length.
[y]Mean separation within the column by Tukey's HSD test, 5% level of significance.

Table 3. Effect of photoperiod on rooting and shoot growth of cutting in *Hardenbergia violacea* L.

| Photoperiod (h) | Rate of rooting (%) | No. of roots per rooted shoots[z] | Length of the shoot (cm) | No. of nodes |
|---|---|---|---|---|
| 10 | 45b | 2.0c[y] | 1.5c | 1.8c |
| 12 | 95a | 5.5b | 4.8b | 2.4b |
| 16 | 95a | 7.5a | 5.6a | 3.6a |

After cutting, plants were subjected to 10, 12, or 16-h photoperiod in a growth chamber kept at 20°C. Observations were carried out 4 weeks after cutting. 20 cuttings were used in each treatment.
[z]More than 1 mm in length.
[y]Mean separation within the column by Tukey's HSD test, 5% level of significance.

**The Effect of Different Concentrations of Rooting Accelerant Oxyberon Solution on Root Development and Shoot Lengths**

The control treatment (0 ppm) resulted in a rooting rate of 10% (Table 4). When 16, 40, and 80 ppm IBA had been used, the rooting rate was 100%. The number of roots was significantly higher under the 16, 40, and 80 ppm treatments when compared with the other treatments, as were the shoot lengths and number of nodes.

Table 4. Effect of IBA concentrations on rooting and shoot growth of cuting in *Hardenbergia violacea* L.

| IBA concentrations (ppm) | Rate of rooting (%) | No. of roots per rooted shoots[z] | Length of the shoot (cm) | No. of nodes |
|---|---|---|---|---|
| 0 | 10d | - | - | - |
| 4 | 30c | 2.8d[y] | 4.3d | 2.6d |
| 8 | 50b | 3.5c | 4.7c | 3.1c |
| 16 | 100a | 8.3a | 6.1a | 3.5a |
| 40 | 100a | 8.5a | 6.2a | 3.4a |
| 80 | 100a | 8.6a | 6.2a | 3.5a |

Cuttings were soaked in different IBA solution for 60 min before planting into rockwool. After cutting, plants were subjected to 16-h photoperiod in a growth chamber kept at 20°C. Observations carried out 4 weeks after cutting. 20 cuttings were used in each treatment.
[z]More than 1 mm in length.
yMean separation within the column by Tukey's HSD Test, 5% level of significance.

**The Effect of Rooting Accelerant and Surfactants on Root Development and Shoot Lengths**

When cuttings were treated with a surfactant alone, no root development was observed throughout the experiment (Table 5). When 0.05% surfactant was added to 16 ppm IBA Oxyberon solution, the root development rate was 100%. This also caused a significant increase in shoot length and number of nodes.

To be its most effective, soil used for reproducing by cuttings needs to be porous, have moderate water-holding capacity, and good drainage. It should also not include fertilizer or organic matter, and should be clean (Fujii, 1968).

Table 5. Effect of the combination treatment of IBA and surfactant concentrations on rooting and shoot growth of cutting in *Hardenbergia violacea* L.

| IBA concentrations (ppm) | Surfactant concentrations (%) | Rate of rooting (%) | No. of roots per rooted shoots[z] | Length of the shoot (cm) | No. of nodes |
|---|---|---|---|---|---|
| 0 | 0 | 0 | - | - | - |
| | 0.05 | 0 | - | - | - |
| | 0.1 | 0 | - | - | - |
| | 0.2 | 0 | - | - | - |
| 16 | 0 | 90b | 8.3d[y] | 4.6c | 1.2c |
| | 0.05 | 100a | 11.5a | 6.8a | 3.3a |
| | 0.1 | 95b | 9.8b | 5.1b | 2.8b |
| | 0.2 | 80c | 9.1c | 3.8d | 1.3c |

Cuttings were soaked in combination of IBA and surfactant solution for 60 minute before planting into rockwool. After cutting, plants were subjected to 16-hr photoperiod in a growth chamber kept at 20°C. Observations were carried out 4 weeks after cutting. 20 cuttings were used in each treatment.
[z]More than 1 mm in length.
[y]Mean separation within the column by Tukey's HSD test, 5% level of significance.

In ornamental trees, any differences in the physical properties of the rooting medium are reflected in variations in root development rate (Tilt and Bilderback, 1987). In

addition, the higher the moisture content, the higher the rate of rooting (Rein et al., 1991). In this experiment, no difference between the rate of rooting, number of roots per rooted stem, shoot length, or number of nodes was found when cuttings were grown on the standard sand; peat moss; akadama mixture, rock wool, or perlite (2:2:1, by vol.) (Table 1). This shows that in *H. violacea*, any medium that is porous, retains water, and drains well is suitable for cuttings.

The suitable temperature for propagation by cuttings depends on the plant but usually ranges from 15-25°C (Fujihara, 1984). In *Dorycnium*, Alegre et al. (1998) report higher rooting rates in cuttings reared at 20°C when compared to cutting reared in a greenhouse with a minimum temperature of 10°C. In this experiment, all *H. violacea* plants developed roots at 20°C, compared with 80% at 15°C and none at 10°C (Table 2). This suggests that the optimal temperature for development of roots from *H. violacea* cuttings is close to 20°C.

Generally auxin treatments with IBA, NAA, or other rooting accelerants are used when propagating by cuttings, to accelerate root formation. In this experiment, when treatments with 16, 40, and 80 ppm IBA were applied onto the cuttings beforehand, a high rate of root development was obtained (Table 3). In *Dorycnium*, 25 $mg \cdot L^{-1}$ and 200 $mg \cdot L^{-1}$ IBA promoted root development (Alegre et al., 1998). In olives, when cuttings were treated with 0.8% IBA, this promoted a high level of root development (Wiesman and Lavee, 1995). In plum trees, high rates of root development were obtained from treatment with 5000 ppm IBA for 1-5 s, or 50 ppm for 18 min. (Nahlawi and Howard, 1972).

In this experiment we found that maximum root production in *H. violacea* cuttings was possible with a comparatively low concentration (16 ppm) of IBA in Oxyberon solution. However, since the suitability of IBA treatment varies depending upon both the type of plant (Yamazaki et al., 1982), and on the treatment duration, more detailed investigations on IBA concentration and duration need to be carried out in order to find a simpler treatment method.

Usually cuttings are shielded from light to prevent rises in temperature, but strong light conditions have been shown to promote photosynthesis in the cuttings, and to promote the movement of auxins to the base of the cuttings (Gemma, 1997). In *Forsythia* when green cuttings were held at photophases ranging from 16-24 h, root development was promoted more strongly than when cuttings were kept in a 12-h photophase (Hata et al., 2009).

In this experiment, there was greater root development under a 16-hour photophase than under photophases of 10 and 12 hours. It was thought that the relatively weak light intensity (10 $\mu mol \cdot m^{-2} \cdot s^{-1}$, meant that a longer photophase was required to enable migration of auxins to the base of the cuttings.

Uda et al. (1994) added the non-ionic surfactant polyoxyethylene lauryl ether to silver thiosulfate solution (STS) for pre-treatment of spray carnations, and found that the retention period was far longer than when STS was used alone. Funakoshi (1988) also found that the addition of neutral detergents enhanced the retention effect of STS when applied to *Gypsophila* and *Bubarujia*. In this experiment, when 0.05% of the surfactant Tween 20 was mixed with 16 ppm IBA Oxyberon solution, high rooting rates were obtained (Table 4). Surfactants promote water absorption in cut flowers and improve water balance (Durkin, 1980; van Doorn et al., 1993). The Tween 20 surfactant used in this experiment is a type of polyoxyethylene lauryl ethers, effective in promoting water absorption in cut flowers. When perennial sweet pea cut flowers were treated with 0.05 mM STS in 10% sucrose with 0.05% Tween 20 for 2 h, the shelf life was extended (Koike and Imanishi, 2009).

This experiment has also shown that root development increases when a surfactant is mixed with rooting accelerant, and it is thought that this is because it promotes water absorption of cuttings.

The above results have demonstrated that high rooting rates can be obtained in *H. violacea* cuttings if they are soaked after cutting for 60 min. in 16 ppm IBA in

Oxyberon with 0.05% surfactant added, and cultured in rock wool at 20°C and LD 16:8 conditions.

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# Field Excursion at IPPS Japan Twenty-First Conference in Kanagawa©

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The annual meeting of IPPS-Japan this year was held in Atsugi City, Kanagawa Prefecture. The excursion was arranged to visit a botanical garden, research institute, and educational farm.

On 4 Oct. PM, we visited botanical garden at Tokyo University of Agriculture, which is located in Atsugi City, where the aim is to collect Zingiberaceae, tropical fruits, rare endemic plants, and traditional Japanese plants. All the participants learned something important about plant protection from explanations by technical staff (Fig. 1).

On the second day, 5 Oct. AM, we visited bio-systems and bio-functions research center at Tamagawa University, where the aim is development of a novel agricultural production system using optical semiconductor devises and development of a plant cultivation system in space. All the participants studied new technologies and techniques.

After a lunch break, our last visit was the Meiji University Kurokawa Farm, which is an educational farm. We learned about organic farming and high-quality, high-yield production techniques (Fig. 2).

The participants enjoyed the field tour and went to the Shin-Yokohama station of Japan Railway or the Hon-Atsugi station of Odakyu Electric Railway, promised to meet again next year in Gunma and said good-bye.

Fig. 1. Mr. Ito, a technical staff of botanical garden, Tokyo University of Agriculture, who explains to participants.

Fig. 2. Prof. Tamaki, Head of the Kurokawa Farm, Meiji University, who explains to participants.

# Technical Sessions, Monday Morning, 27 October 2014©

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The 39th Annual Meeting of the International Plant Propagators' Society-Southern Region of North America convened at 7:45 am at the Hickory Crowne Plaza, Hickory, North Carolina with President Buddy Lee presiding.

**PRESIDENT BUDDY LEE**

President Lee welcomed everyone to Hickory, North Carolina for the 39th Annual Meeting of the International Plant Propagators' Society-Southern Region of North America. He thanked Local Site Committee Chair, Anthony Lebude 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. Saunders thanked the Executive Committee, and Maarten van der Giessen's Sponsorship Committee, which raised $40,750 in cash sponsorships; this was outstanding for the challenging economic times. Lee 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 pushed for good questions and enthusiastic participation at the Tuesday night question box.

Lee announced that this is the second year our region has participated with Great Britain & Ireland (European Region) in the Young Propagator Exchange program between the two regions. He recognized Colm O'Driscoll from Ireland, who toured IPPS-SRNA nurseries prior to the annual meeting. Judson Lecompte from the Southern Region of North America, our designee to GB&I, was also recognized. Both of these young professionals had an incredible exchange experience in our respective regions. This is the second year we are doing the Vivian Munday Young Horticultural Professional Scholarship Work Program (Vivian Munday Scholarship). We currently have a "4-pack" of four young professionals who are making a strong contribution to this year's program. Lee thanked Program Chair and 1st Vice-President, Maarten van der Giessen, for the excellent program and slate of speakers he assembled.

**PROGRAM CHAIR MAARTEN VAN DER GIESSEN**

Program Chair van der Giessen 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 co-chaired by Fred Davies and Alan Shapiro. He then introduced the first moderator, Jane Stanley.

# Edibles for the Landscape©

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As the farm to table movement takes hold across America, home gardeners and landscapers are becoming more aware of the local food movement. Local food may mean from a specified geographic region or even from a home garden. An edible garden does not necessarily have to be relegated to a separate plot in the backyard. Edible plants can easily be incorporated into any landscape design. A well-rounded landscape design includes several elements including: trees, shrubs, flowers, groundcovers, and foliage. There are many examples of edible plants that fulfill each of these landscape elements.

## FRUIT TREES

### Citrus

Since citrus trees are particularly sensitive to cold temperatures, they are not well-suited for most home landscapes. The kumquat, calamondin, and satsuma have the greatest degree of cold hardiness. However, most gardeners can successfully enjoy citrus trees in patio containers. Any type of citrus tree can be grown in a container, but navel oranges, grapefruit, and most other oranges are very vigorous and outgrow all but very large containers.

Naturally small citrus cultivars such as 'Improved Meyer' lemon, satsumas, kumquats, and calamodins are easy to grow in containers. If you can purchase citrus that is grafted onto *Citrus trifoliata* 'Flying Dragon' rootstock, it will be significantly dwarfed, which will extend its life in a container. Following are some recommended cultivars (Porter, 2013):

- 'Owari' satsuma was introduced from Japan and is the most widely available satsuma. The fruit is seedless and matures from October to mid-November. 'Owari' trees tend to be more vigorous than other satsumas.
- 'Nagami' kumquats produce oblong fruit with a smooth rind, deep orange color, and acid juice. They ripen from mid-October through February. The fruit is one and a half to two inches long and one to two inches in diameter and contains seeds. The 'Nagami' tree is vigorous, with a round, bushy top. It is very cold hardy.
- 'Meyer' or 'Improved Meyer' is the only lemon recommended for container culture due to its small degree of cold hardiness. It is not a true lemon, but a cross between a lemon and an orange. It ripens in mid-October and holds on the tree until December or longer. 'Meyer' is better when grown from a rooted cutting than when grafted. It has a strong tendency to bloom and set fruit throughout the year.

### Fig

*Ficus carica* is a native of Asia and was imported into the United States in the 16th century. The fruit is tasty and can be eaten fresh, made into preserves and jams, or used in baking. Figs have the potential to produce an early crop, called the breba crop, on last year's wood in the spring, a main crop on the current-season wood during the summer, and a third crop in the fall. These different crop productions vary from one cultivar to another. Popular fig cultivars include 'Celeste', 'LSU Purple', 'LSU Gold', 'Conadria' and 'Brown Turkey' (Gill et al., 2011).

- 'Celeste' produces small- to medium-size fruit that is resistant to splitting and souring. The fruit is violet to brown with a light strawberry-colored pulp.
- 'LSU Purple' has medium-size, dark purple fruit and good resistance to foliage diseases. Its tendency to produce three distinct crops — a light crop in early spring, a heavy main crop in early July and a later crop sometimes lasting into December — makes it popular.

- ‘LSU Gold’ is a relatively new yellow-fruited cultivar that may still be hard to find, but it is well worth growing. The ‘LSU Purple’ and ‘LSU Gold’ cultivars were developed from crosses made by Ed O’Rourke in the 1950s.
- ‘Conadria’ is a large yellow fig with high sugar content. It can be used for dried figs and fresh fruit. Producing two crops, the first crop is good, while the second crop tends to be better.

Fig trees need room. They can reach heights of 10-15 ft with an equal spread. Plant them in a sunny location away from large trees with overhanging branches. Figs will not produce well unless they receive at least six hours of direct sun daily.

## SHRUBS

### Blueberries

Blueberries are increasingly popular fruits with well-documented health benefits. Blueberry plants are also exceptionally handsome bushes worthy of planting in the home landscape. The fruit can be eaten fresh, or frozen for out-of-season use. Plants have a profusion of white blossoms in late spring, and the leaves are glossy green in summer and have outstanding red foliage in autumn. Blueberry production may present a challenge for some gardeners because the plants need special growing conditions. They require acidic, well-drained soils (Hoover et al., 2009).

There are three main types of cultivated blueberries that can be grown in the Southeast: rabbiteye, Northern highbush and Southern highbush. This section focuses on the rabbiteye and Southern highbush types (Polomski and Reighard, 1999).

In general, rabbiteyes (*Vaccinium ashei*) are the most adaptable, productive, and pest-tolerant of the three types of blueberries. In general, rabbiteye blueberries have some degree of self-incompatibility; therefore, a minimum of two cultivars is required for cross-pollination to ensure maximum fruit. Some recommended rabbiteye cultivars include:

- Early season: ‘Beckyblue’, ‘Bonita’, ‘Brightwell’, ‘Climax’, ‘Premier’, ‘Woodard’
- Midseason: ‘Bluebelle’, ‘Briteblue’, ‘Chaucer’, ‘Powderblue’, ‘Tifblue’
- Late season: ‘Baldwin’, ‘Centurion’, ‘Choice’, ‘Delite’.

‘Woodard’ is a good berry for fresh-eating but develops a tough skin when frozen. ‘Tifblue’, ‘Powderblue’, ‘Brightwell’, ‘Briteblue’, and ‘Centurion’ are most resistant to spring freezes.

Southern highbush blueberries are hybrids derived from crosses between Northern highbush blueberries and native Southern species, mainly Darrow’s evergreen blueberry (*V. darrowii*). Southern highbush cultivars, in addition to lower chilling requirements, also have greater tolerance to high summer temperatures, somewhat greater drought tolerance and develop superior fruit quality under Southern growing conditions. As a rule, Southern highbush blueberries are self-fertile. However, larger and earlier-ripening berries result if several cultivars are interplanted for cross-pollination. The following Southern highbush blueberries are recommended for the garden and landscape:

- Very early season: ‘O’Neal’
- Early/midseason: ‘Cape Fear’
- Midseason: ‘Blue Ridge’ and ‘Georgia Gem’
- Mid/late season: ‘Legacy’ and ‘Summit’
- Late season: ‘Ozarkblue’.

### Pineapple Guava

Feijoa (*Feijoa sellowiana* syn. *Acca sellowiana*) is an attractive evergreen shrub bearing delicious fruits with an unusual, refreshing pineapple-mint flavor. The leaves are soft green on top, silvery underneath. One inch wide white petal flowers have showy red centers reminiscent of fuchsia flowers. These plants are low maintenance with few insects or diseases. Ideal for containers, feijoa also looks excellent in the landscape and makes a beautiful hedge; plant two different plants to insure pollination.

**Aronia**
*Aronia arbutifolia* is commonly known as chokeberry. 'Brilliantissima' is commonly grown by the nursery industry, probably more so than the species. It possesses enhancements to all the desirable features of the species. It blooms and fruit heavily, has larger fruit than the species, produces very glossy dark green foliage, and dependable intense red fall color. Most experts roundly praise this cultivar, and it may serve as a fine native substitute for the invasive, exotic *Euonymus alatus* (burning bush).

## FLOWERS

**Violets and Violas**
Violets (*Viola*) are adapted to woods and pasture. The purple flowers are edible and the plant is medicinal. Make sure your spring salads include violets. Grows exceedingly well in hard bark mulch as a companion with bush fruits such as blueberries.

**Roses**
Rose hips are the large seed pods that form on rose canes after blossom. Some roses, especially *Rosa rugosa* roses, form rose hips that are as big as crab apples—about the size of a quarter! And, in the fall they turn brilliant colors of red and orange, and sometimes even purple.

And, being a true member of the apple family, rose hips are edible. Rose hips are also very high in vitamin C, and you'll often see them listed as the main source for vitamin C in many commercially available vitamins. You can also eat rose petals. Sprinkle them on salads, use them as garnish, or make them into wonderful rose-petal jelly.

## GROUNDCOVERS

**Mint**
Corsican mint (*Mentha requienii*) is a dynamic ground cover and ornamental mint if you can give it lots of moisture. It takes some abuse from being trod on and comes back just fine. If you have a low spot in the garden with a few neglected looking pavers surrounded by bare dirt, Corsican mint may be the solution to your problem. Corsican mint prefers sandy soil and dappled light. It should never be allowed to dry out.

**Rosemary**
Creeping rosemary (*Rosmarinus officinalis* Prostratus Group) is a creeping rosemary cultivars that has made a name for itself as a container rosemary. It is an evergreen ground cover, but also looks natural in containers, hanging baskets and easily wraps around circular wire frames to create topiaries. Creeping rosemary is a tender evergreen perennial with fragrant evergreen foliage and pale blue summer flowers.

## FOLIAGE

**Basil**
Basil (*Ocimum basilicum*) is an easy to grow and easy to use herb. It grows well in pots and in beds. There are many types and cultivars to choose from:

- Thai basil, characterized by its strong licorice fragrance and flavor, is an annual and is also referred to as anise or licorice basil. It reaches heights up to 24 in. and with a nearly two-foot expanse. Thai basil is more easily found in specialty grocery stores that carry exotic or high-end fresh herbs, but is easy to propagate.
- Genovese basil, a well-regarded favorite among foodies, is considered the best basil for use in Italian recipes (pesto, tomato-basil sauce, Caprese salad, etc.) Like sweet basil, this annual has a strong clove fragrance and ranges from 12 to 24 in. in height, but is easily distinguished by its more crinkly and in-turned leaves.

- Lemon basil, similar to the other basils, grows to a height of about 2 ft, but exudes a savory lemon flavor and fragrance. This annual basil is a bit spindlier than its other basil relatives and is characterized by a flatter, narrower leaf.
- Cinnamon basil, the name describes it all, is basil with a cinnamon flavor. Its strong cinnamon scent easily distinguishes it from other basils. It also has a somewhat harrier leaf. This medium-sized annual grows up to 2½ ft tall and produces pale pink to purple flowers.
- 'Siam Queen' is a type of Thai basil that produces mint green leaves with very large flower heads, up to 6 in. across, that give off a spicy anise scent. It reaches heights up to 2½ ft, but it can be pinched back to restrict growth.
- 'Purple Ruffles' is a great plant to spice up the kitchen and the landscape! It is perhaps the most colorful basil for landscapes. Similar in color to 'Dark Opal', this plant is slightly smaller in stature (reaches up to 1½ ft) and its leaves are very frilly and ruffled. While it can handle a shadier spot in the garden, it still needs at least three hours of sunlight to mature properly. 'Purple Ruffles' gives off a combination of licorice and cinnamon scents and produces lavender and pink flowers that can also be eaten. Somewhat difficult to start from seeds, this plants works best from transplants.

**Lemongrass**

Lemongrass (*Cymbopogon citratus*) is an instant tea plant; just a few leaves in a cup of hot water yield a lemony drink. A tropical ornamental grass, it will take over an outdoor bed and will even grow well indoors. It is also known as a source for citral, the essential oil responsible for citronella's lemony scent. Lemongrass comes in two main cultivars: East Indian and West Indian. They have subtle differences but are grown under the same conditions.

Lemongrass is a perennial in growing Zones 10 and warmer but can be grown as an annual in cooler climates, though it may be difficult to grow outside in Zones 8 and colder. In general, plant lemongrass after the danger of frost has passed, in late spring for a late summer harvest. Lemongrass takes at least 100 days and sometimes up to 4-8 months to be ready for harvest.

While this is in no way an exhaustive listing of plants suitable for edible landscaping, it is the author's intention to perhaps pique the reader's interest in edibles and creativity in the landscape.

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# You Say You Want a Revolution: Reinventing the Garden Camellia©

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## BACKGROUND

During the middle portion of the 20th century, landscape architects and backyard gardeners in Zones 7a-9 began to appreciate the versatility of the *Camellia sasanqua* as an American garden staple. Venerable cultivars from Japan were imported by Toichi Domoto on the West Coast and Tsukasa Kiyono in the Southeast. Likewise, near Mobile, Alabama, new cultivars were being bred and introduced by Kosaku Sawada at his Overlook Nurseries. Subsequently, *C. sasanqua* became popular enough that they were distinguished from *Camellia japonica* and gained their own vernacular as "Sasanquas". The terms "japonicas" and "sasanquas", although taxonomic sins, are still useful epithets for grouping the garden camellias.

*Camellia sasanqua* is now accepted to include *C. hiemalis* and genetically that can easily be accepted. Nonetheless, there are distinct differences regarding their functionality within the garden. *Camellia hiemalis* carries DNA from an ancient cross with *C. japonica*. The *C. japonica* provided the offspring more complex flowers with striking color combinations (significantly red influence from anthocyanin) in addition to heavier petal and leaf substance. Generally, it also contributed a higher degree of disease resistance than that usually seen in *C. sasanqua* . Still, the *C. hiemalis* have all the vegetative appearance within the garden of a *C. sasanqua*. Notable examples are the cultivars 'Mine-no-yuki' and 'Shishigashira'.

There are nearly 30,000 named cultivars within the 250 or so species that comprise the genus, *Camellia*. Given that growers in the United States currently produce several hundred of these cultivars, does the nursery industry and gardening world need yet another camellia? In the mid-1990s when I asked myself this question, I would hear the distinctive voice of the philosopher/ballplayer Yogi Berra answer; "Nobody goes there anymore, it's too crowded."

Even so, from a 21st century garden perspective, most of the mid- 20th century *Camellia sasanqua* were problematic. Aspiring to be tree-like in habit, they grew to be large structures. Consequently, when they could not conform to more modest size landscapes, they were either removed or consistently pruned to the point of flower bud cessation. From a pathologist's perspective, many were a magnet for *Glomerella cingulata*, an all-too-common slow necrosis, inherent to many *C. sasanqua*. The cultivars 'Cleopatra', 'Rosea', 'Cotton Candy', 'Setsugekka', and many others in the warm, humid areas of Zones 8-9, are especially susceptible. *Glomerella* is a concern today with many cultivars losing resistance. *Camellia sasanqua* have, after all, only been planted in appreciable numbers in the American South during the last 80 years.

The focus of all of Sawada's work was with *C. sasanqua* (Sawada, 1953). He had released 18 cultivars by 1953, but none with *C. hiemalis* genetics. Although lovely in their simplicity, by 1990 in the Deep South, many were all but extinct because of *Glomerella cingulata* dieback (Fig. 1).

**The Most Exciting Phrase to Hear in Science, the One that Heralds New Discoveries, Is Not 'Eureka!' but 'That's Funny...' (Isaac Asimov)**

In the late 1980s, plantsman, Tom Dodd Jr., told me, "I don't have a "sasanqua" in my garden." He had noted the alarming spread of *Glomerella* affecting mature *C. sasanqua* in the Mobile, Alabama area. The most useful, floriferous, compact, disease-resistant cultivars of "sasanquas" contained *C. hiemalis.* Incredibly, until then, very little hybridizing occurred with *C. hiemalis*. I was privileged to see first-hand the remarkable success Dodd was experiencing with open-pollinated *C. hiemalis* as the seed parents including 'Mine-no-yuki', 'Shishigashira', 'Leslie Ann', and a few others.

In the abbreviated time frame in which Dodd focused on camellias, he introduced several which are now widely grown. The cultivars 'Alabama Beauty' (syn. 'Mr. B'), 'Jessica's Ruffles', 'Stephanie Golden', and 'Reverend Ida' are among his best. By 1994, Mr. Dodd's hybridizer's eye had turned to the *Ilex*. Having learned from Dodd's successes, we began an effort to concentrate on the *C. hiemalis* group.

Fig. 1. *Glomerella cingulata* dieback (left) and lesions (right) on *Camellia sasanqua*.

**THE GOALS OF OUR CAMELLIA PROGRAM WERE**

- Compact, yet vigorous forms — "semi-dwarf" must still require the plants have sufficient life-sustaining force for less-than perfect environments.
- Robust, upright, dense forms — plants suitable for use as specimens or for screening.
- Disease resistance — most significantly to *Glomerella cingulata* and *Phytophora* spp.
- Floriferousness at an early age — a plant in a 3-gal container requires adequate bud production for the garden center trade.
- Ease of production in a nursery environment — roots readily, tolerates both varying irrigation regimes and soil media consistencies.

We have attempted to be careful when introducing a new cultivar. To date we have selected 14 plants from roughly 40,000 open-pollinated crosses.

Few plants are able to create their own market despite how "revolutionary" they may appear to the mindset of the breeder. Coca Cola devotes $3 billion annually to advertising its brand which is recognized by 94% of the world's population. Plant Development Systems' Southern Living Plant Collection has provided the majority of our camellias with a very happy home within their palette of plant materials.

**OVERVIEW OF SOME OF THE MORE RECENT CAMELLIAS GREEN NURSERIES HAS RELEASED**

The following is a brief overview of some of the more recent camellias Green Nurseries has released to the trade. Mature dimensions are for 7-years establishment in the landscape with normal pruning.

- *Camellia sasanqua* (*hiemalis*) 'Green 99-006', October Magic® Bride sasanqua hybrid camellia. USPP 20,539. Dense, rounded to pyramidal habit to 1.5×1.5 m (5×5 ft). Dark green, glossy leaves. Slow growth. Small, double, white mass bloomer in midseason.

- *Camellia sasanqua* (hiemalis) 'Green 94-035', October Magic® Orchid sasanqua hybrid camellia. USPP 20,465. Dense, rounded habit to 1.5×1.5 m (5×5 ft). Dark green, glossy leaves. Medium growth. Small, double pink blends, mass bloomer early to midseason.
- *Camellia sasanqua* (hiemalis) 'Green 99-016', October Magic® Ivory sasanqua hybrid camellia. USPP 24,887. Dense, upright habit to 2.4×1.5 m (8×5 ft). Dark green, glossy leaves. Fast growth. Large double white flowers. Mass bloomer in midseason.
- *Camellia sasanqua* (hiemalis) 'Green 02-003', October Magic® Ruby sasanqua hybrid camellia. USPP 24,538. Dense, rounded growth to 1.2×1.2 m (4×4 ft). Small, dark green leaves. Average growth. Medium double red flowers, mass bloomer in midseason (Fig. 2).
- *Camellia sasanqua* 'Green 98-006', October Magic® Rose sasanqua camellia. USPP 20,539. Dense growth with pyramidal to columnar habit to 3×1.2 m (10×4 ft). Fast growth. Small, double salmon red flowers, mass bloomer in early-mid-season.
- *Camellia sasanqua* (hiemalis) 'Green 99-031', Susy Dirr camellia. USPP 24,888. Dense, upright to rounded growth to 3×2.1 m (10×7 ft). Large, dark green leaves. Exceptionally fast growth. Large double, pink flowers, midseason.

Fig. 2. *Camellia sasanqua* 'Green 02-003', October Magic Ruby® camellia.

**Propagation and Production**

Cuttings are taken from June through September. Following a basal quick-dip of Dip N' Grow® at 2800 ppm, they are placed in a medium of 4 coarse perlite and 1 vermiculite (v/v). The rooting process takes place in 5 × 10 cell-trays with a cell depth of 11 cm (4.5 in.) (T.O. Plastics PL-50-STAR-DP.) Under intermittent mist, root initiation occurs in 15-20 days. Rooted cuttings are overwintered in heated houses and kept to a minimum temperature of 4°C (40°F). During the following April, liners are transplanted to 15-cm-deep (6-in.) containers and placed on a gravel bed under 30% shade. There is a 95% success rate of the rooted liners utilized. There are three sheering periods and in the following March the liners are transplanted to 3-gal containers. By October, the containerized plants are marketable, 30 months after propagation (Fig. 3).

Fig. 3. Cut-away of 15-cm (6-in.) container with the lighter-colored liner root system.

**THE FUTURE**

The amazing influx of new-to-the-western-hemisphere camellia species with selections of sect. *Paracamellia* and sect. *Oleifera*, have caught this hybridizer's eye. Such species as *C. grijsii* (syn. *C. yuhsienensis*) and *C. brevistyla* in particular, have proven to impart numerous desirable characteristics when crossed with the *C. sasanqua* group. Dr. K. Hagiya crossed *C. yushienensis* with *C. sasanqua* (hiemalis) 'Shishigashira' produced the hybrid 'Yume' (Dream), a delightful semi-dwarf camellia with disease resistance and floriferous blooming habit. Within Zone 8, the flowering season of 'Yume' begins in October and extends into March. Recent work on petal blight resistance shows promise for *C. yushienensis* and its hybrids. Recent crosses with 'Yume' as the seed parent have produced striking plants with bicolored flowers throughout winter. The buds are moderately cold hardy. The growth habits can range from groundcovers to vigorous large shrubs.

*Camellia brevistyla* is a close *C. sasanqua* relative with clusters of tiny white flowers in fall. Small leaves are carried on a sturdy, petite scaffold of branches. The species carries the desirable trait of cinnamon colored bark, intensified by cool weather. This is a feature we have been able to transmit to some offspring when crossed with *C. sasanqua*. The bark characteristics, coupled with tiny flowers, and ease of culture open a new world of interest. Perhaps it will be the perfect container camellia of the future? These and other interspecific hybrids with similarities to *C. sasanqua* have blurred the specific epithets of *C. sasanqua* and *C. japonica* to such a degree that the old vernacular of "sasanquas" and "japonicas" has taken on a newfound validity.

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# Unravelling Rose Rosette©

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## INTRODUCTION

Rose rosette is caused by rose rosette virus (RRV) which is transmitted by the eriophyid mite *Phyllocoptes fructiphilus*. Rose rosette was first observed in 1940 in Manitoba, Canada and in California and Wyoming in 1941. The disease has become widespread in regions of north-central, south-central and southeast USA. The incidence of rose rosette has grown exponentially in cultivated roses in the mid-South USA due to increased use of mass plantings of shrub roses in residential and commercial landscapes.

All cultivated roses (shrub type, hybrid tea, floribunda, grandiflora, and miniature roses) are thought to be susceptible to the disease. Other roses reported to be susceptible are: *Rosa woodsii*, *R. bracteata*, and *R. rubiginosa* (syn. *R. eglanteria*).

Many articles have been written on rose rosette and described the variable symptoms associated with the disease. However, few articles have offered management strategies for combating the disease other than rogueing symptomatic plants. In the few cases where control recommendations have been made (such as the use of miticides); the recommendations were based on observations made for other virus diseases of roses or on virus diseases and/or eriophyid mites on other crops. Published research that has investigated methods for managing rose rosette in different aspects of rose culture (propagation and production nurseries, retail centers, landscape beds, etc.) is limited.

## SYMPTOMS OF ROSE ROSETTE VIRUS INFECTED PLANTS

Rose rosette symptoms are complex and variable as plants of the same cultivar may have different symptoms at the same or different location(s). The role that variable genetics within the virus population, environmental influences such as time of season when a plant becomes infected, or plant age at time of infection, is unknown. The variable symptoms associated with rose rosette make diagnosis difficult and rose rosette may be confused with herbicide damage. Often reddening of a rose stem due to rose rosette is difficult to detect among healthy, red young foliage (red flush) of other plants within the rose bed (Fig. 1). However, foliage of roses infected with RRV maintained red pigmentation for the life of the foliage whereas foliage of healthy roses turn green in 3-4 weeks.

Fig. 1. (A) Rose plant symptomatic with rose rosette (arrow) nestled within a bed of asymptomatic and presumably healthy Knock Out® plants. (B) An infected, symptomatic cane within container Drift® roses may go undetected if growers are not vigilant.

In spring and fall, many healthy roses have reddened foliage. When roses are infected with RRV, the foliage may be red throughout the summer (Fig. 2A). Diseased roses may also have strapped (unusually long, thin) leaves. However, in some plants, little red pigmentation is obvious (Fig. 2B). Increased thorniness and flattening of stems (fasciation) is often observed (Fig. 2C), but may be absent in symptomatic tissues (Fig. 2B). Canes may become a large mass of distorted shoots (witches' brooms) (Fig. 2D).

Rose bushes will decline and begin to die from rose rosette 3-4 years after infection (Fig. 3). Large plants in the south may last a few years longer. Cane mortality is usually observed in spring when symptomatic canes fail to push out new foliage since canes with rose rosette symptoms appear to be more susceptible to winter-kill/desiccation. Low starch reserves in symptomatic canes may be responsible for decreased spring growth and ultimately death of plants. Infected roses may have diminished root systems which may be a result of decreased carbohydrate storage. Large commercial plantings or private rose gardens can be decimated by rose rosette if the disease is left unchecked.

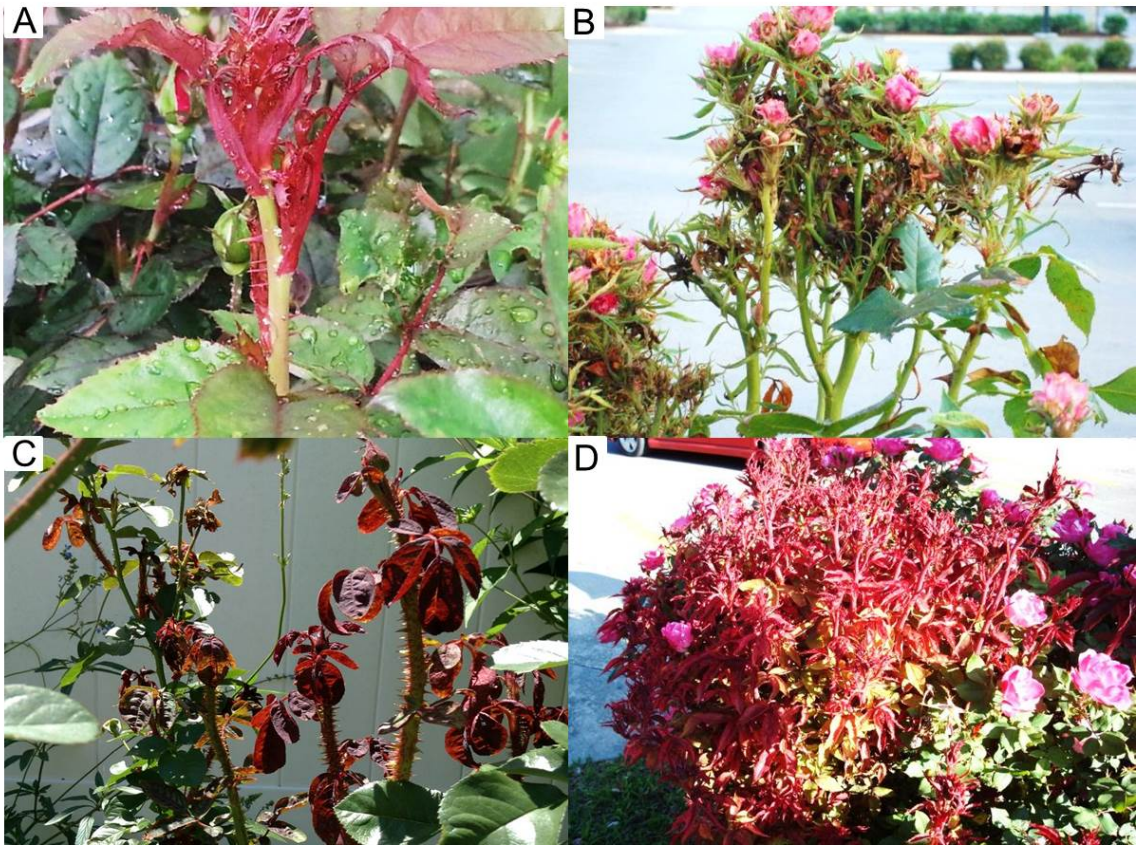


Fig. 2. (A) Reddening of a stem infected with rose rosette; note the thin, elongated leaves and the unusually thickened cane (stem) with increased number of thorns (pickers). (B) In some infected canes, foliage stays mostly green and may or may not display increased thorniness. (C) Increased thorniness is common in many plants symptomatic for rose rosette and may be accompanied with flattened stems (fasciation). (D) Masses of shoot proliferation (witches' brooms) are often associated with plants that are very susceptible or have been symptomatic for more than one year. These witches' brooms may become so large (larger than a bushel basket) that the plant cannot support them and the plant may fall over.


Fig. 3. (A) Death of these rose bushes will occur 12 months to 3 years after first symptoms were apparent depending on age and susceptibility. (B) If left unchecked, rose rosette will destroy entire beds of roses. Spread may appear slow at first due to long latent periods in newly infected plants. It is common for incidence of symptomatic roses to remain low in a large bed of newly planted roses for 1-2 years and in the next year, have nearly all plants become rapidly symptomatic.

**SPREAD OF ROSE ROSETTE**

Rose rosette virus is transmitted by an eriophyid mite. Although these mites are wingless, they may "balloon" in air currents, as do dust particles, and thus can be spread long distances. However, the closer a rose is planted to a rose infected with RRV, the more likely it is to become infected. In observations in Tennessee, rose beds located near a source of RRV have a pronounced edge effect (the roses nearest the source are more likely to become infected with the disease than roses located on the opposite side of the bed). Distribution of initially infected plants in a large rose bed will appear random if the plants were infected prior to planting or if there is a great distance between the rose planting and the inoculum source of RRV.

**MANAGEMENT OF ROSE ROSETTE**

Roses should be inspected for symptoms of RRV before being used for propagation or planting. If possible, a PCR test for RRV should be conducted. Most testing is done by the plant diseases diagnostic labs at Texas A&M University and Oklahoma State University. Even if the plants you select for purchase are free of rose rosette symptoms, you should inspect all roses at the nursery. If some are symptomatic, it would be best to buy elsewhere where all roses appear to be healthy. If you observe rose rosette symptoms on a few roses at a nursery, there are likely to be more infected, but asymptomatic (latent infections) roses at that location.

Once roses are transplanted, plants should be inspected regularly for symptoms of rose rosette. Symptomatic plants should be rogued as soon as possible since infected plants may harbor large populations of eriophyid mites that may spread RRV to other roses. Rogued plants should be bagged at the site of removal and not dragged through the garden or left piled near the garden.

At the Beall Family Rose Garden (200 bush garden located within the University of Tennessee Gardens), plants are inspected several times a week for symptoms of rose rosette. Roses are rogued at first observation of symptoms. Over a 5-year period, the garden has annually lost 2 to 4% of its roses to rose rosette. However, no rose adjacent to a rose that was rogued has developed symptoms of rose rosette. Since the garden's plan calls for replacement of 5% of its roses annually to keep the garden up-to-date and "fresh," losses of roses due to RRV have not been noticeable by garden patrons. The key

to success for a management plan based on rogueing is early detection of symptomatic plants and immediate rogueing of diseased roses.

Several publications on the web have suggested using miticides and/or pruning out of symptomatic canes to eliminate RRV or reduce its incidence. There are no research data available to support either of these suggestions although research is underway to determine if these potential management strategies are effective.

Since eriophyid mites "balloon" in the air instead of being active flyers, a barrier placed between a rose planting and a possible source of eriophyid mites and RRV may reduce incidence of RRV in a rose garden. Barriers of *Miscanthus sinensis* (Chinese or Japanese silver grass) will reduce incidence of RRV in plantings of roses when compared with incidence of RRV in rose plantings without barriers.

## RESISTANCE TO ROSE ROSETTE VIRUS

Although all known cultivars of roses used commercially are considered to be susceptible to RRV, some species of roses have been reported to be resistant to RRV or transmission of RRV by eriophyid mites. Some rose species have been reported as resistant to RRV. However, these reports have been made by observing roses in gardens and not through replicated testing. Roses that have been reported as resistant are: *R. setigera*, *R. acicularis*, *R. arkansana*, *R. blanda*, *R. palustris*, *R. carolina*, and *R. spinosissima*. The interspecific hybrid, 'Stanwell Perpetual' (*R. spinosissima* and *R.* × *damascena*) is susceptible to RRV (Bruce Monroe, pers. commun.). Therefore progeny of crosses made with resistant roses may not be resistant. There is a critical need to test rose species for resistance to *P. fructiphilus* and rose rosette virus in controlled, replicated experiments. These types of experiments will be conducted over the next 3-5 years by a combined team from Texas A&M University, University of Delaware, University of Tennessee, and Star Roses (West Grove, Pennsylvania).

## FUTURE OF ROSES AS IMPACTED BY ROSE ROSETTE VIRUS

More roses will succumb to RRV before short term and long term management plans can be developed growing roses at the propagation, wholesale, retail, and landscape levels. Asymptomatic, infected rose are apparently moving undetected in the nursery trade. Rose rosette will continue to spread into new areas providing the climates in those areas are conducive for supporting populations of multiflora roses or other rose species able to function as a reservoir for both RRV and *P. fructiphilus*. However, a newly funded USDA Specialty Crops Research Initiative grant proposal for developing short and long term measures to combat RRV was recently funded and will combined the multidisciplinary talents of 19 scientists at state, federal, and private labs. Short term strategies to reduce the impact of RRV on the rose industry will be developed while the team works to develop resistant *Rosa* germplasm for use in long term solutions to rose rosette.

## ACKNOWLEDGEMENT

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# Mulch Type and Depth Influences Weed Control on Three Major Weed Species in Nursery Container Production©[1]

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## SIGNIFICANCE TO THE INDUSTRY

A number of factors over the past several years have forced container-grown plant producers to alter production practices. Increasing labor cost and new immigration laws have forced growers to rely more on herbicides for weed control. Problems associated with herbicide use in container production include non-target loss, achieving correct calibration, and the expense of repeat applications a year (Case and Mathers, 2006). Non-chemical weed control methods could diminish non-target herbicide loss and reduce potential environmental concerns. Data from this study reveals that one application of various mulch species at a depth of at least 5 cm (2 in.) will provide long-term control of spotted spurge, phyllanthus, and eclipta.

## INTRODUCTION

Weeds have been noted to cause major problems in container crop production by reducing the crop value through competitive effects (Berchielli-Robertson et al., 1990) and reducing marketability due to demands for weed free plants (Walker and Williams, 1989). Numerous researchers have reported that only one weed in a small container (trade gal. or 1-gal.) could affect the growth of a container crop (Berchielli-Robertson et al., 1990; Fretz, 1972; Walker and Williams, 1989) but this is highly variable depending on both the crop and weed species. Fretz (1972) reported that one planted red-rooted pigweed (*Amaranthus retroflexus*) resulted in 47% reductions in growth of a trade-gallon container-grown *Ilex crenata* 'Convexa' and one-trade-gallon container-grown *I. crenata* 'Convexa' and one crabgrass (*Digitaria sanguinalis*) reduced the growth of *I. crenata* 'Convexa' up to 60% when compared to the weed free control. One eclipta plant (*Eclipta prostrata*) was observed to have the ability to reduce the shoot dry weight of *Rhododendron* 'Fashion' (Berchielli-Robertson et al., 1990). With the extent of loss from weeds plainly observed and researched, it comes without questioning why concerned nurseries sometimes spend as much as $4000 per acre to control weeds (Pellet and Heleba, 1995). This seems like an egregious amount of money; however, marketability for container crops can be directly associated with the demand for weed-free plants (Simpson et al., 2002).

The necessity to control weeds in container production has driven two practices in container production, hand pulling and herbicide applications. Hand weeding is an increasingly expensive option to do increasing labor cost (Gilliam et al., 1990) and further complicated by new immigration reforms. To reduce the need for hand pulling, nursery growers typically apply preemergence herbicides 3 to 5 times annually. Problems associated with herbicide applications in container production include non-target herbicide loss (Case and Mathers, 2006). This problem is further convoluted with increased container spacing at the time of application. Porter and Parish (1993) showed 12 and 23% non-target loss on trade-gallon containers when configured in a hexagonal pot-to-pot configuration and square pot-to-pot configuration, respectively. Gilliam et al. (1990) reported similar results in that non-target losses ranging from 51 to 80% when herbicides were applied to trade-gal containers spaced 18 to 30 cm on center. Increasing demand for instant landscapes and large container production has led to many growers to begin producing more crops in 7-gal containers and larger. Weed control practices differ from that used in smaller container production. Increased herbicide non-target loss between the large spacing required for large container production renders herbicide

[1] First Place – Graduate Student Research Paper Competition.

applications inefficient and raises environmental concerns.

Mulches have proven to be an effective non-chemical alternative for weed control in large containers. Several criteria must be met in order for a mulch to be considered effective. Effective mulches must be readily available, inexpensive, and acceptable to consumers. Waste products were a focus for many years in mulch research. Products that would normally be sent to a landfill such as newspaper or tires have been evaluated as mulches (Pellet and Heleba, 1995). Smith et al. (1997) reported that newspaper pellets at 2 in. depth controlled spurge in the landscape for at least 60 days. However, waste paper has been shown to reduce available nitrogen when applied to a container's surface as mulch (Glenn et al., 2000). Ground tires were used in a separate study to provide good initial control, but weeds gradually began to penetrate the barrier after 2 months (Calkins et al., 1996). Fabric disk over various materials have also been researched but have found limited success do to voids around the seams or being blown away by winds (Appleton and Derr, 1990). For the most part, waste product mulches have been deemed ineffective due to limited availability and consumer acceptability.

Tree derived mulches such as chipped cedar, pine-bark mini-nuggets, and Douglas fir have widespread availability, reasonable consistency, and acceptable by consumers (Llewellyn et al., 2003). Pine-bark mini-nuggets, as with other tree-derived mulches, create an environment that is not conducive to weed germination due to low fertility, large particle size, and hydrophobic properties (Richardson et al., 2008). Case and Mathers (2003) reported good long container term weed control mulched with Douglas fir and pine-bark nuggets in combinations with either acetochlor applied at 2.5 lbs ai/A, flumioxazin at 2.0 lbs ai/A, or oryzalin at 2.0 lbs. ai/A. Neither oryzalin nor flumioxazin provided long term control when applied alone, but pine-bark nuggets did provide good long term control. Other readily available tree-derived mulch species such as Chinese privet, sweetgum, and eastern red cedar could be used as mulch in container production in lieu of commercialized pine bark mini-nuggets.

The objective of this study was to evaluate four readily-available mulch species at multiple depths for long term weed control and phytotoxicity in nursery crops grown in large containers. The four species tested were Eastern red cedar (*Juniperus virginiana*), ground whole loblolly pine (*Pinus taeda*), Chinese privet (*Ligustrum sinense*), and sweetgum (*Liquidambar styraciflua*). Mulch treatments were evaluated with and without dimethenamid-p herbicide (Tower®).

## MATERIALS AND METHODS

This study is currently being observed at the Paterson greenhouse complex of Auburn University in Auburn, AL. The experiment was initiated 19 April 2014, Eastern red cedar, loblolly pine, Chinese privet, and sweet gum trees, 10 to 20 cm (4 to 8 in.) in diameter measured at 30.5 cm (12 in.) from the soil, were harvested. Only the trunk portions of these trees were used to provide mulch. Harvested trees were chipped with a chipper on 23 April 2014. Along with these four mulches, pine bark mini-nuggets were included (Pine Bark Mini-Nuggets Landscape, Garick, LLC. Cleveland, Ohio) to provide a commercially comparative mulch treatment. Particle size distribution was determined with a series of screens (Fig. 1). Treatments consisted of a factorial arrangement of five mulches (eastern red cedar, loblolly pine, Chinese privet, sweetgum, and pine-bark min-nuggets), three mulch depths (1, 2, and 4 in.), and two herbicidal treatments [No herbicide and dimethenamid-p (Tower)]. Two additional treatments were a non-treated control (no mulch with no herbicide) and a no mulch with herbicide for a total of 32 treatments. Three weed species (long-stalked phyllanthus (*Phyllanthus tenellus*), eclipta (*Eclipta prostrata*), and spotted spurge (*Euphorbia maculata*)) were tested, each receiving all 32 treatments. Each treatment was replicated five times for a total of 60 pots per weeds species (note: there are three mulch depth treatments within each mulched container). The study was arranged in a complete random design within each weed species.

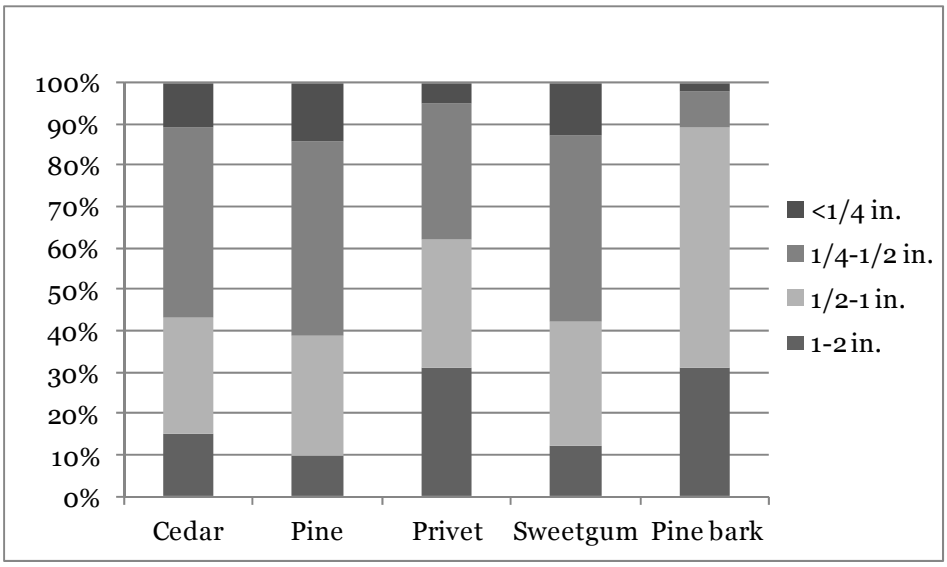


Fig. 1. Particle size distribution by mulch species.

On 26 May 2014, 15-gal containers were filled 12.7 cm (5 in.) from the top with a substrate that was 6 pine bark and 1 sand (v/v) amended per cubic yard with 2.3 kg (5 lbs.) dolomitic lime, 6.4 kg (14 lbs.) of Polyon® 18-6-12 (Pursell Technologies, Sylacauga, Alabama) and 0.7 kg (1.5 lbs.) Micromax® (Scotts Co., Maryville, Ohio). Pots were placed on the nursery pad and irrigated twice daily for 3 days with 2.5 cm (1 in.) of water to allow for settling and accurate adjustment of substrate depth. Tower was then applied at 30 fl. oz./A to the herbicide designated pots as a liquid application (30 gal/A) with a $CO_2$ pressure backpack sprayer. The space at the top of the pots was to allow space for dividers. These dividers consisted of untreated plywood cut, grooved, and glued to divide the pots into thirds. Each third of the pot was seeded with 10 seeds of long-stalked phyllanthus, eclipta, or spotted spurge applied to the surface of the media on 31 May 2014. The three partitions of each pot were designated one of the three mulch depths so that each pot contained 2.5, 5.1, and 10.2 cm (1, 2, and 4 in.) of mulch. Mulch was spread also on 31 May 2014.

Weeds were allowed to grow for exactly 30 days after seeding. At this time, weeds, if any, were counted, clipped at the mulch or substrate surface, and fresh weights were taken. These data were expressed as percent reduction relative to the non-treated control. Thus, a "0" control indicated equivalency to the control (100 = no weed growth). One week after weed harvest, the containers were sprayed with paraquat dichloride (Gramoxone® Inteon by Syngenta) to kill any remaining weeds. One week after this treatment, pots were reseeded accordingly on top of the mulch with 10 seeds of the designated weed species. To test the longevity of weed control, this process was repeated three times during the summer of 2014. Data was subjected to analysis of variance using SAS which reflected the factorial treatment arrangement.

In conjunction to the weed control study, snowball viburnum (*Viburnum macrocephalum*) and wax leaf ligustrum (*Ligustrum japonicum*) up sized from a 1-gal. containers to 7-gal containers on 31 May 2014 to determine if the mulch species or depth caused phytoxicity injury to either species. These 1-gal container plants were transplanted in 7-gal containers filled with the same substrate used in the weed control study, leaving 10.2 cm (4 in.) from the top of the containers. Treatments consisted of the aforementioned mulches, two mulch depths [5.1 and 10.2 cm (2 and 4 in.)], two levels of dimethenamid-p (Tower) (no herbicide and herbicide), for each of the two ornamental species for a total of 22 treatments (including control and herbicide with no mulch). Each treatment was replicated 5 times for a total of 110 pots per ornamental species. The study was arranged

in a complete random design within each ornamental species and arranged in a factorial arrangement. Tower was applied as previously described as a directed spray to the media surface on 2 June 2014. The containers were then mulched with the designated treatments on the same day.

Phytotoxicity ratings were taken by two researchers and their ratings averaged. The rating scale was numbered 0 to 10 with 0 being no observed injury and 10 being an observed dead plant. Ratings were taken at 30, 60, 90 DAT and will be recorded again at 120 DAT with plant growth indices (height × width × perpendicular width) also taken at 120 DAT.

**RESULTS AND DISCUSSION**

In the weed control portion of this study at 30-d after seeding, mulch depth was shown to have the most influence on both weed counts and weed fresh weights. Data for the first round of this study was taken 30 June 2014. Mulch type only had a significant effect on weed counts of long-stalked phyllanthus and no other significance (Table 1). Mulch depth and Tower herbicide treatments revealed significance across both spotted spurge and phyllanthus on weed count and weed fresh weight. All treatments other than the non-treated control exhibited complete eclipta control and, therefore, it was excluded from Table 1.

After the data were collected from round 1 of the experiment, all containers received a burn down treatment of Gramoxone (paraquat) to kill and non-target or remaining weeds. The containers were then reseeded with 10 seeds per partition of each container with seeds scattered on top of the mulch on 18 July 2014. Thirty one days after seeding, the weeds were counted and fresh weights were taken. Round 2 of the experiment showed that the preemergent herbicide, Tower, had seemingly lost all activity and showed no significant reduction in weed count or fresh weight in comparison to the control treatment (Table 2). Mulch species was revealed to have significance differences on spotted spurge weed counts. Pine-bark mini-nuggets, sweetgum, and privet mulches had control percentages of 94, 93, and 91%, respectively, when compared to the control treatments. On the other hand, cedar and ground whole loblolly pine had 83 and 74% control, respectively, when compared to the control treatments. Depth of the mulch treatments, across all species, showed significance in both weed count and fresh weight with the exception of eclipta, with which no significance was observed in fresh weight. Treatments with 2.5 cm (1 in.) of mulch reduced the weed fresh weight of spotted spurge by 80.3% when compared to the treatments of no mulch with no herbicide and the treatments of no mulch with herbicide. Treatments with 5.1 cm (2 in.) of mulch reduced the foliage fresh weight of spotted spurge by 99.7% and treatments with 10.2 cm (4 in.) of mulch were observed showing complete control of spotted spurge.

Table 1. Round 1: Analysis of variance for weed control as determined from seedling counts and fresh weight.

| Source of variation | Spotted spurge | | Phyllanthus | |
|---|---|---|---|---|
| | Count | Weight | Count | Weight |
| | Probability | | | |
| 1. Mulch species | 0.0015 | NS | 0.01 | NS |
| 2. Depth | <0.0001 | 0.0002 | <0.01 | <0.01 |
| 3. Tower | NS | NS | <0.01 | <0.01 |
| 4. Mulch*Depth | NS | NS | 0.03 | NS |
| 5. Mulch*Tower | NS | NS | NS | NS |
| 6. Depth*Tower | 0.03 | NS | <0.01 | <0.01 |

Data was collected for Round 1 on 20 June 2014, 30 days after seeding on 30 May.

Table 2. Round 2: Analysis of variance for weed control as determined from seedling counts and fresh weight.

| Source of variation | Spotted spurge | | Phyllanthus | | Eclipta | |
|---|---|---|---|---|---|---|
| | Count | Weight | Count | Weight | Count | Weight |
| | Probability | | | | | |
| 1. Mulch species | 0.0015 | NS | NS | NS | NS | NS |
| 2. Depth | <0.0001 | 0.0002 | <0.0001 | <0.0001 | 0.01 | NS |
| 3. Tower | NS | NS | NS | NS | NS | NS |
| 4. Mulch*Depth | NS | NS | NS | NS | NS | NS |
| 5. Mulch*Tower | NS | NS | NS | NS | NS | NS |
| 6. Depth*Tower | 0.03 | NS | NS | NS | NS | NS |

Data was collected for Round 2 on 18 Aug. 2014, 31 days after seeding on 18 July.

The phytotoxicity test on snowball viburnum and was leaf ligustrum have shown no observed injury 30 and 60 days after treatment (DAT). Pending 90 and 120 DAT injury data and 120 DAT growth indices, we expect the current trend to continue and reveal that all treatments to both species of ornamentals cause no injury.

Data for the last of the three rounds of the weed control experiment will be taken on 1 Oct. 2014. It is expected that this data will follow the trend already taking place and that is that herbicide will no longer have any effect on weed counts or fresh weight and that mulch depth will have the main effect. As the mulches begin to degrade further, we do expect to see some difference in the mulch species based upon chemical differences between species.

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# Changes in Root Growth and Physical Properties in Substrates Containing Charred or Uncharred Wood Aggregates©[1]

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## INTRODUCTION

In recent years, biochar (BC) has attracted attention for use as a horticultural substrate amendment due to its potential benefits, such as promoting substrate/rootzone biology and nutrient holding/exchanging capacity. Biochar also has the potential to be a local and renewable substrate component produced from waste products and regionally available material (Peterson, 2013). The potential for horticultural use of BC in soilless substrates with greenhouse crops is clouded, however, because initial reports of BC in substrates do not show consistent results or benefits. There is a need to explore the impact of the vast range of BC properties on their potential use in greenhouse and nursery container production (Altland and Locke, 2012).

Biochar has been shown to be a potential use as a replacement for perlite in greenhouse mixes (Northup, 2013), because it is lightweight, porous, and it is thought to have potential economic benefit (cost savings) over perlite. Increased root growth has also been reported when BC was amended to a peat-based substrate (O'Hara, 2013); however quantification of increased root growth in biochar amended substrates has not been published.

To investigate the potential of using BC in greenhouse substrates, BC was produced with known/measurable parameters so that a definable and repeatable product was used in these studies. Mini-horhizotrons and rhizometers were used to quantify and observe root growth and changes in substrate physical properties amended with BC (Judd, 2013). The objectives of this study were: 1) to test the effects of BC and root growth on substrate physical properties over time, and 2) test the effects of BC amended substrate on plant root growth.

## MATERIALS AND METHODS

Loblolly pine trees (*Pinus taeda* L.) were harvested and hammer-milled to yield 6.35 mm pine-wood chips (PWC). A portion of this material was reserved to test physical properties, and the rest of the material was used to produce biochar at North Carolina State University. The BC production system used in this study was a top-lit updraft gasifier (Boyette et al., 2012). On 17 Apr. 2014, 1.5 $m^3$ of the PWC material was loaded into the gasifier reactor using a conveyor to insure level placement of the material. The PWC material was lit at the top inside the gasifier reactor, and then the reactor was quickly closed to control the gasification of the material. Combustion was sustained by regulating the amount of air entering from the bottom (500 $f \cdot min^{-1}$) and passing up through the material. A vent at the top of the reactor allowed combustible gas from the process to leave the system, and this gas was lit to reduce the amount of smoke produced. A temperature probe inside the reactor measured the internal temperature of the flame front and resulting BC as the front passes. The temperature of the flame front during this production was 720°C. Once the flame front reached the bottom of the gasifier, the air flow was shut off and compressed nitrogen gas was then fed through from the bottom for 24 h, prevent any flare up as the BC cooled. Once cooled, the BC was removed from the reactor and stored in 1.5 $m^3$ industrial bags under shelter.

[1] Second Place – Graduate Student Research Paper Competition.

**Rhizometers**
Three substrates were used: 4 peat moss and 1 perlite (PL) (v/v), PWC, or BC. All substrates were tested for initial pH and then amended with dolomitic limestone at 3.56 $kg \cdot m^{-3}$ to achieve a target pH of 5.8. Forty rhizometers were filled with one of the three substrates, with the same amount of substrate (≤5%), and tapped five times to achieve a similar bulk density in each rhizometer. Marigold (*Tagetes erecta* 'Inca Orange') plugs were planted into 20 of the packed rhizometers and the other 20 rhizometers were left fallow. Rhizometers were completely randomized in the greenhouse. Initial substrate physical properties indicated similar container capacity among the substrates; therefore all rhizometers were irrigated similarly by hand, as needed depending on weather conditions. Plants were fertilized at each watering with 200 ppm nitrogen with Peters Professional® 20-10-20 Peat-Lite Special (The Scotts Co., Marysville, Ohio).

Once a week [7, 14, 21 and 28 days after planting (DAP)], ten rhizometers were harvested, of which five had marigold plants and five were fallow. These rhizometers were then used in the NCSU Porometer method (Fonteno et al., 1995) to determine substrate physical properties, including total porosity (TP), container capacity (CC) and air space (AS). Data were subjected to the general linear model procedures (SAS Institute version 9.3, Cary, North Carolina). Means were separated by Least Significant Differences (LSD) at $P \leq 0.05$.

**Mini-Horhizotrons**
Three substrates were used: 4 peat moss and 1 perlite (PL) (v/v), pine-wood-chips (PWC), or biochar (BC). All substrates were tested for initial pH and then amended with dolomitic limestone at 3.85 $kg \cdot m^{-3}$ to achieve a target pH of 5.8. Four mini-Horhizotrons were divided in the center to separate each of the three chambers and allowed for one of the three substrates to fill the chamber. Previous work has been done to indicate the capability of the mini-horhizotron to have a different substrate in each chamber without significantly affecting root growth (Judd et al., 2014). Once filled, the divider was gently removed, allowing for each substrate to be united in the center, where one plug of tomato (*Solanum lycopersicum* 'Roma') was planted. Mini-horhizotrons were randomly placed on a greenhouse bench and irrigated similarly by hand as needed (since the CC of all three substrates was similar). Plants were fertilized at each watering as described above.

Root length measurements (cm) were taken on the three longest roots appearing on the clear side of each chamber every 3 DAP until 21 DAP. Each chamber has two measureable chamber sides (and six measured roots) for each substrate in one mini-horhizotron. At 21 DAP, the study was terminated and shoots were removed at the substrate surface in the mini-horhizotrons. The root balls in the mini-horhizotrons were removed and the different substrate sections were separated and roots removed/washed, in order to determine root mass within the specific substrate in which it was growing. Data were subjected to the general linear model procedures, and root length measurements were subjected to regression analysis. Means were separated by LSD at $P \leq 0.05$.

## RESULTS

**Rhizometers**
For the PL substrate, there were no differences between planted and fallow rhizometers for TP, CC, and AS at all of the measurement dates except at 7 DAP when planted rhizometers had increased CC and decreased AS compared to fallow rhizometers (Fig. 1; TP data not shown). For the PWC substrate, at 7 and 28 DAP the planted rhizometers had decreased AS compared to fallow, and at 14 DAP planted rhizometers had increased CC compared to fallow. For the BC substrate, there were no differences between planted and fallow rhizometers for TP, CC, and AS at all of the measurement dates. Comparing the planted rhizometers among the three substrates, the BC substrate was similar to the PWC substrate and greater than the PL substrate in CC at all measurement dates; and BC substrate was similar to PL substrate in AS at all measurement dates (Figs. 1A and B).

Comparing the fallow rhizometers, BC substrate was similar to both the PL and PWC substrates in AS; and for CC, the BC substrate was similar to PWC substrate.

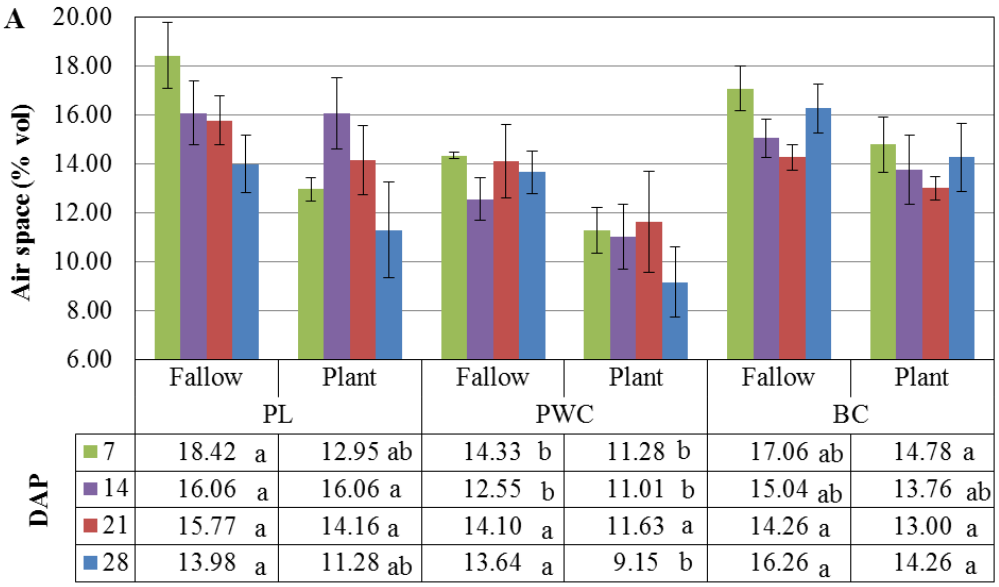


Fig. 1. (A) Air space for three substrates, 80% peat amended with 20% perlite (PL), pine-wood-chips (PWC), or biochar (BC) for both fallow and planted Rhizometers. (B) Container capacity for three substrates, 80% peat amended with 20% PL, PWC or BC for both fallow and planted Rhizometers. Standard errors bars are shown to represent means separation ($P \leq 0.05$). Tables below graphs show the means separation among substrates for fallow or planted Rhizometers, separated by days after planting (DAP).

**Mini-Horhizotrons**

In the beginning of the study, tomato roots growing in both the BC and PL substrate had greater root growth than roots in the PWC substrate (Fig. 2A). From 15 DAP until the end of the study, roots growing the in PL substrates were similar to the roots growing in the PWC substrate, however roots growing the BC substrates were longer than roots in the PWC substrate. Data from the dry weight analysis indicates that root growth was not different among the substrates at the termination date (21 DAP; Fig. 2B).

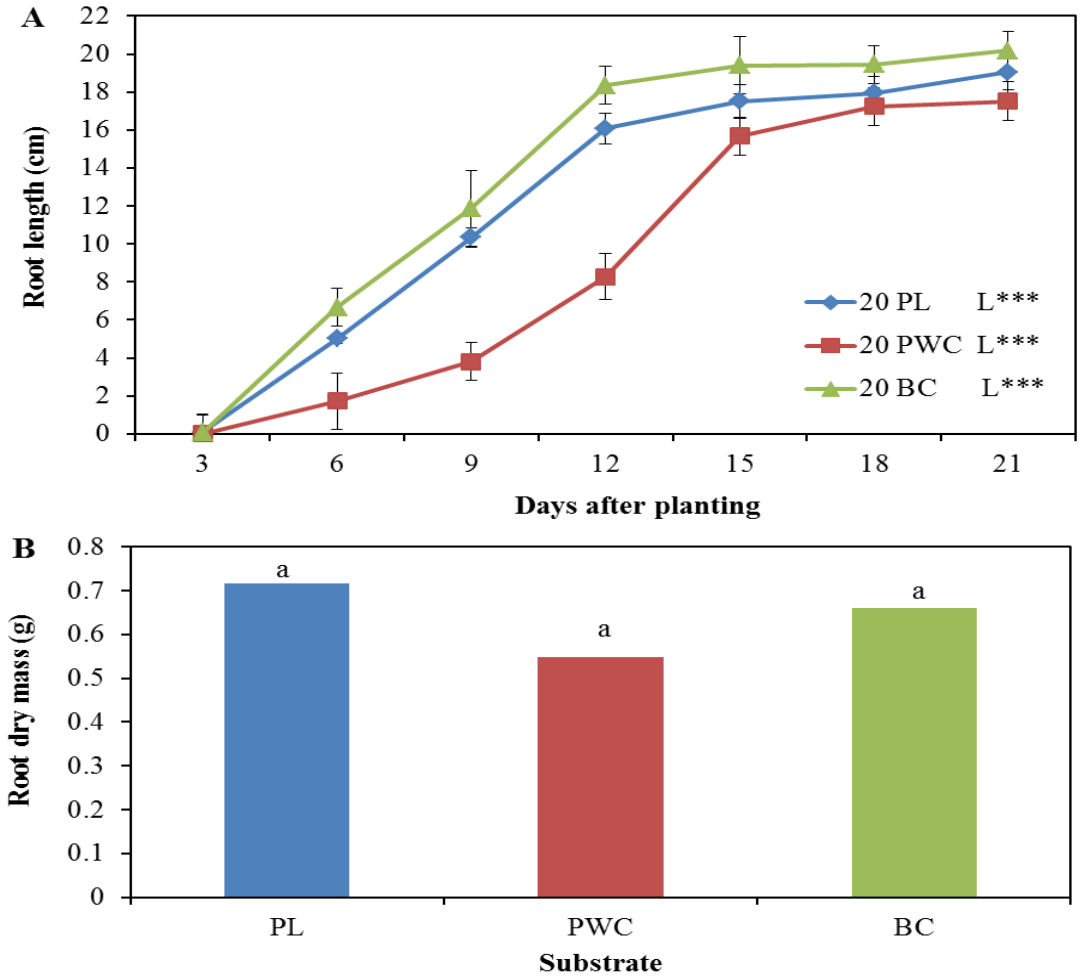


Fig. 2. (A) Root length measurements of tomato (*Solanum lycopersicum* 'Roma') plants in mini-Horhizotrons when grown in 80% (v/v) peat amended with 20% of perlite (PL), pine-wood-chips (PWC) or biochar (BC) with error bars representing means separation ($P \leq 0.05$). L*** represents significant linear effects when $P \leq 0.001$. (B) Root dry mass of tomato plants grown in mini-Horhizotrons, means separated across substrates by Least Significant Difference (LSD; $P \leq 0.05$), and same letter indicates means are not significantly different.

## DISCUSSION

Data from the substrate physical properties provide evidence that peat amended with BC at 20% (v/v) creates a comparable substrate environment as when amended with PL or PWC. Substrate settling due to irrigation seemed to have a greater effect on substrate physical properties than the marigold roots, due to the physical properties in both the fallow and planted rhizometers increasing/decreasing at the same rate. There were observable differences in root growth along the clear chambers of the mini-Horhizotron, with greater root growth in BC substrate compared to roots in the PWC substrate. This could be due to the charring process, as there may be a potential organic compound in charred material that promotes root growth (Kochanek et al., 2014).

This work provides additional evidence of the potential use of biochar in greenhouse substrates for crop production. This study indicates that BC can blend with peat similar to perlite and produce substrates with similar physical properties. Tomato roots growing in the 20% BC substrate were similar in length to roots growing in the PL substrate, indicating that BC may be suitable as a PL replacement. Biochar has other potential

advantages over PL, such as opportunity to sequester carbon (Dumroese et al., 2011), possible lime reduction/replacement for pH modification (Northup, 2013), and using unstable or waste materials as a feedstock to produce a beneficial amendment.

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# The Japanese Maple Collection at SFA Gardens©

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The generally accepted origin of all maples is central China, primarily in Hubei, Sichuan, and Yunnan provinces (Gelderen, 1994). Over 100 million years ago, the family *Sapindaceae* (syn. *Aceraceae*) radiated from there, moving westward, southward, and to the northeast, the latter trek taking maples into eastern Siberia and ultimately into North America. Most abundant during the Miocene from 25 to 5 million years before present, the range of maples was greatly reduced into the present day temperate regions with the ice age which began about 5 million years ago. While there are a few tropical maples, most of the 150 species today can be found in temperate regions. Rarely abundant, the species is often sympatric — that is, several maple species often reside in the same habitat without crossing. That paints the picture that leads our discussion to one maple species, a group we call the Japanese maples.

Japanese maples typically describes the cultivars of *Acer palmatum* and *Acer japonicum* (fullmoon maple). Although there are two dozen additional species in Japan (more if you count introduced species), these two species have received the most interest and use. In both, but especially in *A. palmatum*, there's a tendency to sport or produce unique seedlings — thus the increased pace of cultivar introductions. Like so much in horticulture, the temptation to name, propagate, distribute and promote a "new" plant, is just too much.

The definitive text for Japanese maples is by J.D. Vertrees, a Timber Press publication, now in the fourth edition (Vertrees, 2009). With the death of Vertrees in 2003, the more recent versions have been coauthored and amplified by Peter Gregory, who is the retired manager of the world-famous Westonbirt Arboretum in Gloucestershire, England. Gregory and Hugh Angus (who recently retired as Head of Collections at Westonbirt) visited Stephen F. Austin State (SFA) Gardens in November 2010. This was a rare opportunity for our garden to capitalize on maple experts who have enjoyed long careers with attention to this genus, the cultivars, and the nuances of growing maples. For a broader understanding of Japanese maples and related species, readers are encouraged to review an *Illustrated Guide to Maples* (Le Hardÿ de Beaulieu, 2003).

Cultivars are typically divided into eight groups: palmate, dissectum, deeply divided, linearilobum, dwarf, semi-dwarf, variegated, and unusuals. This is an arbitrary delineation. From small trees, to shrubs, to small dwarfs, there's a cultivar for anyone's taste. The big bold palmate types hold up better in the heat of a Texas summer, while the highly dissected types tend to leaf burn in summer. There are variegated cultivars. In Japanese, markings on the leaf are called "fu" with over 20 kinds of variegation described. With many variegated cultivars, there's some tendency to revert, easily controlled with a snip or two.

## STEPHEN F. AUSTIN GARDENS

Stephen F. Austin (SFA) Gardens comprises 58 ha (128 acre) of on-campus property at Stephen F. Austin State University, Nacogdoches, Texas. Tree, shrub, and herbaceous perennial evaluation at SFA Gardens is scattered across gardens and landscapes. Nacogdoches is Zone 8b with an average annual rainfall of 1219 mm (48 in.). June through August is characteristically hot and dry. In recorded history, 1 Sept. 2000 was the record high, 44.4°C (112°F), and 23 Dec.1989 was the record low -17.8°C (0°F). Soils are generally well drained, slightly acidic, and the native flora is dominated by pine, oak, river birch, sweetgum, sycamore, Florida maple, hornbeam, elm, hackberry, pecan and hickory.

## CULTIVARS

Dirr described over 40 Japanese maple cultivars in the *Manual for Woody Landscape Plants* (Dirr, 2009), but a conservative estimate of cultivars currently available in the trade exceeds 1000. Stephen F. Austin Gardens is home to 454 *A. palmatum* and *A. japonicum* trees (Stump, 2014). The nomenclature of Japanese maples is confusing with many plants we have purchased later proven not true to type. For red foliage color, we favor (Amoenum Group) 'Bloodgood', (Matsumurae Group) 'Chitoseyama', (Amoenum Group) Fireglow', (Matsumurae Group) 'Moonfire', 'Hefner's Red', (Amoenum Group) 'Osakazuki', (Amoenum Group) 'Oshio-beni', (Palmatum Group) 'Shaina', (Matsumurae Group) 'Trompenburg', (Dissectum Group)'Tamukeyama', and (Amoenum Group) Red Emperor™ Japanese maple. Other desirable cultivars include: (Palmatum Group) 'Orange Dream' and (Amoenum Group) 'Tsuma-gaki' for unique foliage color in the spring, (Dissectum Group) 'Seiryū' for a cutleaf that develops into a strong small tree, (Dissectum Group) 'Orangeola' as a durable shrub dissectum, 'Tsukasa Silhouette' as uniquely fastigiated, 'Ryusen' as a fast growing weeping form, and, finally the coolest toadstool forms ever, any of the 'hime' cultivars: (Dwarf Group) 'Yuri-hime', (Dwarf Group) 'Oto-hime', (Dwarf Group) 'Shishio-hime', or (Dwarf Group) 'Tama-hime' (syn. 'Yatsubusa Tamahime'). Over many years, we have concluded that full moon maples are a bit difficult in our climate, prone to slow growth and leaf burn. However, *Acer japonicum* 'Vitifolium' has reached good stature and its fall color has been a striking red/orange.

## CULTURE

At SFA Gardens, the strategy for over 25-years has been to either buy small plants via various mail order nurseries or acquire graft wood and propagate them ourselves. We then grow them for 1 to 2 years in containers. Cost is a major reason for that strategy. Large containerized Japanese maples can be expensive. Another reason is the fact that very few cultivars are offered in the South in retail or wholesale nursery outlets. In our region, sunlight and exposure has a large impact on Japanese maple survival, growth and performance. In east Texas, full morning sun is preferred. Full exposure to a western sun can be deleterious. Cultivars that feature variegated foliage or highly dissected leaves need additional protection. After locating the tree, think soil drainage. Japanese maples like well drained humus-rich soils and we have learned through experience that planting on a slight berm or knoll is best. At SFA Gardens we rarely dig a hole more than half the container root ball depth, choosing instead to plant high and then mound up around the plant, following that with heavy mulch except near the trunk itself. Japanese maples are tolerant of sands to clays, preferring slightly acidic soils. Develop an irrigation plan for the critical establishment years. At SFA Gardens, we utilize drip or sprinkler irrigation. Either works well. Once established, Japanese maples are amazingly drought tolerant in our Pineywoods region. When it comes to pruning, we usually say why? The tree's natural form is the goal. Cut away any shoots that arise from below the graft and, yes, you can remove a damaged limb or low hanger if you wish — but put away the saw. Whatever you do, don't try to hack your way to a meatball or cube — the maple police may come calling.

## PROPAGATION

We collect seed in the fall from various cultivars when they first show a brown hue and then stratify for approximately 120 days. Most improved cultivars are grafted; some can be rooted. There is controversy on own rooted cultivars. Some report that the own rooted plants are weak and that vigorous rootstocks are important to the growth rate and performance in the landscape. That has not been our experience. For example, we have about a dozen "hime" cultivars, small toadstool forms, that are own rooted and they have grown into sizeable specimens of good health. Still, the general recommendation remains that cultivars should be grafted on vigorous *A. palmatum* seedlings. Dwarf cascading types can be grafted high which costs more but leads to interesting form and structure.

## CONCLUSIONS

Japanese maples are becoming increasingly popular in Southern USA landscapes. Twenty-five years ago, they were rarely encountered in Texas or Louisiana retail outlets. If available, they were often listed as “red” or “green”. Today, Japanese maple cultivars are widely available in garden centers, although the diversity of cultivars available remains low. The showcase of Japanese maples at SFA Gardens has impacted the popularity of the species in our region. The collection is comingled with a large collection of azaleas, camellias and other small flowering trees under a high canopy forest composed primarily of loblolly pines.

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# Development and Application of Foliar Applied Rooting Solutions©

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## INTRODUCTION

To propagate plants from cuttings, Kees Eigenraam told me about the 'foliar' (leaf) application of rooting solutions with Rhizopon products. That was in 1989 when I came to know Kees. Our introduction was associated with my company, Hortus USA, importing his Dutch Rhizopon plant rooting products into the USA.

In those pre-Goggle Scholar days, I did extensive book and journal reading about plant propagation. Nowhere could I find a reference to 'foliar' use. Before growers used foliar methods for applying rooting hormones, plant propagation from cuttings was limited to basal methods. While he had written information, few growers outside Kees' Dutch and European customers knew of foliar methods.

Foliar application of rooting solutions has a recent history. The earliest extensive study was Davies' histological and physiological research comparing root formation in juvenile and mature cuttings (1978, 1980, 1982). Davies and Joiner (1980) found foliar application of water base IBA rooting solutions to be effective to induce roots. Kees developed the first commercial foliar methods in 1985. At the time, Kees did not know the research by Davies. The first commercial users were Dutch growers propagating chrysanthemum cuttings.

## SPRAY DRIP DOWN METHOD AND TOTAL IMMERSE METHOD

Lacking other names and basic information, I termed the 'Spray Drip Down Method' and the "Total Immerse Method". Over the years, Kees and I improved and documented the methods. Now, growers worldwide use the methods to propagate many types of plants from cuttings with water base indole-3-butyric acid (IBA) rooting solutions. IBA is the most useful rooting hormone. For plants suitable to be propagated from cuttings, growers apply the solutions to leafy cuttings of annual, perennial, and woody plants in the active growing state. Compared with other propagation methods, foliar methods have improved rooting quality, reduced misses, reduced labor cost, and lower rate application savings.

The Spray Drip Down Method is used by annual plant growers such as Dummen's Red Fox rooting stations and Yoder Chrysanthemums, perennial plant growers such as Aris Green Leaf Plants and Keepsake Plants, and woody plant growers such as Bailey Nurseries. The Total Immerse Method is used with tissue culture plantlet transplanting at the greenhouse stage. Total Immerse is also used on large homogenous crops such as *Hedera* (ivy) and pot roses (*Rosa*).

## FOLIAR AND BASAL METHODS

I know of five foliar and basal methods to propagate plants from cuttings. I do not advocate use of foliar methods all the time. Depending upon the plant variety and season, basal methods are sometimes better. Some plant taxa, such as selected cultivars of chrysanthemums, are propagated by both foliar and basal methods in the same facility in parallel.

### Basal Methods

Three methods are used to apply rooting hormones to the basal end of cuttings. The methods are used all year, on leafy and leafless cuttings, in the active growing and dormant states. The Basal Dry Dip Method use rooting hormone powders, and the Basal Quick Dip and Basal Long Soak Methods use rooting solutions.

**Foliar Methods**
Two methods are used to apply rooting hormones to the leaves of cuttings taken in the active growing state. The methods are not used on leafless or dormant cuttings. The Spray Drip Down and Total Immerse Methods use water base IBA rooting solutions.

**Basic Foliar Practice**
Growers take leafy cuttings from stock plants in the active growing state since there must be internal sap flow. Dormant cuttings are not used since there is limited metabolic activity and restricted sap flow and vascular uptake. Leafless cutting have no "leaf" entry points. A water base IBA solution is applied to leaves which enters the plant's vascular system through open pores in leaves via stomata. Stomata are open in a temperature range of 16-32°C (60-90°F), provided cuttings are well hydrated.

## SCIENTIFIC STUDIES RELATING TO FOLIAR APPLICATION

**Efficacy**
Davies and Joiner's study (1980, 1982) demonstrated the efficacy of foliar application of water base IBA rooting solutions to induce rooting.

**Substances Used**
The natural occurring auxins, IAA and IBA, induce root formation. Endogenous IBA and IAA are both produced in shoot apices and young developing leaves. Through *B*-oxidation in the cutting, IBA is converted to IAA to enhance rooting (Hartmann et al., 2011). IAA is unstable in solution and sensitive to light. Hence, the more stable, water base IBA solutions are best used for foliar applications.

**Carrier Needed**
Water is the universal solvent in plants. Special formulations of IBA can be made into water base rooting solutions. Water base IBA solutions are suitable to apply by foliar methods. While IBA is insoluble in water, it is soluble in alcohol. The alcohol base solutions should not be used for foliar methods, alcohol can cause foliar burning or 'alcohol burn' which is detrimental to the cutting.

**Entry Point of the Solution**
The entry point of applied IBA into the plant is though stomata and also run-off accumulation at the base of the cutting. While mostly found on the underside of leaves, stomata can also be found on other plant parts including upper leaf surfaces, stems and specialized structures. Their function is to regulate interchange of gasses, including water vapor between the plant and the environment. The stomata have two principal parts, the internal pore and the surrounding guard cells. The guard cells regulate the size of the pores. For foliar application of rooting solutions to work successfully the pores must be open. Studies show stomata are open when cuttings are well hydrated and when temperatures and other factors are suitable for translocation of gas, vapor and liquid. Stomata close when cuttings are wilted.

**Solution Movement within the Plant**
The stomatal cavities contain air spaces and leaf mesophyll cells which can absorb fluids such as water base IBA solutions. Solution absorption is caused by pressure differentials between the relative humidity outside the leaf and the stomatal cavity, i.e. VPD — vapor pressure deficit (Hartmann et al., 2011). After the applied IBA solution enters the leaves, it is absorbed and enters vascular bundles (the phloem). The bundles facilitate translocation of fluids through the plant. Along with leaf produced IAA, the applied and natural IBA is translocated in a polar direction to the basal end of the cuttings — and adventitious roots are initiated and formed. One should avoid high auxin concentration which can cause phytotoxicity, foliar burning and necrosis of the cutting stem base.

Growers should trial at the lowest possible rates to avoid phytotoxicity.

## FOLIAR METHODS

### The Spray Drip Down Method

The Spray Drip Down Method can be used on many small production lots at one time. Growers first stick the cuttings into media. No personnel protection equipment (PPE) is required to stick untreated cuttings; thin gloves may be used solely for sanitary purposes. It is necessary for grower to use a water base IBA solution such as Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. A sprayer is selected for the best use in the facility. The solution is sprayed onto the leaves of the cuttings until there is a drip down. The drips are a visual indicator that an adequate amount of solution has been applied. Growers should try to treat both the top and bottom of cuttings. An excess application is best. The solution is used one time to avoid biological contamination between production lots. The typical application is about 10 $m^2$ liter (200 $ft^2$/gal). Misters can be turned on after about 30-45 min or until the solution dries on the leaves.

### The Total Immerse Method

The Total Immerse Method can be used for large homogeneous plant lots that are clean and disease free. Large leaf cuttings benefit by having both sides of the leaves treated at one time. The method requires little setup and can be used on large or small production lots.

A simple tub and strainer basket are used to treat the cuttings. Growers use a water base IBA solution as above. Cuttings are dipped into the solution until the leaves are completely covered with liquid, about five seconds. When used to treat tissue culture plantlets, growers must take care not over fill the basket, thereby avoiding cutting breakage. Long immersion is not recommended to avoid adverse reactions. After dipping, growers stick the cuttings into media. Since biological materials from dipped cuttings enter the solution, it is best to dispose the solution between different production lots at the end of the work day.

### Solutions Used by Foliar Methods

The US EPA prohibits un-registered or technical grade IBA products to be used by growers for propagation. Two US EPA registered products are allowed to be used to make water base IBA rooting solutions and are labeled for use by foliar application: Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets (Phytotronics, <www.phytotronics.com>).

Indole-3-butyric acid can be made into solutions in two ways. Specially formulated IBA can be dissolved in water to make rooting solutions. IBA “as produced” is water insoluble; it can be dissolved in solvents such as. There are other commercially produced, EPA-labeled auxin concentrate products that have an alcohol base that are mixed with water to form more dilute formulations. If applied to the leaves of cuttings, alcohol rapidly evaporates and dehydrates plant tissue and can burn tissue. In my studies, foliar applications to cuttings with solutions containing with as little as 5% alcohol content can cause phytoxicity and death.

When using foliar methods, I do not recommend use of wetting agents in solutions made using Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets. Trials show no differences using wetting agents.

Some growers prefer to measure and mix solutions rather than dry measure the Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets. Using the required number of grams or tablets, a concentrate solution can be made. The required portion of the concentrate is put in the production tank. Water is added to dilute to the required volume. Hortus IBA Water Soluble Salts solutions can be made to over 80,000 ppm IBA using water, which would be too high an auxin concentration for cuttings. Unless otherwise specified, thin waterproof gloves are adequate for handling water base rooting

solutions.

Water base IBA rooting solution products are used by both basal and foliar methods. These solutions replace any pre-mixed rooting solutions when used at the same IBA rate. In growing facilities where both basal and foliar methods are used, this eliminates the need to inventory different rooting solution products.

I have been told some growers have wanted to make rooting solutions using dry dip rooting hormone powders. These powders contain mostly insoluble talc and are not practical for foliar applications.

**Temperature of the Solution and Cuttings**

Growers can propagate in cool greenhouses or when cuttings are taken from coolers. Based upon my research, the standard foliar application temperature range for cuttings and solutions is 16-32°C (60-90°F), provided the cuttings are hydrated.

**Time between Sticking and Spraying**

I did trials to determine the effect of time between sticking and treatment by the Spray Drip Down Method. Davies and Joiner's studies (1980) indicated that there was a variation in rooting after several days between sticking and treatment, i.e. it is best to apply foliar auxin applications within the first 48-h of sticking. There was a decline in rooting after waiting more than a week to apply IBA. My trials determined that it is best to treat the same day as sticking. For PPE purposes, it is advantageous for the treatment person to do spraying at the end of the work day when other production workers are not in the greenhouse. In hot climates, where daytime temperatures are high, spraying is sometimes done early in the morning after sticking, when temperatures are lower.

**Hydration and Misting**

Growers should use well hydrated cuttings when using foliar methods. IBA in the rooting solution enters the leaf within a few minutes after application through open pores in stomata. Wilted cuttings have closed stomata, therefore the cuttings must be re-hydrated before treatment. With the Spray Drip Down Method, mist systems must be turned off before treatment to avoid diluting the rooting solution and restored about 30-45 min after treatment. With the IBA runoff accumulation, some of the auxin will also be taken up at the base of the cutting.

**Keeping Solutions**

As previously mentioned, it is best to keep unused solutions for no more than several weeks. Unknown biological substances from untreated pond water, wells, or city water, may cause the IBA to degrade. The Total Immerse Method requires sticking the cutting into the solution. The cuttings bring biological substances which can cause contamination if the solution is stored and not discarded after use. Hence, it is important to dispose the solution after use at the end of the work day. The Spray Drip Down Method uses the solution one time. Unused solutions can be kept, however, not for a very long time.

**FOLIAR RATES**

The same rates are used by the Spray Drip Down and Total Immerse Methods.

**Annual Plant Cuttings**

Some tender plant varieties and juvenile cuttings are treated at rates 80-100 ppm IBA. The normal trial range is from 80-200 ppm IBA. If leaf distortions occur, the rates need to be adjusted downward.

**Perennial and Woody Plant Cuttings**

Perennial and woody plant cuttings have similar rates. The selected trial rates are 500, 1000, and 1500 ppm IBA. Rates above 1500 ppm IBA are rarely needed except for some mature cuttings. Rates below 500 ppm IBA are sometimes needed for tender, juvenile

perennial cuttings.

**Tissue Culture Plantlets**
When transplanting tissue culture plantlets, the Total Immerse Method can be used with Rhizopon AA Water Soluble Tablets at 1-3 tablets per liter of water. For blueberry, two Rhizopon AA Water Soluble Tablets per liter are used.

**Transplanting Divisions**
The Spray Drip Down Method is used when transplanting decorative grass divisions. Rates are similar to those used for annual cuttings. Juvenile cuttings require lower rates than mature cuttings. Growers generally know which of their cuttings are seasonally easy or hard-to-root and adjust their rates. The basal quick-dip rates are usually too high a concentration for foliar application.

**Cuttings**
The rules for taking annual, perennial and woody plant cuttings are simple. Take leafy cuttings in the active growing state. It is always best to use cuttings-from-cuttings when possible. It is important not to take dormant or leafless cuttings which are better propagated by basal methods. Do not cut leaf tips. Some growers cut the tips of large leaf cuttings to obtain more cuttings in a propagation tray. The cut causes a wound that is open to infection. Wounds in the tip area create competing 'sinks', which ties up valuable resources (metabolites) to heal the leaf wound, rather than induce root formation at the basal end.

**Secondary and Transplant Applications**
A post, second Spray Drip Down Method foliar application can be used on leafy cuttings in the active growing state that were first treated by any auxin application method. The second application helps to improve root formation on slow-to-root cuttings. Applications can be done weekly or as required. Rates are similar those used for first foliar application for cutting type and species.

One of the major ways to use the Spray Drip Down Method is to treat divisions and young rooted cutting transplants. Growers of ornamental grasses use this method on transplant divisions at rates as if they were annual cuttings.

**Labor Savings, Quality Control, and Material Cost**
Foliar methods have reduced labor cost, with better control, compared with basal methods. It is faster to stick cuttings when foliar batch treating. There are no 'misses' as may happen with traditional quick-dip basal methods. Foliar methods, at low rates, have lower material cost than high rate basal methods.

**Trials are Necessary**
Before conversion of production to foliar application, growers should conduct initial trials. Growers should do trials on small lots, keeping accurate records of methods, rates, time of the year and varieties tested. The review of results should also consider the facility advantages, and labor and setup costs for each method.

**Hybrid System**
In the same growing facility, a hybrid system with both basal and foliar methods is often used at the same time on cuttings propagated in the active growing state. Selection of methods and rates depend upon the species and cultivars.

**ADVANTAGES OF FOLIAR PROPAGATION METHODS**
- Foliar bulk treated cuttings are uniformly treated and avoid quick-dip basal treatment skips.
- Foliar methods use about one-third the labor compared with individual treated basal

methods.
- Foliar methods have low material cost due to the reduced rates.
- The Spray Drip Down Method minimizes cross contaminate diseases and pathogens since solutions are used once.
- The Spray Drip Down Method's well-trained application person is the only worker needing PPE.
- Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets have zero hour restricted entry interval (REI).
- What was learned in school may be out dated: The latest edition of *Hartmann and Kester's Plant Propagation: Principles and Practices* (Hartmann et al., 2011) discusses commercial foliar methods.
- The number of growers using foliar methods has rapidly increased as they bring their knowledge of foliar method success when changing jobs.
- For cost savings and efficiency: foliar propagation methods can save money, improve quality, save time, and reduce labor.

**SUMMARY**

Foliar methods are easy to understand and use:
- Growers select cuttings from plants that are propagated from cuttings using rooting hormones.
- Growers can propagate annual, perennial, and woody plants from cuttings.
- Leafy cuttings are used.
- Cuttings are to be in an active growth stage, hence, dormant and leafless cuttings are not used.
- Water base IBA rooting solutions are used.
- Cuttings are to be well hydrated before and after treatment; Application is to be made at temperatures from about 16-32°C (60-90°F).

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# Bridging the Generation Gap©

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"Bridging the Generation Gap" is an International Plant Propagators Society (IPPS) specific lecture discussing ways to increase and retain membership and attendance at annual meetings. Inspired from the questions asked in the "Membership Proposal" for 2014/2015 by the International Board, the strategies presented are aimed to reach a new generation while maintaining the long standing integrity of IPPS.

## REINVENTING THE PROPAGATOR

Mechanization has changed the face of plant production. With the integration of efficient technology nurseries can operate with fewer employees. These advancements have enabled plants to be produced very consistently with a high level of quality. However, this shift has impacted the employment of many nurseries and the membership of professional association's worldwide.

Box store trends have also contributed to a major shift in the green industry. Through the mass market economic structure the green industry has fallen prey to a dangerous trend of devaluing our products and accommodating unnecessary warranties. The expectations and responsibility of the end consumer have changed dramatically in the last decade. Plant warranties eliminate the consequence of not learning how to grow plants. The mass market has also created a bottle neck with regard to available plant material. By limiting the selection of plants down to a few genera we have devalued the diversity that makes horticulture such a broad and interesting opportunity.

The time has come for a renaissance of the professional plant propagator! Like the modern day Brew Master, this is a career that the public is genuinely fascinated by. Everyone in IPPS has important and interesting information to share with the world. The propagator is the heart and soul of a nursery and that is something to celebrate!

## STRATEGIES TO REACH A NEW GENERATION

IPPS is a professional organization and the most efficient way to secure new members is through the existing network of nurseries active in the region. Member nurseries can approach new hires as an investment for International Plant Propagators Society. Promote an annual IPPS membership and attendance at the yearly meeting as a benefit of employment. Just like vacation and sick days, membership in a professional organization is a bonus of employment and is a great strategy for attracting quality young talent. A professional work environment will attract young professionals.

Utilizing and staying current on social media trends is an effective and inexpensive way to reach new members. Connecting with people from across the world is easy, sharing photos and information is instant and social media is free and used on the individuals terms. There are many different platforms of social media that are popular, including Facebook, Twitter, Instagram, and LinkedIn.

One powerful tool of social media is the Hashtag. According to Wikipedia, it is (noun) "a word or an un-spaced phrase prefixed with the hash or pound character (#) to form a label. It is a type of metadata tag." In short, it is a way of organizing content based off a specific title, such as #IPPS2014. Hashtags are used on all forms of social media, though they do not cross reference.

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[1] Editor's Note: Brie Arthur is a member of the IPPS Southern Region, North America (IPPS-SRNA) and serves as "Social Media Chair," helping to promote the group to a wider audience. Additionally she is providing support to the International Board of IPPS with regard to Marketing and Development. FB: Brienne Gluvna Arthur, IG: BrieThePlantLady, TW: BriePlantLady, LI: Brienne Gluvna Arthur.

Facebook (FB) is a powerful resource to easily connect with the user. It is also a critical component to driving browser searches. There are several ways to utilize Facebook for IPPS purposes. First, the IPPS Southern Region PAGE: this is critical for posting links that connect to the website and to rank consistently on search engines. The goal of the FB Page is to keep content current by posting 2-3 times per week. Short, relevant messages that direct visitors to the website for membership and meeting information are the most effective use for a page. This is not a forum for photo shares or discussion, as the posts from non-administrators cannot be made public.

The current IPPS-SRNA Facebook page has 450 "likes" and is reaching up to 200 users per post. The circulation of the group page posts is restricted as means of charging the user. These posts can reach a much broader audience if IPPS members share the group posts through their individual pages. These shared posts allow the message to be circulated without financial input.

The IPPS International Group was created on Facebook as a means of connecting members globally in an easy to use, real time format. GROUPS provide a forum for ongoing discussions and photo share. Users can easily utilize the group from a mobile device, thus enabling real time interaction. Meeting photographs can be shared and organized into albums for everyone to enjoy. Technical discussions can be tracked and networking information collected.

The IPPS identity should extend beyond this meeting. Often we are all gathered at the same trade shows and symposium. We can easily plan seasonal events through the IPPS Group. These satellite meetings can provide the opportunity for young members to network and work towards a common IPPS driven goal, such as a campaign to increase membership. Young members often have the time and energy to engage because their professional responsibilities are less.

## INCREASING ATTENDANCE AT ANNUAL MEETINGS

Some of the obvious solutions for increasing meeting attendance are already being well executed thanks to the efforts of Helene Dodge. Having an up to date website with clear, concise information is paramount. Posting meeting information in a timely manner will allow planners to schedule their year early and young members the opportunity to begin saving if the meeting is not subsidized by their employer. Active links that can easily be shared on social media will help direct traffic to the website and make the user experience easy and hassle free.

Promote one special aspect of the meeting in advance to create excitement and anticipation. Share the fun memories through social media and the website to further engage members and beyond. Schedule tours at a diverse selection of horticultural facilities including public gardens, food producers, annual and perennial growers and college campuses.

## WHY IPPS MATTERS

At the very core of the IPPS value to "Seek and Share Knowledge" is the desire to gather as a society to generate a sense of community, inspiration and fellowship. In researching the value of professional memberships I began asking friends and mentors for their opinions. To the experienced IPPS members: How they are you engaging with a new generation? The young professionals were asked: Why do you value IPPS? The participants each have a unique point of view, and are full of great insights!

Matt and Tim Nichols: "We value IPPS as a group because of the face to face interaction with experts who have real life experience. It has a great blend of information and camaraderie for the industry. IPPS provides a resource of practical and useful information that becomes essential for anyone who wants to advance their horticultural knowledge."

Maarten van der Giessen: "I reach the next generation by grabbing them by the sleeve, just as my mentor, Brice Briggs did to me. The younger folks are interested in the

industry and are hungry for information. When you're talking plants there is no generation gap! The excitement is universal."

Judson Le Compte: "The mix of industry, academia, beginners, students, and professional producers makes IPPS my favorite meeting. The openness to share is so welcoming. The dynamic at IPPS is so different from any other meeting I have attended. No other group has been as inviting to students as IPPS."

Bobby Green: "IPPS is so much more than propagation protocols and the HOW of plant reproduction. It is the WHY of propagation. From new plant introductions to high and low tech clonal techniques, there is something here for every aspiring plants person. We often decry the lack of volume of young folks entering the industry, but as is often the case, one person with enough passion can change the world."

Ryan Guillou: "We always talk about how gardens are ever changing and not static. It is important to view our professional community in the same way. IPPS provides the opportunity to stay current, discuss ideas, and most importantly prevent reinventing the wheel. Why make the same mistakes as someone else?"

David Creech : "Passion for plants is difficult to teach. Entertain, educate, enlighten. Lucky are those who wake up every day eager to get to the garden. Increase attendance by reducing registrations costs for students and new professionals. Also, encourage word of mouth to endorse IPPS membership. We could invite professors to speak if they bring students to the meeting."

Ben Gregory: "IPPS is a brilliant resource to meet people, learn and travel: the three most important things for a young professional. This is a perfect time to join and become an active member. Everyone is so inviting and shares so many different ideas that are relevant."

Kay Phelps: "Every college in the USA with a horticulture department could encourage students to attend at least one professional meeting in their graduating year. They will see and learn that there is so much to this business. This would be a great opportunity to extend their knowledge."

**ADDING VALUE TO MEMBERSHIP**

Membership is more than attending the annual meetings. Create a "Networking" section on website where members can be highlighted. Add a calendar of green industry events to better connect members through-out the year. Include historical information on the website to emphasize the IPPS motto through the generations. Cross promote IPPS at industry events to further recognize the identity and importance of the association.

**SENDING MEMBERS OFF WITH PURPOSE**

Now more than ever, sending members off with purpose is paramount. Collectively we need a mission to accomplish and the young members can be a great resource. We need to set a goal, such as of increasing membership and attendance at annual meetings by 25% or fundraising for scholarships to support the next generation of professionals.

My final point is to challenge each one of you to find one new member for 2015. We can double attendance if each person in the society brings just one new colleague next year. The knowledge, experience and gratitude of the International Plant Propagators Society is worth preserving and sharing. Now it is up to all of us to ensure this group will remain for generations to come.

# New Insights into Breeding and Propagating Magnolias©

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It is a fascinating time to be growing magnolias. Recent developments, including a refined understanding of the evolutionary relationships, availability of new germplasm, and a formidable group of plant breeders, propagators, and aficionados are synergizing a magnolia renaissance. These forces are leading to exciting new hybrids, improved production methods, and a resurgence of interest in magnolias.

## SYSTEMATICS AND CYTOGENETICS

With the advent of molecular phylogeny, flow cytometry, and the continued reassessment of morphology and taxonomy of the subfamily Magnolioideae, the understanding of the evolution, genetics, and relationships among magnolia species has improved considerably (Azuma et al., 1999, 2001, 2004; Figlar, 2000, 2006; Figlar and Nooteboom, 2004; Kim et al., 2001; Kumar, 2006; Nie et al., 2008; Parris et al., 2010, Qiu et al., 1995). The now widely-accepted taxonomic treatment of this group has *Magnolia* as the sole genus in the subfamily Magnolioideae with former genera *Manglietiastrum*, *Manglietia*, *Michelia*, *Pachylarnax*, and *Parakmeria* embedded within sectional ranks. More specifically, the former genus *Michelia* is now placed within subgenus *Yulania*, section *Michelia.* The former genus *Manglietia* is now placed in subgenus *Magnolia*, section *Manglietia*. The former genera *Manglietiastrum*, *Parakmeria*, and *Pachylarnax* are now placed in subgenus *Gynopodium*, section *Gynopodium* (see Table 1 for an abbreviated classification with selected taxa. A more complete classification can be found at the Magnolia Society International website <http://www.magnoliasociety.org/Classification>. This reorganization is something of a revelation that has significant implications for breeding and propagation of magnolias.

The cytogenetics of magnolias is complicated with over 250 species that range in ploidy level from diploid to hexaploid. Research by Parris et al. (2010) provides detailed information on ploidy of over 300 species and cultivars of magnolias. This reference gives insights into reproductive biology, confirmation of numerous hybrids and induced polyploids, and provides a valuable database for magnolia breeders.

### Implications for Breeding

Plant breeders typically want to combine desirable traits from different parents. Genetic diversity is the raw material at hand and the greater the available diversity, the greater the potential opportunities — within limits. Plant breeding is a genetic reunion of sorts, bringing together divergent linages, but if the lineages/species are too distinct, they will lack reproductive compatibility and genetic synteny and will either not hybridize or may hybridize and produce undesirable or sterile offspring. Thus, detailed information on the relatedness of different species provides insights into what plants may or may not hybridize. The reorganization of *Michelia*, *Manglietia*, and to a lesser extent *Parakmeria*, *Manglietiastrum*, *Pachylarnax* into specific subgenera and sections within the genus *Magnolia* provides valuable insight and direction for plant breeders. As a result of this new understanding, many new hybrids are being developed that have considerable potential to combine and enhance flower color, cold hardiness, fragrance, persistent foliage, and a range of mature sizes and habits (Table 2). Although best success is generally had breeding among magnolias of the same taxonomic section, magnolias will often hybridize if they are simply in the same subgenus. Crosses between magnolias in different subgenera are rare, though Bill Smith (pers. commun.) was successful in

hybridizing *M. lotungensis* (subgenus *Gynopodium*) and *M. virginiana* (subgenus *Magnolia*).

Polyploidy is an important factor in plant breeding because it can influence reproductive compatibility, fertility, and expression of traits. The greatest success is generally had breeding among parents of the same ploidy. Interploid hybrids can often be produced, but fertility of the progeny may be greatly reduced. For example, *M. liliiflora* (4*x*) and *M. stellata* (2*x*) will hybridize, but produce mostly sterile triploids. Hybrids between *M. acuminata* (4*x*) and *M. denudata* (6*x*), *M. campbellii* (6*x*) and *M. liliiflora* (4*x*), *M. liliiflora* (4*x*) and *M. sprengeri* (6*x*), and *M. denudata* (6*x*) and *M. liliiflora* (4*x*), generally produce pentaploids with very low or no female fertility and limited male fertility. Crosses between *M. virginiana* (2*x*) and *M. grandiflora* (6*x*) and *M. sieboldii* (2*x*) and *M. grandiflora* (6*x*) have been successful and produced tetraploid progeny with limited fertility.

Table 1. Organization of selected *Magnolia* species, hybrids, and cultivars by current taxonomy and ploidy levels with informed speculation on candidate understocks for experimentation, particularly in the SE United States of America.

| Classification | Ploidy | *Magnolia* scion taxa | Magnolia candidate understocks (other than own species)[1] |
|---|---|---|---|
| | | Subgenus *Magnolia* | |
| Section *Magnolia* | 2*x* | *guatamalensis*, *sharpie*, *virginiaina* | *virginiana* var. *australis* (may sucker some) |
| | 6*x* | *grandiflora*, *tamaulipana* | *grandiflora* |
| Section *Gwillimia* | 2*x* | *coco*, *delavayi*, *hodgsonii*, *liliifera* | Possibly *virginiana* var. *australis* (may sucker some) |
| Section *Rhytidospermum* | 2*x* | *obovata* (*hypoleuca*), *officinalis*, *rostrata*, *tripetala*, *sieboldii*, ×*wieseneri* (*obovata* × *sieboldii*) | *tripetala* or *obovata* |
| Section *Manglietia* | 2*x* | *aromatica, changhungtana, conifera*, *fordiana*, *garrettii*, *hookeri*, *insignis*, *kwangtungensis*, *ovoidea*, *yuyuanensis*, *insignis* × *yuyuanensis* | *yuyuanensis* (good cold hardiness) or possibly *virginiana* var. *australis* (may sucker some) |
| Section *Macrophylla* | 2*x* | *macrophylla* | *tripetala* or *obovata* |
| Section *Auriculata* | 2*x* | *fraseri* | *tripetala* or *obovata* |
| Section *Kmeria* | 2*x* | *thailandica* | Possibly *virginiana* var. *australis* (may sucker some) or *tripetala* |
| Intersectional hybrids | 2*x* | *insignis* × *sieboldii* *insignis* × *virginiana* e.g., 'Katie-O'; *obovata* × *virginiana* e.g., 'Nimbis'; *sieboldii* × *virginiana*; ×*thompsoniana* (*virginiana* × *tripetala*); *yuyuanensis* × *virginiana* | Possibly *tripetala* *virginiana* var. *australis* (may sucker some) |
| | 4*x* | ×*freemani* (*virginiana* × *grandiflora*) e.g., 'Maryland'; *sieboldii* × *grandiflora* e.g., 'Exotic Star' | *grandiflora* |

Table 1. Continued.

| Classification | Ploidy | *Magnolia* scion taxa | Magnolia candidate understocks (other than own species)[1] |
|---|---|---|---|
| | | Subgenus *Yulania* | |
| Section *Yulania* | 2*x* | *amoena*, *biondii*, *kobus*, *salicifolia*, *stellata*, *zenii*, salicifolia 'Wada's Memory'; ×*loebneri* (*kobus* ×*stellata*), e.g., 'Leonard Messel', 'Spring Snow' | *stellata*, *kobus*, ×*loebneri*, *stellata* × *liliiflora* |
| | 3*x* | *stellata* × *liliiflora*, e.g., 'Ann', 'Betty'<br>*acuminata* × *stellata* | ×*loebneri, kobus*, *stellata* × *liliiflora*<br>*acuminata*, ×*brooklynensis* |
| | 4*x* | *acuminata*, *cylindrical*, *liliiflora*, ×*brooklynensis* (*acuminata* × *liliiflora*) e.g., 'Black Beauty', 'Judy Zuk', 'Solar Flair', 'Sunburst', 'Sunspire', 'Yellow Bird' | *acuminata*, ×*brooklynensis*, *cylindrica*, *kobus*, ×*loebneri*, ×*soulangeana*, 'Alexandrina', 'Galaxy', 'Heaven Scent', 'Rustica Rubra', 'Yellow Lantern' |
| | 5*x* | *acuminata* × *denudata,* e.g., 'Butterflies', 'Elizabeth', 'Ivory Chalice', 'Legend', 'Sun Ray'<br><br>*campbellii* × *liliiflora*, e.g., 'Star Wars', 'Vulcan'<br><br>*liliiflora* × *sprengeri*, e.g. 'Galaxy', 'Spectrum'<br>×*soulangeana* (*denudata* × *liliiflora*) | *acuminata*, ×*soulangeana*, 'Alexandrina', 'Galaxy', 'Heaven Scent', 'Rustica Rubra', 'Yellow Lantern'<br>×*soulangeana*, 'Alexandrina', 'Rustica Rubra' ,'Galaxy', 'Heaven Scent'<br>*sprengeri*, ×*soulangeana*, 'Galaxy'<br>×*soulangeana*, 'Alexandrina', 'Rustica Rubra' |
| | ~5*x*-7*x* | Advanced generations of ×*soulangeana* and other related cultivars: 'Albatross', 'Black Tulip', 'Cleopatra', 'Daybreak', 'Frank's Masterpiece', 'Genie', 'Jon Jon' , 'March Till Frost', 'Paul Cook', 'Rose Marie', 'Tina Durio', 'Todd Gresham', 'Sayonara', 'Sunsation', 'Yellow Lantern' | ×*soulangeana*, 'Alexandrina', 'Galaxy', 'Heaven Scent','Rustica Rubra', 'San Jose', 'Yellow Lantern' |
| | 6*x* | *campbellii*, *dawsoniana*, *denudata*, *sargentiana, sprengeri*, *denudata* × *sprengeri*, *sargentiana* × *campbellii*, ×*veitchii* (*campbellii* × *denudata*) | *sprengeri*, 'San Jose', 'Galaxy', 'Heaven Scent' |
| Section *Michelia* | 2*x* | *cavaleriei*, *champaca*, *chapensis*, *doltsopa*, *ernestii*, *figo*, *floribunda*, *foveolata*, *fulva*, *laevifolia*, *lanuginosa*, *maudiae*, *martinii*, *odora*, *shiluensis*, *sirindhorniae*, ×*alba* (=*champaca* × *montana*), ×*foggii* (=*figo* × *doltsopa*), *laevifolia* × *figo* | *foveolata* or *laevifolia.* Possibly *kobus*, *liliiflora*, *stellata*, *liliiflora* × *stellata*, ×*loebneri* |

Table 1. Continued.

| Classification | Ploidy | *Magnolia* scion taxa | Magnolia candidate understocks (other than own species)[1] |
|---|---|---|---|
| | | Subgenus *Gynopodium* | |
| Section *Gynopodium* | 6*x* | *lotungensis*, *yunnanensis* | Possibly *grandiflora* |
| Section *Manglietiastrum* | 2*x* | *sinica* | Possibly *virginiana* |

[1]Candidate understocks identified here may be more readily available or have better long-term compatibility, cold hardiness, regional or soil adaptability, disease resistance, or be suitable for hybrid scions than other alternatives. Note, candidate rootstocks may not be in the same taxonomic group or ploidy level as the scion.

Table 2. Partial list of reported interspecific hybrids among plants formally classified in the genus *Manglietia, Michelia*, and *Parakmeria* and now classified as *Magnolia* (adapted from Figlar, 2014).

Subgenus *Magnolia*
- *M. sieboldii* × *M. insignis*
- *M. tripetala* hyb. × *M. insignis*
- *M. grandiflora* × *M. insignis*
- *M. insignis* × *M. grandiflora*
- *M. insignis* × *M. sapaensis*
- *M. sapaensis* × *M. insignis*
- *M. changhungtana* × *M. insignis*
- *M. insignis* × *M. fraseri*
- *M. macrophylla* subsp. *ashei* × *M. insignis*
- *M. yuyuanensis* × *M. insignis*
- *M. yuyuanensis* × *M. virginiana*
- *M. sieboldii* × *M. yuyuanensis*

Subgenus *Yulania*
- *M. foveolata* × *M. laevifolia*
- *M. laevifolia* × *M. foveolata*
- *M. foveolata* × *M. figo* var. *crassipes*
- *M. acuminata* var. *subcordata* × *M. figo* var. *crassipes*
- *M. laevifolia* × *M. maudiae*
- *M. laevifolia* × *M. champaca*
- *M. stellata* hyb. × *M. laevifolia*
- *M. stellata* × *M. figo* var. *skinneriana*

Subgenus *Gynopodium* × Subgenus *Magnolia*
- *M. lotungensis* × *M. virginiana*

## IMPLICATIONS FOR PROPAGATION

### Stem Cuttings

Although the capacity of magnolias to root from stem cuttings varies considerably among species and cultivars, many taxa can be readily propagated in this way. Conventional wisdom has indicated that deciduous magnolias are best rooted in the spring from softwood cuttings while evergreen taxa are generally rooted from semi-hardwood cuttings in the fall (Tubesing, 1998). However, this is not always the case. For example, rooting for *M. virginiana* var. *australis* 'Santa Rosa', a deciduous to semi-evergreen cultivar was

optimized at 83% from November semi-hardwood cuttings treated with a 1-s dip of 5,000 ppm liquid IBA in 50% isopropanol (Griffin et al., 1999) while cuttings from *M. laevifolia* 'Michelle', an evergreen species, rooted from 88 to 96% from softwood cuttings take in early June with no significant effect of a 5-s dip of K-IBA in water ranging from 0 to 50,000 ppm (unpublished research, Gillooly and Ranney). These observations suggest that we may need to reevaluate our approaches and look more closely at timing and rooting windows including softwood cuttings for evergreen species, particularly in section *Michelia*. Might general cutting propagation protocols apply to taxonomic sections? Some propagators are also reporting good success treating certain magnolia cuttings with very high rates (10,000-50,000 ppm) of IBA (Ethan Guthrie, pers. commun.; Sharma et al., 2006) which deserves further study.

**Grafting, Graft Compatibility, and Rootstock Selection**

Although own-rooted plants produced from cuttings or micropropagation are often preferred and minimize issues with rootstock suckering, there can be advantages to grafting. Rootstocks can have a profound influence on growth of the scion and can potentially enhance adaptability to poor soils and resistance to diseases, insects, and nematodes (Garner, 1988; Hartmann et al., 2010; Macdonald, 1986; Ranney et al., 1991; Ranney and Bir, 1994; Ranney and Whitman II, 1995; Rom and Carlson, 1987). And, the difficulty of rooting some magnolia species and cultivars often makes grafting the next best option available to propagators.

Magnolias are generally considered to have broad graft compatibility (Treseder, 1978) to the point that scion/rootstock combination are often given little consideration and generic rootstocks (e.g., *M. kobus*) are used for a broad range of taxonomically distinct scions. Initial graft success can depend on many factors including the condition and handling of both the rootstock and scion, skill of the grafter, timing, environmental conditions, aftercare, production/propagation systems, etc., that may have greater initial importance than the genetic relatedness of the component parts. Although true short-term graft incompatibility is rarely observed in magnolias (at least within a given subgenus), rootstock selection can potentially influence long-term graft compatibility, regional adaptability, and disease resistance that may take years to manifest.

There is little information on how ploidy levels might influence graft compatibility and scion/rootstock relationships, but it is well documented that ploidy can influence cell size, rate of growth, gene expression, and a host of other morphological and physiological characteristics. In tea (*Camellia sinensis*) the ploidy of the rootstock influenced the shoot density of the scion (Bore et al., 2006). With magnolias, variation in ploidy is also associated with particular species and taxonomic sections, and is thus somewhat correlated with phylogeny. So, with all other things being equal, a similar ploidy in the scion and rootstock may be desirable.

Disease resistance and tolerance to poor drainage (hypoxia) are also important considerations in rootstock selection. A number of diseases can infect the root system and rootstock stem of magnolias including *Botryospheria dothidea*, *B. obtusa*, *Cerrena unicolor*, *Cylindrocladium* spp., *Ganoderma lucidum*, *Nectria* spp., *Oxyporus latemarginatus*, *Phytophthora* spp., *Schizophyllum commune*, and *Verticillium* spp. (Sinclair and Lyon, 2005). It is not uncommon to see stem cankers on the rootstock stem of magnolias below the graft union in nurseries and landscapes (Fig. 1). Although there is little information on differential resistance to these diseases among magnolia species and cultivars, they may vary substantially when used as rootstocks. Magnolias also vary considerably in their tolerance to poor drainage. Some species like *M. virginiana* are often native to swampy, riparian habitats and are tolerant of periodic inundation, while others, like *M. sieboldii* are typically found in more mountainous habitats and are relatively intolerant of poorly-drained soils (Callaway, 1994; Gardiner, 2000).

Fig. 1. *Magnolia* ‘Rose Marie’ grafted on an unidentified rootstock with a stem canker.

It is difficult to study long-term compatibility and performance of tree rootstocks in a formal manner and issues like herbicide damage, poor soil conditions, or low planting depth can sometimes be confused with rootstock or grafting problems. However, astute propagators have made valuable observations. Lane (1993) reported good success grafting *M.* ×*wiesneri* (*obovata* × *sieboldii*) onto *M. obovata* (syn. *hypoleuca*) in subgenus *Magnolia* and *M. campbellii*, *cylindrica*, *dawsoniana*, *sprengeri*, ‘Albatross’, and ‘Yellow Bird’ onto *M.* ‘Heaven Scent’ (a complex hybrid among *M. campbellii*, *denudata*, and *liliiflora* - 5*x*) in subgenus *Yulania*. Hooper (1990, 2010) conducted long-term observations on many magnolia scion/rootstock combinations and found differential growth of the scion and rootstock stem caliper was a common problem and that *M. campbellii* hybrids in particular tended to outgrow many rootstocks. Combinations that did work well included *M.* ×*brooklynensis* (*acuminata* × *liliflora*) and other *M. acuminata* hybrids on *M.* ×*loebneri* (*kobus* × *stellata*) ‘Merrill’ and that ‘Merrill’ appeared to be more resistant to root diseases than most *M. kobus* seedlings under their conditions. Also, *M. campbellii* cultivars and hybrids including ‘Caerhays Belle’, (Raffillii Group) ‘Charles Raffill’, (Raffillii Group) ‘Kew’s Surprise’, and ‘Mark Jury’ worked well on the vigorous *M.* ×*soulangeana* (or possibly *M.* ×*veitchii*) ‘San Jose’ as did *M. doltsopa* ‘Silver Cloud’. Hooper (2010) also reported that although *M.* ‘Genie’ grew well when grafted onto *M. kobus*, flowering was more precocious when grafted onto *M.* ×*soulangeana* including seedling from *M.* ‘Rustica Rubra’. Dummer (1979) reported on successful graft combinations in magnolias and suggested grafting *M. campbellii* cultivars on *M. campbellii* seedlings or *M.* ×*soulangeana; M.* ‘Charles Coates’ (*sieboldii* × *tripetala*), *fraseri*, *officinalis*, *sieboldii*, and ×*wiesneri* on *M. tripetala* or *M. obovata*; *M. acuminata* on *M. kobus*; *M. cylindrica*, *dawsoniana*, and *sprengeri* on *M.* ×*soulangeana*; and *M. acuminata*, *salicifolia*, ×*thompsoniana*, and *virginiana* on *M. kobus*. Charles Tubesing (pers. commun.) had good long-term success (25+ years) grafting *M. campbellii* and *sargentiana* onto seedlings of *M. sprengeri* var. *diva* grown in British Columbia. Tubesing also reported that although he had good results grafting *M. acuminata* hybrids

onto seedling *M. acuminata* understocks, this species is not the most amenable to container culture.

Alternatively, he has had good initial success grafting *M.* 'Savage Splendor', 'Blushing Belle', and 'Rose Marie' onto rooted cuttings of 'Yellow Lantern', a hybrid of *M. acuminata* × *M.* ×*soulangeana* 'Alexandrina'. As a further example of how rootstocks can enhance regional adaptability, Tubesing also observed that grafting *M. sieboldii* onto *M. tripetala* produced better, longer-lived trees growing in silt/clay soils at the Holden Arboretum in Kirtland, Ohio, than did *M. sieboldii* when grown on its own roots. Brian Humphrey, a highly experienced magnolia propagator in the United Kingdom, has steered away from using *M. campbellii*, *denudata*, *sieboldii*, ×*soulangeana* as understocks due to poor root system quality, lower initial graft success, and reduced growth rates for scions such as *M.* 'Jurmag 1', Black Tulip™ hybrid magnolia, 'Jurmag 2', Felix Jury™ hybrid magnolia, 'Iolanthe' and *Magnolia sargentiana* var. *robusta* 'Trengwainton Glory' (pers. commun.). Humphrey generally prefers using *M. kobus*, *stellata* (e.g., 'Royal Star'), ×*loebneri* (e.g., 'Leonard Messel'), *liliiflora* 'Nigra', and particularly the de Vos / Kosar Little Girl hybrids (*M. liliiflora* ×*stellata*) as understocks since they root readily from cuttings, graft well, and produce vigorous plants. He further reported that plants of *M.* 'Star Wars', 'Spectrum', and 'Galaxy' have performed well grafted onto *M. kobus* for over 28 years in the United Kingdom and that plants of *M. doltsopa*, *figo*, and 'Jack Fogg' grew well when grafted onto *M. stellata* and the Little Girl hybrids.

Using seedlings of *M.* ×*soulangeana* for understocks could be a bit of a gamble. *Magnolia* ×*soulangeana*, a cross between *denudata* (6*x*) and *liliiflora* (4*x*), produces $F_1$ pentaploids (5*x*). Plants with an odd number of chromosome sets (anisoploids) like this tend to produce offspring with variable chromosome numbers (aneuploids) and phenotypes, if they have any fertility at all. Advanced generations of *M.* ×*soulangeana* can vary considerably in form and vigor with ploidy ranging from 4.6 to 8.5*x* (Parris et al., 2010). Using clonal selections of *M.* ×*soulangeana* as rootstocks, like *M.* 'Alexandrina', 'Rustica Rubra', or related hybrids like *M.* 'Galaxy', 'Heaven Scent', 'San Jose', or 'Yellow Lantern' would be more consistent. Another advantage of using desirable scion cultivars as clonal understocks is that the rootstock of any failed grafts can be grown on for sale as a premium own-rooted cultivar. Of course, rootstock suitability may vary considerably by location, climate, soil conditions, and disease pressure.

In attempts to summarize this information and organize it in a phylogenetic and cytogenetic framework, a list of some commonly grown scion taxa are presented by subgenus, section, and ploidy with suggestions for candidate rootstocks (Table 1; Note: It should be emphasized that these candidate rootstocks are merely suggestions for experimentation and have not necessarily been tested). From a graft compatibility standpoint, it is generally safest to use a rootstock that is closely related to the scion. However, from a practical standpoint, one has to work with rootstocks that are currently available and other gains in disease resistance, cold hardiness, soil adaptability, and precocious flowering may be had by selecting rootstocks from other sections and ploidy levels, but preferably from the same subgenus. Ultimately, using clonal rootstocks that root readily from stem cuttings would provide more consistency and allow for critical testing and evaluation of specific scion/rootstock combinations if the added cost could be justified. For example, experimenting with specific cultivars of *M.* ×*loebneri* like *M.* 'Leonard Messel', 'Merrill', or 'Spring Snow' as understocks might provide improved and more consistent performance than seedlings of *M. kobus*. Cultivars like *M.* 'Alexandrina', 'Galaxy', 'Heaven Scent', 'Lennei', 'Rustica Rubra', 'Yellow Lantern', the Little Girl hybrids, and other cultivars that root readily from cuttings might be tested more extensively as rootstocks rather than seedlings of *M.* ×*soulangeana*. From a practical approach, it would be desirable to identify what own-rooted magnolias do well in any particular area and consider using those as candidate rootstocks for related scions. In many cases, disease resistance, regional adaptability, growth rate, and low suckering may be more important for rootstock selection than strict relatedness, at least within a subgenus.

With greater understanding of the phylogeny, cytogenetics, and propagation of magnolias, the opportunities for developing and growing new hybrids continues to escalate. The future of cultivated magnolias is bright.

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# Current Opportunities and Best Practices for Ginseng©

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## THE STATUS OF AMERICAN GINSENG

American ginseng (*Panax quinquefolius*) is a small, slow-growing herbaceous perennial herb that grows in hardwood forests throughout most of eastern North America. It is similar to Asian ginseng (*Panax ginseng*) that has been used in Asia as a medicinal herb for thousands of years. Overharvesting of wild populations of ginseng in China, Korea, and Japan made the root of this plant very valuable. The first American ginseng was exported to China from Canada in the mid-1700s. It was well-accepted by the Chinese and soon huge amounts of American ginseng roots were being harvested from forests from Southern Ontario and Quebec south to North Carolina for export to China.

American ginseng is still a highly valued root that is wild-harvested and cultivated throughout its native range, and over 90% of it is exported to Asia. Wild-harvesting ginseng has been a source of income for generations of families in the Southern Appalachian Mountains. In hard economic times people turn to the abundant forests to hunt, fish, and gather medicinal herbs. Since ginseng is worth 10× or more than any other herb in the forest, a whole culture has developed around the gathering and selling of it.

Because of its popularity, American ginseng is no longer abundant in North American forests. To protect the plant from becoming an endangered species, there are now state, federal, and international regulations governing the trade of ginseng. Internationally, ginseng is protected by the Convention on International Trade in Endangered Species (CITES). In the United States, the CITES regulations are managed by the U.S. Fish and Wildlife Service. On the state level, it is regulated by one of several state agencies, usually the department of agriculture or department of natural resources. These regulations include designated harvest seasons and minimum ages for roots to be dug. Only registered dealers can sell ginseng roots across state lines. Most wild-harvesters and many growers sell their ginseng to these dealers who must then obtain a CITES permit or certificate to export cultivated or wild-collected ginseng, sliced roots, or parts of roots.

## CULTIVATION OF AMERICAN GINSENG

There is not sufficient wild ginseng left to satisfy demand, so ginseng is also cultivated. On the Asian market, ginseng is graded into 30 or more grades based on its appearance. Old, bulbous,"man-shaped" wild roots with long necks of bud growth scars and concentric rings around the root are the most valuable. How ginseng is cultivated greatly affects its value and there are three major production systems that are used. Ginseng is almost exclusively propagated by seed.

### Production Systems

**1. Polypropylene Shade Cloth Structure System.** Most of the ginseng cultivated in North America is grown under tall, black, polypropylene shade cloth structures. The majority of that industry is based in Ontario and Wisconsin. By using high plant populations, fertilizers, and fungicides, roots can be harvested in 3 to 4 years. This system produces very high yields of large, smooth roots that bring about $75 per dried pound.

**2. Woods-Cultivated System.** Ginseng is also grown in a woods-cultivated system. This is very similar to the artificial shade system with seed sown densely into raised beds that have been limed and fertilized for optimum results. Fungicides are usually needed because the dense foliage makes the plants more susceptible to a number of diseases. The advantages to this system are that the shade is free and the roots, which can be harvested in 5 to 6 years, look a little more wild than those produced under artificial shade. Root

yields are lower than under artificial shade, but the roots bring about $200 per pound. Disadvantages are that many growers do not have appropriate forested areas for ginseng production, it can be difficult to get equipment into the woods, and beds must be fit around trees, streams, and other natural obstructions.

**3. Wild-Simulated System.** The third production system is referred to as wild-simulated. The objective of this system is to produce a root that is indistinguishable from a wild root. To grow wild-simulated ginseng, the leaf litter is raked away, a little gypsum may be scattered on the soil surface, seed is scattered at a very low rate (about 1 oz. of seed over 100 $ft^2$), and the leaf litter is raked back over the seeded area. No fertilizers or fungicides are used. The grower tries to protect the plants from wildlife, but does little else. The roots are usually grown for 10 years or more and yields are very low, but the roots bring prices very similar to those of wild. At this time, that is about $800 per dried pound. The advantages of this system are that it is easy and inexpensive. The disadvantage is the long wait time till harvest during which many things can happen to the roots.

## OPPORTUNITIES FOR GROWERS

### Wild-Simulated Ginseng Production

Consumers in Asia and other countries are showing increased interest in wild-simulated ginseng, which should help reduce pressure on wild populations. We refer to this as "conservation through cultivation". Consumers are becoming more educated about the plight of wild ginseng and desire a more sustainable and affordable product. Many manufacturers and herbalists who currently use wild ginseng are now seeking a more consistent product that is traceable, clean of any possible contaminants and adulterants, and can have a positive identity to satisfy the requirements of the federal Good Manufacturing Practices.

### Native Seed for Growers

Most of the commercially available ginseng seed used for propagation comes from plants grown under artificial shade structures. Because the plants are regularly treated with fungicides, the seed probably produces plants with little natural disease resistance. So the suitability of that seed for growing ginseng in a wild, unprotected environment is probably not ideal. There is also much discussion among botanists about bringing germplasm from these northern artificial shade gardens into the forests. Many would like to see the creation of native germplasm repositories and sources for providing native seed to growers. There is not agreement about whether these seed sources should be public, private, or a combination of the two.

Ginseng seed is not easy to produce and sell. When the ginseng berries are ripe, the seeds contained therein have immature embryos. The seed must be stratified in a moist environment and exposed to alternating warm and cold temperatures to satisfy their double dormancy requirements. The usual method of handling ginseng seeds involves putting green (freshly harvested seed) in moist sand in a stratification box and burying the box in a shaded area outdoors where it is exposed to natural temperature changes and rain. After a year the seed is removed from the box and sold as stratified seed. The stratified seed is usually planted in the fall and expected to germinate the following spring.

### Ginseng Seedlings

Although ginseng is almost always grown from seed, some growers and many gardeners prefer to plant 1- to 2-year-old ginseng seedlings. Few nurseries provide these seedlings and fewer still provide them in commercial quantities.

### Ginseng for Home Gardeners

Gardeners are interested in including ginseng in their native plant, shade, and medicinal plant gardens, but there is limited plant material and information available for them.

**Ginseng as a Potted Plant**
Ginseng can be grown in pots and sold as large plants (1-gal pots) for planting in the garden. Ginseng can also be sold as a unique potted plant by florists with a card describing its history and healing properties along with instructions on how to plant it in the garden.

**Vegetative Propagation**
Ginseng can be vegetatively propagated by cutting the bud with a little bit of the rhizome off the top of the root. This method is rarely used and many people don't believe it work. Some conservationists would like to encourage wild-harvesters to do this whenever they dig a root; that is in addition to planting any seeds that may be on the plant when they dig it. More research needs to be done on this method.

## THE CHALLENGES

All is not rosy in the world of ginseng. Because of the high value of the roots, poaching from public lands and stealing from private lands are a big problem. Stealing ginseng from a grower is a felony in some states, but catching the thieves is difficult and prosecuting them is rare. The prevalence and threat of these illegal activities should not be taken lightly. Anyone who grows ginseng should expect to have some stolen and should take every measure to protect their plantings. Recent "reality" television programs that glamorize wild-harvesting ginseng and give the impression that it is an easy way to make money have only exasperated the problem.

Diseases such as *Alternaria* and *Phytophthora* can cause serious damage to a bed of ginseng. Site selection to avoid areas with poor drainage and close monitoring of plants is necessary to prevent diseases from getting out of hand.

Wildlife, such as deer, groundhogs, voles, and turkeys, can also cause serious damage to a ginseng planting. In some areas, deer browse is considered the major threat to ginseng.

## MORE INFORMATION

This has been a very brief introduction to ginseng and just a few of the opportunities available to growers. For more information, refer to the book *Growing and Marketing Ginseng, Goldenseal and Other Woodland Medicinals* by Jeanine Davis and W. Scott Persons, 2014, New Society Publishers. Also visit the website, <http://ncherb.org>, and the many articles and links therein.

# Opportunities for Horticulture to Feed the World©

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**By the middle of the 21st century, the world population will increase 30% to more than 9 billion. Food production will need to increase 70% to meet increased demands. The numbers do not add-up how the world can realistically meet the increased demand for food. For the first time in human history, food production will be limited on a global scale by the availability of land, water, and energy. Food issues could become as politically destabilizing after 2050 as energy issues are today. More efficient technologies and crops will need to be developed to address this challenge — and equally important, better ways of applying these technologies locally for farmers. Simply put: technologies are not reaching enough smallholder farmers. A greater emphasis is needed in high-value, horticultural crops which create jobs and economic opportunities for rural communities, enables more profitable, intensive farming of small tracts of land in urban areas. Better information delivery (extension), reducing high crop losses and improving the value-chain from farm to fork are critical.**

## INTRODUCTION

High-value horticultural crops play a key-role in helping to feed the world with nutritionally healthy food (Harvesting the Sun: A Profile of the World of Horticulture, 2012). Horticulture, as part of specialty crops, represents 50% of the farm-gate value of all crops produced in the USA, and unlike cotton, corn, rice, soybean and other staple crops, they receive little government subsidization. While staple cereal crops are needed for their starch and calories, they do not supply the vitamins and minerals found in fruits and vegetables. There are opportunities for increased vegetable and fruit production and consumption to ensure a diet rich in vitamins and micronutrients (Bowman, 2013).Then there is the economics of scale: a smallholder farmer can be commercially successful growing high-value horticulture crops under small-acreage in rural, peri-urban or urban environments, while hectares are required to commercially farm cereals.

In California, the fastest growing segment of new farmers is female, non-Anglo, intensively growing horticulture crops on small acreage. In Ghana, the tomato industry is dominated by the "Tomato Queens of Accra" from production to marketing. A greater emphasis is needed in high-value, vegetable, fruit and ornamental plants which create jobs and economic opportunities for rural communities; enable more profitable, intensive farming of small tracts of land in urban areas; and employ smallholder entrepreneurs, especially women (Davies, 2012; Konuma, 2013).

## INCREASED FOOD DEMANDS AND URBANIZATION

By the middle of the 21st century, the world population will increase 30% to more than 9 billion. By 2030, 60% of the population will live in urban areas, and will reach 70% by 2050 (Wilson, 2014). Food production will need to increase 70% to meet higher demands. The numbers do not add-up how the world can realistically meet the increased demand for food, with environmentally and economically sustainable systems. For the first time in human history, food production will be limited on a global scale by the availability of

[1] Editor's Note: F.T. Davies served as a Senior Science Advisor/Jefferson Science Fellow at the Bureau of Food Security/Office of Agriculture Research & Policy, USAID – US Agency for International Development, Washington, D.C. (2013-2014).

land, water, and energy. Poverty is the principle cause of hunger. Some 75% of the world's chronically poor are found in mid-income countries, i.e., China, India, Brazil (World Hunger Education Service, 2013). Food issues could become as politically destabilizing after 2050 as energy issues are today (Friedman, 2008).

Indonesia is an example of a developing country facing significant nutritional and food security issues. The country imports 50% of its food while more than half of Indonesian children are malnourished. More than 60% of the 40% of Indonesians working in agriculture live at the poverty level, and there are large losses of product from farm to fork (i.e., 35% losses in tomatoes and rice) because of an inefficient supply chain that lacks SOPs — standard operational procedures and GAPs — good agricultural practices (Anonymous, 2014). These are daunting food security, human health, economic and political stability issues. Moreover, there are many other developing countries with fewer resources face that more severe challenges than Indonesia.

To reduce land pressures, more programs are needed in sustainable agriculture and resource management, as well as reducing food loss from farm to fork in developing countries. This includes increased infrastructure of roads, adequate storage facilities, good agricultural practices (GAP), post-harvest practices and developing cooperatives/ agricultural clusters (Friedlander, 2014).

## MEGATRENDS AFFECTING HORTICULTURE

Some 70% of the world's seven billion people own or have access to mobile phones. A billion people actively use Facebook. Indonesia, a developing country, is the fourth highest user of Facebook. Kenya is the largest user of mobile money. Some 30% of Kenya's GDP is spent through mobile phones (Mims, 2013). The largest region in the world to use mobile money is sub-Saharan Africa — one of the poorest regions in the world.

There are many innovative information and communication technologies (ICT). Most developing countries lack an organized, integrated USA-type land-grant system of research, teaching, and extension delivery for producers and consumers. In the developing world there is increasing emphasis on public-private hybrids of extension/information delivery to smallholder farmers. National governments, international agencies and NGOs are starting to utilize ICT technology for information delivery for smallholder farmers. The modernizing extension and advisory education program (MEAS) at USAID utilizes ICT technology as well as farmer schools, farmer-to-farmer and other programs: <http://agrilinks.org/activity/modernizing-extension-and-advisory-services>.

Digital Green video programs <http://www.digitalgreen.org/> is a low-cost platform to help with information transfer to smallholder farmers and consumers in India and Africa. Local, progressive smallholder farmers are recorded in their local language and dialect and used to transfer best practices to other local farmers. The 'Shamba Shape-Up" farm makeover reality TV show <http://www.shambashapeup.com/> reaches over ten million viewers in Kenya, many of them small-holder farmers. The International Potato Center (CIP) in Nairobi, has helped develop a series on "Shamba Shape-Up TV shows to educate the public and small holder farmers about highly nutritious, orange-fleshed sweet potatoes (OFSP). The series includes OFSP nutritional importance (high beta carotene for combating vitamin A deficiency), field preparation, propagation, planting, production, harvesting, post-harvest handling, storage, — and ideas on better ways to prepare and cook OFSP (Bouis and Islam, 2012).

## PACKAGE APPROACH OF HIGH VALUE HORTICULTURE CROPS LINKED TO MARKETS

Lack of access to credit, insurance, low quality seed, lack of technical assistance and direct links to markets limits the ability of smallholder farmers to become more commercially successful. Amiran <http://www.amirankenya.com>, which is a commercial greenhouse supplier in Kenya, has developed Amiran "farmer kits" to improve the livelihoods of smallholders. It is a micro-niche approach for producing high-

value horticulture crops from smallholders linked to markets. There is also support from the Kenyan government and commercial banks supplying low-interest loans and reinsurance that is used for micro-insurance of production inputs (i.e., high value horticulture seed, greenhouse materials, drip-irrigation, chemicals, etc.). The $4,000 micro-loan package is to be paid off over a period of several seasons, based on the high-value vegetable crop cash flow. The program targets young producers, 35-years and younger, who are required to contribute 10% collateral. The vegetable production system utilizes low-cost, insect-screened greenhouse structures and outdoor drip irrigation. There is access to trainers, pest-certification — and assistance to forge direct links to markets.

## CONSILIENCE AND HORTICULTURE

Successful programs in horticulture use consilience. This evolution of collaboration with horticulture and other disciplines has been going on for some time. We see it in thriving programs addressing societal issues, such as health, obesity and nutrition. Some 2/3 of all deaths are diet related: obesity, hypertension, heart disease, diabetes, etc. In the developing world, treating HIV patients in Kenya is compounded when they have diet-related diseases, plus malnourishment which limits effective treatment. A nutritious diet of vegetables enhances efficacy of HIV treatments (Weller, 2014).

A horticultural program built around consilience is the Cancer Prevention Laboratory (CPL) that Henry Thompson runs in the Department of Horticulture and Landscape Architecture at Colorado State University <http://www.cropsforhealth.colostate. edu/>]. The CPL conducts both pre-clinical and clinical research, the goal of which is to identify practical solutions that will empower an individual to adopt lifestyles that achieve and maintain a lower risk for cancer. They use consilience in tackling chronic disease prevention. This includes developing crops for health, integrating plant breeders, producers, retailers, biologists, chemists, health care professionals — and ultimately consumers. Because our food supply is a primary source of many chemicals that contribute to the interplay of forces that promote as well as prevent the development of cancer, the CPL is part of the College of Agricultural Sciences. This permits cancer researchers to regularly interact with investigators responsible for decisions that impact the health characteristics of the foods ultimately made available to the consumer. The CPL judges that enhancement of the health benefits of the foods made available to consumers could have global impact on human health and wellbeing.

## SUMMARY

Production of horticulture specialty crops is an opportunity to: reduce malnourishment, hunger, poverty, and to generate employment, create niche market opportunities for smallholder farmers on small acreage, and generate income for women. Unlike field crops (e.g., corn, wheat, rice, sorghum) which require larger land availability for economies of scale, horticulture can be profitable under reduced acreage. Building roads enables smallholders to have closer access to peri-urban and urban markets; this favours high-value, nutritious, intensively-grown vegetables, fruits, and flowers — as compared to field crops (Reardon, 2013).

Through sustainable intensification in urban and peri-urban environments, we can efficiently grow high value horticultural crops vertically, in synthetic media under protected culture (CEA — controlled environmental systems) from hoop-houses to modified greenhouses and buildings. To support the developing and developed world population increases, niches are needed of commercial small-holder to large-holder farmers producing in peri-urban and urban environments. It is all part of the nexus of Food, Energy, Water, Sanitation, and Health-Nutrition.

There are many opportunities for young and more experienced horticulturists to participate in addressing world food challenges. This includes the U.S. Peace Corps <http://www.peacecorps.gov/>, USAID Farmer to Farmer program <http://www. usaid.gov/what-we-do/agriculture-and-food-security/supporting-agricultural-capacity-

development/john-ogonowski> and various NGOs — non-government organizations <http://theglobaljournal.net/top100NGOs/>.

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# Propagation at Carolina Native Nursery©

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## NEW JERSEY TEA

The name, New Jersey tea (*Ceanothus americanus*) was coined during the American Revolution. The leaves were boiled and used as a substitute for tea. From personal experience, as we boil the seed prior to planting, the aroma smells of tea. One problem we have in the native plant business is finding liners that are not too large. *Ceanothus americanus* has a maximum height of 1 m (~3 ft) and is drought resistant. It is an early-to mid-summer bloomer.

As the demand of this plant became apparent to us, we were determined to figure out how to best grow it. We certainly could not find a nursery growing liners, as is the case with other plants we grow. We originally brought some to the nursery from a plant rescue that took place in Henderson County, North Carolina. Those original 20 plants sold quickly. So, as we have with many plants at Carolina Native we asked the question: to propagate by seed or cuttings? Which was going to be quickest method to get a good quality plant in the most cost effective timeframe? We have expertise in both methods, where to look for research, and the patience to do it.

### The Bottom Line: Use Seed Propagation and Grow Your Own Plants

The seed capsules will disperse the seed 1.2 to 1.8 m (4 to 6 ft) from the plant. It is important to harvest the seed when it ripens and turns black. As you begin to find open capsules, you will have a week or two to harvest or you will have to pick up seed from the ground. Clean the seed. Then boil a pot of water, add seed to boiling water and then turn off the heat. Soak those seeds for 24 h. We sow the seed into pine bark, the same medium we will shift the seedling transplants into. This reduces shock, which is extremely important in the ericaceous plants we grow.

Germination take approximately 2-3 weeks and we start fertilization with the 20-20-20 (N-P-K) at half rate on a weekly basis until we are prepare to move the seedlings to a RootMaker® flat of 18 cells. RootMakers grow the dense, fibrous root system we need in all the liners we grow. We will continue to grow them in the 18-cell flats, pruning at least 2 to 3 times until we are ready to transplant the next spring; we are currently experimenting with plant growth regulators for height control. Potting up in the March/April timeframe of the following spring will produce a full, 0.5-0.6 m (18-24 in.) 3-gal container plant ready to sell. We will top dress with Harrell's 18-4-8 (N-P-K) 6-month formulation at 62 g.

### Vegetative Propagation

We have tried all the hormones — K-IBA, IBA, and liquid and talc formulations at varying levels. We found that 8000 ppm Dip 'N Grow (IBA and NAA) worked the best with a 60% rooting and overwintering the rooted liners in flats. We found a pine-bark mix worked better than peat-based media, since this species does not like a lot of moisture. However, seedling produced liners work the best.

**1. Side Note.** These plants are addictive for rabbits and need to be protected. Rabbits will eat them to the ground and the plants will not recover.

## MAPLELEAF VIBURNUM

*Viburnum acerfolium* is found from Florida to Maine, and as far west as Texas. The species is 1-1.2 m (3-4 ft) wide by 1.5-1.8 m (5-6 ft) tall. Ornamental features include creamy-white flowers, black fruit that hangs like cherries, and great fall color. It is a

difficult plant to grow, requiring shade and a relatively dry, not too moist site. Mapleleaf viburnum needs to be watered by hand in the nursery and closely monitored.

**Seed**
Takes 2 years to propagate from seed, which is difficult to find.

**Cuttings**
We also use screened pine-bark medium and RootMaker flats with 18 cells. Cuttings are from current year's growth taken during the summer and 8-13 cm (3-5 in.) long. We use 8000 IBA talc plus Celluwet (sodium carboxymethyl cellulose, Coor Farms Supply) and get 60% rooting. The most important thing here is to overwinter the rooted liners in an unheated greenhouse. We will pot up the following spring and top dress with Harrell's 18-4-8 (N,P,K) 6-month formulation at 62 g. It will take 2 years from this point to have a nice, fully rooted 0.6 m (2 ft) plant. Water only as needed and keep the plant on the dry side.

**MOUNTAIN ANDROMEDA, MOUNTAIN FETTERBUSH, MOUNTAIN PIERIS**
*Pieris floribunda* is a dark green broadleaf evergreen, ericaceous shrub, cold hardy ornamental plant. It is a slow grower that obtains width and height dimensions of 1.2-1.5 m (4-5 ft). It should be planted in full sun in well-drained soil, let me repeat: well-drained soil! It does not like high humidity. We collected seed from Shining Rock Wilderness in Pisgah National Forest (North Carolina). It can be found in boulder fields and on ridge tops in Virginia south of Roanoke.

**Seed Propagation**
We grow it from seed and have very successful germination from seed we gathered 5 years from the Shining Rock Wilderness. Seed flats have screened pine bark with approximately 1/8 in. peat on top. We want the roots to grow into the bark as soon as possible. In our experience, if ericaceous seedlings are grown in peat, when the plants are transferred to larger containers with a pine-bark medium the roots will not want to venture out of the peat. So we sprinkle the seeds onto the peat, cover the flats with clear plastic covers, put them on heated benches maintaining a temperature around 15.5°C (60°F), and wait 2-3 weeks. Once germination occurs we activated lighting from 10 PM to 4 AM and begin the following schedule:

***Pieris* Seedling Care and Feeding**
Our recommendations are similar to Jay Jackson's presentation last year. For biweekly algae control use Xerotron-3 (Griffin Greenhouse and Nursery Supplies) at ¾ tablespoon per 2 gal as a drench.

**Recommendations**
For fertilization apply 20-20-20 (N-P-K) with a ¼ tbs per gal at germination until true leavers appear. When the true leaves appear, use injector concentration rates, alternating one every 10 days with stock solutions of: 20-20-20: 5.1 oz/1 gal, 21-7-7: 4.8 oz/1 gal, and 5-11-26: 5 oz/1 gal. We monthly apply the biostimulant Essential® Plus Organic 1-0-1 at 2 oz/gal as a water drench. We weekly alternate fungicides captan and Heritage® at 1 tbs/gal. Gnatrol® is applied biweekly at 8 teaspoon/gal. Yellow sticky cards are used to monitor insects.

In April we will pull the seedlings out of the flat and plant in RootMaker flats of 18 cells with screened pine bark. We prune 2-3 times for developing fully rooted liners for planting into 3-gal squats containers the following spring. We will top dress with Harrell's 16-6-11 (N-P-K) 6-month formulation at 63 g.

**SMOOTH HYDRANGEA**

With *Hydrangea arborescens* and *H. arborescens* subsp. *radiata* the overall process for seed propagation is the same as for the *P. florbunda*. But the separating differs. We separate the seedlings in the winter to plant in the RootMaker flats of 18 cells. The roots are firmer in the winter. Even though the root systems can be relatively small, the plants flush quickly in the spring. By midsummer we have pruned them twice and they are ready to move up to a 3-gal pots by midsummer. They will be top dressed with Harrell's 14-3-17 (N-P-K) 6-7 month product at a rate of 87 g for 3-gal pots. By the end of the growing season we will have a decent 3-gal plant and by the end of the next spring's flush, we have produced a beautiful plant — 18 months from a seedling to a full 0.6 m (2 ft) 3-gal plant.

# Fifty Shades of Green: Whipping Fungus Gnats in to Submission Using Biological Control©

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Many growers are incorporating some aspect of biological control in to their crop management programs. Reasons include better pest control, resistance management, and operational efficiency as well as marketing and customer-driven preferences. Several suppliers have been active in the nursery/greenhouse biological control realm for many years, and their websites are a great source of technical information. Syngenta Bioline <http://www3.syngenta.com/global/bioline/en/Pages/home.aspx>, Koppert <http://www.koppert.com/>, and Biobest <http://www.biobest.be/home/> are some of most well-known in our industry, and have field technical staff for grower support.

Most successful initial biological control programs are integrated in to existing pest management protocols, with realistic expectations and a single target pest. Fungus gnat control in propagation is a good starting point, since their biological control agents are easy to use, relatively inexpensive, and the odds of success are good if the program is properly executed.

Fungus gnat larvae are the #1 insect problem in propagation. Their feeding reduces callus formation, destroys tender new roots, and girdles stems. Fungus gnat damage also increases plant infections from fungal and bacterial pathogens. Economic impacts include reduced seedling and cutting survival, increased rooting time for cuttings, and increased fungicide costs and plant losses to secondary diseases.

Adult fungus gnats are nuisance pests and can annoy workers and customers, as well as vectoring fungal spores. Adults do not damage plants, their primary objectives are dispersal and procreation. However, the presence of mature fungus gnat indicates an existing problem with larvae. Sticky cards can be used to monitor adult populations. Place one yellow sticky card per 93 $m^2$ (1000 $ft^2$), and monitor weekly. Counts of >20 gnats per card is considered to be the economic threshold for treatment.

Fungus gnat larvae are slender, pale, dark-headed maggots, 5 mm or less in length. They feed on organic matter, with a preference for living plant tissue like roots, and are a major problem in many aspects of ornamental production. The addition of vermiculite or perlite to media reduces fungus gnat larval activity; they favor plant-based materials like compost, peat, bark, and coir. High soil moisture and warm temperatures are also conducive to fungus gnat reproduction.

Evidence of fungus gnat larval damage in propagation includes poor rooting and establishment, wilting, and nutritional deficiencies due to root damage. To find larvae, look in the top 1.3 cm (0.5 in.) of media and in the root zone. Potato slices are a good survey tool. Place small pieces of peeled potato on the media surface, and leave overnight. These will attract the maggots, which can be seen when the pieces are moved. If the potato slices disappear, rodents or other vertebrates may be present in the greenhouse. Fungus gnat hot spots can be determined by placing suspect pots in plastic bags for a couple of days and monitoring adult emergence.

If a control program is warranted, taking some initial steps will increase your success rate. Communicate with your employees. Everyone involved with the crop should have a basic understanding of what your integrated crop management program entails. This helps reduce errors in irrigation, chemical applications and other inputs that could jeopardize program results.

Sanitation is critical to long-term fungus gnat control. Clean up algae, plant waste, weeds, and pooling water that can harbor fungus gnats. Also check stock and pet plants for fungus gnat presence. If you plan to utilize biological control agents, avoid pyrethroids (Scimitar®, Talstar™, Decathalon®) or organophosphates (DuraGuard®,

Orthene®) for 4 to 6 weeks prior to releases. These products can damage some biological control agents (BCAs), but will not affect nematodes or bacteria. Some fungicides (Cleary™ 3336, Banner® Maxx®) can impact BCAs as well; check the company websites mentioned earlier for compatibility charts for most commonly used chemicals and fertilizers.

To start your fungus gnat control program, consider conventional treatment if populations are high. Insect growth regulators like Citation®, Distance®, and Adept® are excellent choices to help reduce larval populations in the soil, and can be used in conjunction with nematodes. Drenches with insecticides like Flagship™ or Safari® knock down both larval and adult fungus gnats and can reduce populations to levels that will respond to biological controls.

Once populations are low, or propagation is just beginning, initiate biological control before fungus gnats become a problem. As with most pest and disease control programs preventive treatments are more successful and less expensive than rescue applications.

Biological control agents that work best with soil drenches or through irrigation systems are nematodes and bacteria. Nematodes (*Steinernema feltiae* spp.) are available from several commercial sources (Exhibitline®, Nemasys©, etc.). They seek out fungus gnat larvae, penetrate through anal and oral openings, and release bacteria that kill the maggots. Beneficial nematodes are available year-round, and are easy to use. Nematodes tolerate fairly broad temperature [13 to 29°C (55 to 85°F)] and moisture ranges, and will also attack thrips pupae in the soil.

*Bacillus thuringiensis* subsp. *israelensis* (Gnatrol®) [B.t.i.] is a bacterium that infects fungus gnat maggots, and works best on 1st instar larvae, the smallest stage. Ingestion of the bacteria disrupts cell function, and efficacy is density dependent since the bacteria are passive and need to be eaten by the maggots. *Bacillus thuringiensis* subsp. *israelensis* is specific to fungus gnat larvae, and won't control other greenhouse pests.

In many cases, regular applications of nematodes alone will prevent or control low level infestations of fungus gnats. *Bacillus thuringiensis* subsp. *israelensis* can be used too in addition to nematode releases as needed. Make sure that propagation medium does not dry out excessively, or is not water-saturated. Both of these conditions will limit the efficacy of beneficial nematodes and B.t.i.

Other BCAs used against fungus gnats include the predatory mite *Hypoaspis miles.* Adult mites live for months, and will establish if conditions are right. These mites are promiscuous feeders, and attack most soil-dwelling creatures, including fungus gnat and shore fly larvae, thrips pupae, root aphids, as well as nematodes (good and bad), and springtails (Collembola). These are typically used by experienced growers, and work best when used along with other controls.

The rove (staphylinid) beetle, *Atheta coriaria*, is another broad spectrum feeder. Adults and immatures favor fungus gnat maggots and pupae and can be used to supplement nematodes in biological control programs. These fast-moving insects are active at dusk, and can be effective against a number of insect pests in propagation. Rove beetles enter diapause, a type of hibernation, in the winter, and are only seasonally available.

There are different approaches to fungus gnat control in propagation based on population size (Table 1) and type of treatment (Table 2). These are general recommendations and can be adjusted based on problem severity, crop type and budget.

Continue to use sticky cards and visual surveys to determine fungus gnat population levels and adjust releases and treatments as needed. Successful biological or integrated control programs require attention to detail and careful tracking. In most cases, they are not easier or less expensive than programs using pesticides exclusively, but do have some advantages. These include no re-entry intervals for treated crops, lower costs on safety equipment, and reduced resistance problems in target pests. Focused projects are best when starting a new approach to pest management, and biological control of fungus gnats in propagation is a great place to begin.

Table 1. Fungus gnat control based on population size.

| Fungus gnat control | Low populations <20 flies/week on sticky card | Moderate 20-50/week | High populations >50/week |
|---|---|---|---|
| Option 1<br>Best for propagation when cover is minimal, and for long-term crops like woodies and perennials. Less labor intensive | Use nematodes at preventative rate prior to potting, follow up with B.t.i. in 2 weeks. Apply nematodes every 2-4 weeks, alternate with B.t.i. | Release nematodes at mid-rate for 3 weeks, monitor and adjust rate and interval. Add B.t.i. once/month if needed | Use nematodes and B.t.i. weekly at high rates, release *Hypoaspis* mites as well. Consider IGR application at 2 week intervals |
| Option 2<br>Use when canopy is closed, later in propagation cycle or short-term crops | Release rove beetles at low rates at potting; follow 1 week later with mites. Repeat in 2 weeks | Use rove beetles or mites at moderate rates for 3 weeks | Use rove beetles and mites at high rates for 3 weeks, also nematodes at high rates if soil surface is accessible |

B.t.i. = *Bacillus thuringiensis* subsp. *israelensis*, IGR = insect growth regular.

Table 2. Fungal gnat control with an insect growth regulator, nematodes, predatory mites and Staphylinid beetle.

| Treatments | Product | Rate | Frequency | Comments |
|---|---|---|---|---|
| 1 | Citation® Insect growth regulator | 2.66 oz./100 gals drench | Apply as a drench 7 to 14 day interval as needed | Citation® application allows a start with a clean crop |
| 2 | Exhibitline™ sf *Steinernema feltiae* (Insect pathogenic nematode) | Apply as a drench using 50,000/$ft^2$ | Preventative: 7-21 day interval Curative: 7-14 days interval | Apply when soil temperatures are between 55-85°F. *S. feltiae* can be tank mixed with Citation |
| 3 | Hypoline™ *Hypoaspis miles* (predatory mite) | *H. miles*: 10-25 mites/$ft^2$ Hot spot: 50 mites/$ft^2$ | Apply 1-2 times per crop, actively reproduce at 50-90°F | Apply evenly on soil and under benches. *H. miles* and *S. feltiae* can be released the same week |
| 4 | Staphyline™ *Atheta coriaria* (Staphylinid beetle) | 0.5-1.0/$ft^2$ Hot spot: 2X rate | Make two releases at 7-day intervals to encourage swift establishment | Pest catches will decline over 2-6 weeks |

To increase your chances of good results with biological control programs, here are some tips:

- Accurately identify the target pest.
- ID Key people, engage entire staff.
- Start small.
- Start clean.
- Communicate with suppliers about ordering beneficials.
- Maintain good scouting and record keeping.
- Modify spray programs as needed, don't rush to treat if problems break out.
- Watch for secondary pests and diseases.
- Audit scouting data, identify trends and hot spots.
- Celebrate your success!

For more information, go to <www.syngentaflowers.com>.

# Water Retention of Processed Pine Wood and Pine Bark and Their Particle Size Fractions©

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## INTRODUCTION

The wettability of a material intended for horticultural use is integral for high quality plant growth and performance. The ability of a substrate material (organic or inorganic) to capture and retain water (wettability) contributes to water-holding capacity and improved plant growth (Plaut et al., 1973). Many horticultural substrate materials, such as pine bark, experience hydrophobicity at low moisture levels (Beardsell and Nichols, 1982; Fonteno et al., 2013; Michel et al., 2001) which in turn has deleterious effects on irrigation efficiency and crop production. Further advantages of a substrate material being able to capture water include maintaining plant quality in post-production retail environments. Some research suggests that the variation in size and structure of milled pine bark particles may contribute to water holding (Airhart et al., 1978). The purpose of this study was to explore how processed pine wood, pine bark, and their resulting particle fractions capture and retain water using the wettability method described by Fields et al. (2014).

## MATERIALS AND METHODS

Unprocessed pine bark nuggets and coarse loblolly pine wood chips (*Pinus taeda*) were acquired from local sources in southeast North Carolina (NC). Both materials were processed in a hammer mill (Model 35; Meadows Mills, North Wilkesboro, NC) at the Substrate Processing and Research Center located at the Horticultural Field Laboratory on the campus of North Carolina State University located in Raleigh, NC. The materials were then processed through a hammer mill with no screen inserted in order to assure a wide variation of particle sizes (known to occur as experienced in personal observations). Moisture content of the materials were not adjusted prior to processing but were processed as received. To prevent moisture loss after milling, processed materials were sealed in plastic 55-gal. drums for further testing. Both the processed pine wood and pine bark were then sieved and grouped into four individual size fractions: extra-large, >6.3 mm; large, <6.3 mm >2 mm; medium, <2 >0.5 mm; and fine, ≤0.5 mm. Materials were not oven dried as is typical for particle size distribution analysis, in order to avoid hydrophobicity observed in organic materials and the need to keep the substrates moist for wettability testing. Substrates were sieved at the moisture content (MC) observed after milling, 29 and 44.5% for the pine wood and pine bark respectively. The sieved fractions and the non-sieved pine wood and pine bark were then hydrated to a MC of 50% by weight for testing. Additionally, materials were tested at 25% MC. To achieve the lower MC approximately 300 ml of each substrate were spread 2 cm deep on a tray and allowed to air-dry until reaching 25% MC. A total of 20 treatments were used in this study [2 materials × 5 substrates (four fractions plus the non-sieved material) × 2 MC = 20 treatments].

Water capture and retention of materials were determined by the wettability protocol described by Fields et al. (2014). The equipment used for water capture testing consisted of a transparent cylinder 5 diameter × 15 cm height, with a mesh screen attached to the bottom using a rubber ring; a 100 ml plastic vial, 4 cm diameter; a 250 ml separatory funnel; and a 250 ml beaker placed at the bottom. The vial had 5 holes in the bottom in order to act as a diffuser, effectively spreading the force of water over the surface of the materials. The vial was fixed into position in the top of the transparent cylinder with a rubber O-ring to allow for precise adjustments in positioning. The transparent cylinders were packed to a bulk density within 5% of samples of the same material. Each hydration

event used 200 ml of water. Flow was controlled with the funnel stopcock and water diffused evenly onto the materials. Water effluent that drained through the materials was recorded and the moisture retained was calculated by subtraction. Ten hydration events were conducted on each of the 20 treatments with 4 replications per treatment. Values at 10 were used as an estimation of maximum hydration. Data were analyzed using general linear model procedures and regression analysis (SAS Institute version 9.3, Cary, NC). Means were separated by least significant differences at $P \leq 0.05$.

## RESULTS AND DISCUSSION

Volumetric water content (the amount of water retained after each hydration event) in fractioned wood treatments with an initial MC of 50% (Fig. 1) were significantly greater after 10 hydration events than wood fractions with an initial MC of 25% (Fig. 2). This was not seen in the initially processed non-sieved pine wood material. The improved wettability of wood with higher MCs has been seen in previous work (Fields et al., 2014). Bark however did not react as expected or as previous report by Fields et al. (2014). Hydration curves (Figs. 3 and 4) exhibited different patterns for 50 and 25% MC. However the only significant difference at the end of the 10 hydration events was seen in the medium size (2.0 to 0.5 mm) particles with 78 and 68% water content for the 50% and 25% MCs respectively. Fines for both materials retained the most amount of water compared to any other treatment (Table 1). The behavior observed in bark at 25% MC is contrary to the hydrophobic nature that one would expect, and that has been observed (Airhart et al., 1978; Fields et al., 2014) in pine bark at low MCs. One possible explanation for this may be that the milled bark was processed differently than would commonly be found within industry practices. The random fracturing of particles during processing may have contributed to changes in particle surface area and structure of the bark, allowing it to capture water more efficiently. Further research is needed comparing the water capture of unprocessed versus hammer milled pine bark, fresh versus aged pine bark when unprocessed and when hammer milled.

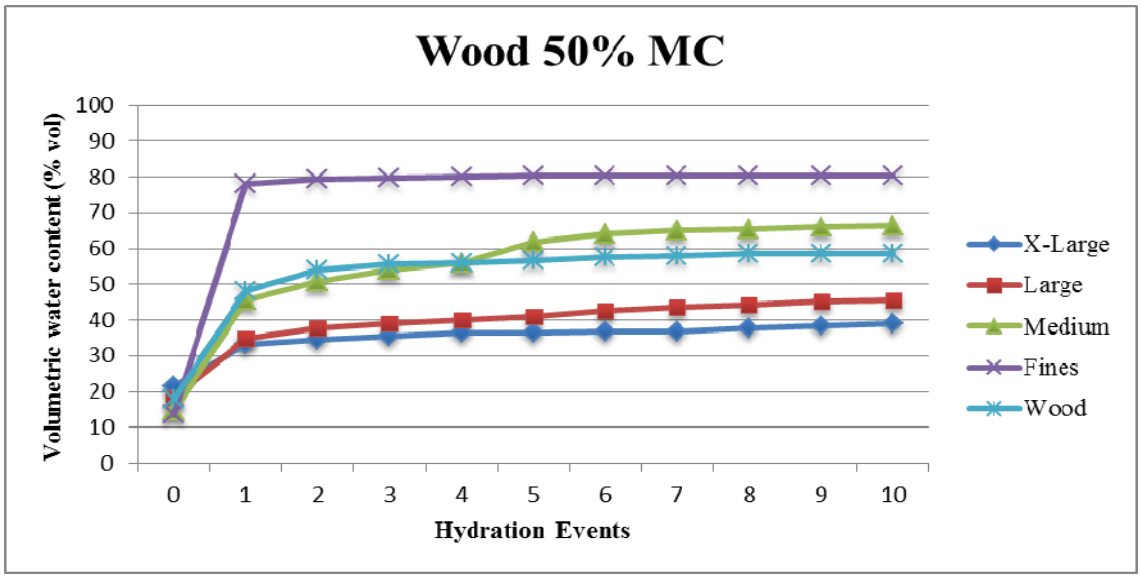


Fig. 1. Hydration curves for processed pine wood and corresponding fractions with an initial moisture content (MC) of 50%. Volumetric water content is the amount of water retained after each hydration event. X-large particles >6.3 mm in diameter. Large particles <6.3 mm >2 mm in diameter. Medium particles <2 >0.5 mm in diameter. Fine particles ≤0.5 mm in diameter. Processed wood, non-sieved material.

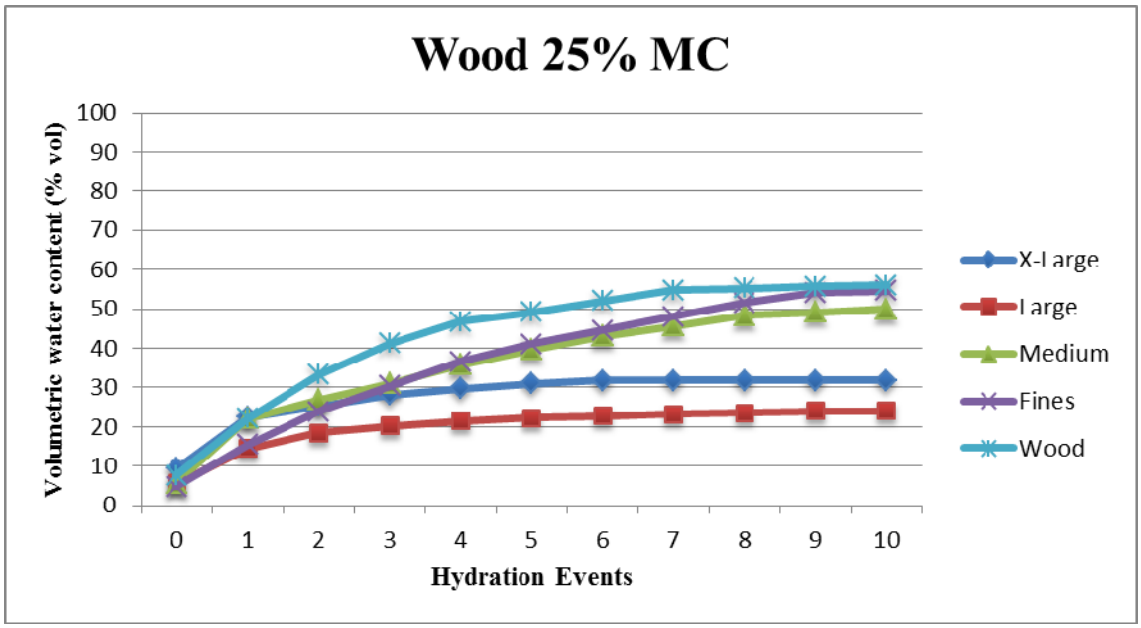


Fig. 2. Hydration curves for processed pine wood and corresponding fractions with an initial moisture content (MC) of 25% (by weight). Volumetric water content is the amount of water retained after each hydration event. X-large particles >6.3 mm in diameter. Large particles <6.3 mm >2 mm in diameter. Medium particles <2 >0.5 mm in diameter. Fine particles ≤0.5 mm in diameter. Processed wood, non-sieved material.

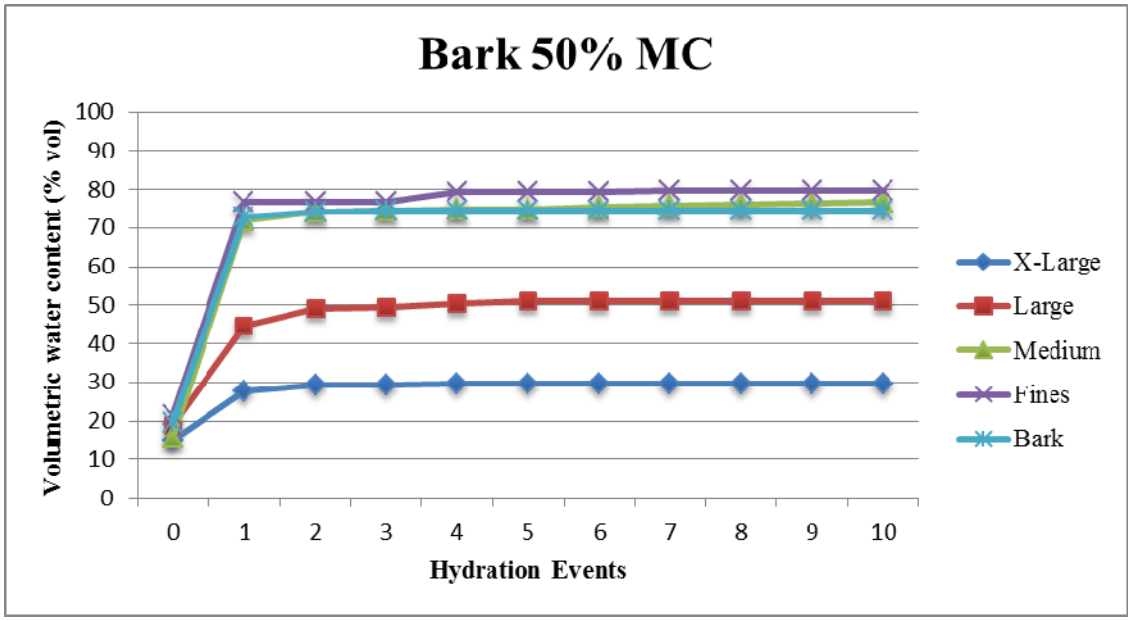


Fig. 3. Hydration Curves for processed bark material and corresponding fractions with an initial moisture content (MC) of 50%. Volumetric water content is the amount of water retained after each hydration event. X-large particles >6.3 mm in diameter. Large particles <6.3 mm >2 mm in diameter. Medium particles <2 >0.5 mm in diameter. Fine particles ≤0.5 mm in diameter. Processed bark, non-sieved material.

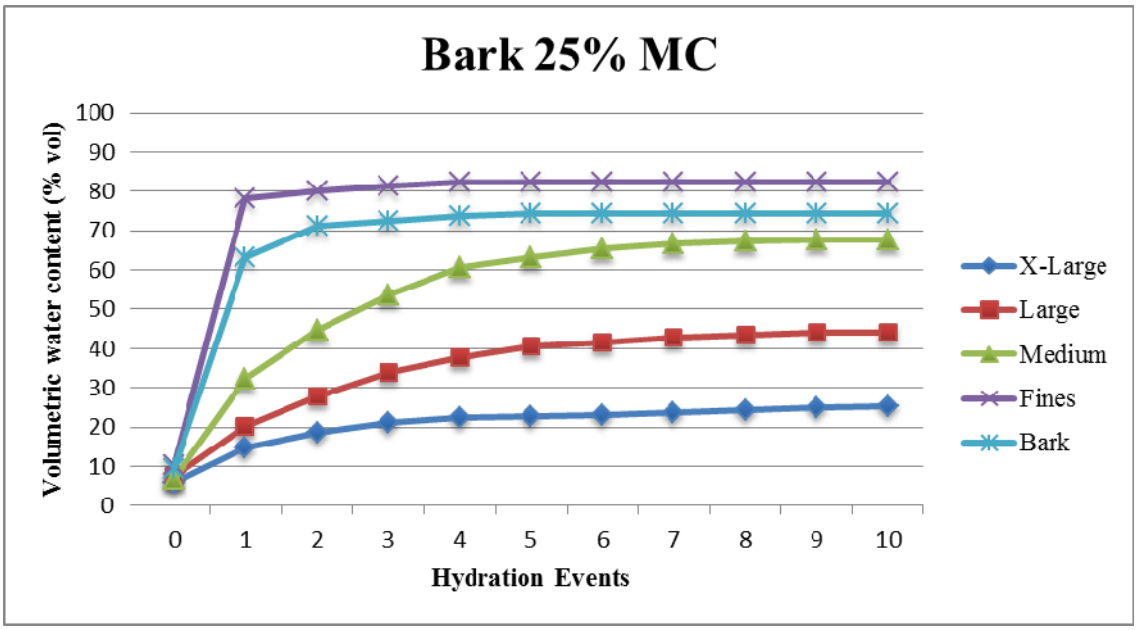


Fig. 4. Hydration Curves for processed bark material and corresponding fractions with an initial moisture content (MC) of 25%. Volumetric water content is the amount of water retained after each hydration event. X-large particles >6.3 mm in diameter. Large particles <6.3 mm >2 mm in diameter. Medium particles <2 >0.5 mm in diameter. Fine particles ≤0.5 mm in diameter. Processed bark, non-sieved material.

Table 1. Water content (% volume) of processed pine bark and pine wood after ten hydration events (maximum hydration).

| Initial moisture content | Extra large (>6.3 mm) | Large (6.3 to 2.0 mm) | Medium (2.0 to 0.5 mm) | Fines (≤0.5 mm) | Whole material |
|---|---|---|---|---|---|
| Wood 25% | 31.9 b[z] | 24.1 b | 49.9 c | 54.5 b | 56.0 b |
| Wood 50% | 39.0 a | 45.7 a | 66.4 b | 80.3 a | 58.5 b |
| Bark 25% | 25.4 c | 44.2 a | 67.6 b | 82.4 a | 74.0 a |
| Bark 50% | 29.5 bc | 51.0 a | 76.7 a | 79.8 a | 74.5 a |

[z]Means separation between all materials by LSD, P<0.05. Means followed by the same letter in the same column are not significantly different.

Additionally the initial moisture content of these materials at the time of hammer milling may also have an influence on the subsequent substrate surface area, size and structure. Only after exploring how these variables relate to internal porosity, water availability and the hydrophobic nature of pine wood and pine bark materials could these substrate materials be better understood. Potential implications of engineering pine bark and pine wood substrates to capture and release water easily and efficiently could vastly improve crop irrigation management and substrate wettability issues.

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# Effect of Pest Management Strategies on Economics of Small Scale Tomato Production in Mississippi©

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**Evaluation and improvement of management techniques is important to increase the viability of small scale vegetable production. Three management strategies, including calendar spray schedule, integrated pest management (IPM), and organic pest control, were evaluated in terms of their effect on yield and economic return for 'Celebrity' and 'Bush Early Girl' tomatoes in Mississippi. In Spring 2014, significantly greater yields were obtained from the IPM management system for both tomato cultivars studied. Significantly greater economic return was obtained from 'Bush Early Girl' IPM than for other 'Bush Early Girl' treatments. Total return from the 'Celebrity' IPM treatment was greater than that for the 'Celebrity' calendar treatment but not the 'Celebrity' organic treatment. When considered across both cultivars, the IPM management treatment resulted in significantly greater yields and total return than other treatments.**

## INTRODUCTION

The production of vegetables and melon in Mississippi (MS) accounted for an economic impact of $145.1 million in 2007 (USDA, 2007). In addition to this, vegetable production generated a total of $60.5 million in labor income (Posadas, 2011). Tomatoes grown in the open field accounted for 431 acres of production on 426 farms. Greenhouse production of tomatoes accounts for a further 31 farms, with approximately 4.6 acres under glass (USDA, 2007). Vegetables may be chosen as alternative crops for small scale production due to the potential for high economic return on small acreage. Small farms account for 81% of local food sales (Low and Vogel, 2011).

Insect pests have a significant impact on both crop yield and quality. However, there is limited information on the degree of damage resulting from insect pressure in small scale vegetable production. Between 20 and 30% of yield is lost annually in crops with extensive pest protection (Lucas, 2011). These losses may be even greater in crops where restricted use pesticides and resistant cultivars are unavailable. Many small scale vegetable producers lack certification for restricted pesticide use and may use cultivars with limited genetic resistance (e.g., heirloom cultivars) due to consumer demand. Improved crop protection strategies to limit damage may significantly increase production efficiency and food security (Lucas, 2011).

Concerns about health and environmental impact of the use of synthetic pesticides have led to significant changes in production practices. Integrated pest management (IPM) involves the judicious use of pesticides in response to field sampling of pest populations. Integrated pest management programs have been widely successful in reducing pesticide use while increasing profitability of crop production (Allen and Rajotte, 1990). Further, public concern about the health and environmental effects of pesticides is increasing. Organic production of vegetables is an increasingly important segment of the small scale vegetable production sector. In 2007, organic crops were harvested on 36 farms over a total of 482 acres in Mississippi (USDA, 2007). The efficacy of control for conventional pesticides is often greater than organic controls. When management practices were investigated, the type of pesticide used was the most important factor affecting insect populations (Hummela et al., 2002).

The objective of this study is to evaluate the effect of insect and disease pest management strategies on the economics of small scale vegetable production. The strategies to be considered in this study are management based on a calendar spray

schedule, integrated pest management (IPM) using conventional pesticides, and management using organic controls.

## MATERIALS AND METHODS

Three management strategies were evaluated on two cultivars of tomato commonly available to growers in South Mississippi. In the first treatment, conventional insecticides were applied every 14 days after transplant regardless of observed insect pest populations. In the second treatment, conventional pesticides were applied when sampled insect populations were greater than established economic thresholds. The third treatment utilizes economic thresholds; however, pesticides used in this treatment were limited to those allowed in organic production. Tomato cultivars for this study include *Solanum lycopersicum* 'Celebrity' and 'Bush Early Girl' (Harris Seeds, Rochester, New York). These cultivars were transplanted into field plots 15 Apr. 2014 in accordance with recommendations provided by the Mississippi State University Extension Service. Plants were obtained as seed and grown under greenhouse conditions at the South Mississippi Brach Experiment Station prior to transplantation to field plots.

Plots were established in four locations in southern MS, including Kiln, MS, the South Mississippi Branch Experiment Station in Poplarville, MS, the Beaumont Horticultural Unit in Beaumont, MS, and the Stone County USDA Research Station located near Wiggins, MS. Six plots were established at each study location consisting of each of three treatments on each of the two cultivars on which these management practices were evaluated arranged in a randomized complete block design.

Plots for this study consisted of two 1.8×1.8×0.2 m (6 ft×6ft×8 in.) raised beds. Beds were constructed from four 5×20 cm (2×8 in.) boards. The growing media in each box consists of composted pine bark screened to 1 cm (⅜ in.) (Eaks Nursery Materials, Seminary, MS). Prior to planting, media from raised beds was sampled and submitted for testing at the Mississippi State University Soil Testing Laboratory. Recommendations for fertilization and lime application for tomatoes were followed. Watering of plots was conducted by drip irrigation system. Watering between study sites varied according to the needs of plants at that location. Sampling of plots was conducted weekly and consisted of whole plant visual examinations of four plants per plot.

Pesticides applied in this study were limited to those commercially available without a Private or Commercial Pesticide Applicator's license. In the calendar spray treatment, applications of Carbaryl (Sevin®, Bayer Environmental Science, Research Triangle Park, North Carolina) in a liquid formulation were conducted every 2 weeks after planting. This insecticide is chosen due to its broad availability, common use, and activity against a wide range of insect pests.

For the conventional, integrated pest management treatment, pesticide applications were conducted as dictated by pest populations. The pesticides used for this treatment were selected according to recommendations issued by the Mississippi State University Extension Service for control of the pest insect. Similar recommendations were followed for organic treatment plots. Insect thresholds from the Mississippi State University Extension Service were used when available. All plots for this study were sprayed prophylactically for common fungal diseases using a broad spectrum fungicide. Fungicide applications included Myclobutanil (Spectracide Immunox® Multi-Purpose Fungicide Spray Concentrate for Gardens, Spectrum Group, St. Louis, Missouri) and Chlorothalonil (Ferti-lome Broad Spectrum Landscape and Garden Fungicide Voluntary Purchasing Group, Bonham, Texas). All pesticides were used in accordance with label directions.

In order to evaluate management strategies in terms of economic benefit, the cost of inputs was recorded. The cost of all pesticide treatments was calculated by measuring the volume of pesticides applied. To accurately measure the amount of pesticides applied, average output from a 1-gal pump sprayer (Chapin International, Batavia, New York) over a period of 1 min was determined. The time spent applying pesticides to plots was measured and the actual volume applied was calculated. Pesticide costs were recorded as a proportion of the actual retail cost of purchase of those pesticides. Time spent in

managing each treatment was measured and recoded. Activities for which time will be recorded include harvesting, sampling for insect populations in IPM and organic treatments, and pesticide application. Value of time worked was calculated from hourly wage data obtained from the Bureau of Labor Statistics <http://www.bls.gov/>.

Harvest of fruit from plots was conducted twice weekly. Fruit harvested in each plot was weighed and rated as marketable or unmarketable. Weights were recorded for both marketable and total yield. Value of fruit was calculated using averages available as the National Fruit and Vegetable Retail Report of the USDA Agricultural Marketing Service (USDA Agricultural Marketing Service, 2013). The cost of management practices was subtracted from the total yield value for each plot to obtain the actual value of production.

Data in this study was analyzed by SAS v. 9.3 using PROC ANOVA and means separation (SAS Institute Inc., Cary, North Carolina). Factors evaluated using these procedures included total weight of harvested tomatoes, value of production by weight, and economic return (value of harvested tomatoes less input costs.

## RESULTS AND DISCUSSION

During the Spring 2014 season, greatest mean yields of marketable fruit 15.4 kg (33.9 lbs.) were obtained from Celebrity tomatoes under the IPM management system. These yields were significantly greater than those from other treatments for both cultivars ($P$<0.05). Marketable yields from the Bush Early Girl IPM (29.2 lbs.) were significantly greater than those from all treatments excluding that from Celebrity tomatoes under the calendar management system (Table 1).

Table 1. Tomato cultivars, pest management strategy, marketable yield and economic returns.

| Treatment | Marketable yield (lbs.) | Economic return ($USA) |
|---|---|---|
| Early Girl IPM | 29.243±6.02 A[1] | 51.98±11.63 A |
| Early Girl Calendar | 18.248±4.06 B | 28.71±8.28 B |
| Early Girl Organic | 13.005±5.6 B | 27.54±15.55 B |
| Celebrity IPM | 33.856±6.08 A | 62.02±11.83 A |
| Celebrity Organic | 25.389±5.06 B | 44.64±12.48 AB |
| Celebrity Calendar | 19.231±4.37 B | 43.38±9.87 B |
| IPM | 31.549±6.12 A | 56.99±12.12 A |
| Calendar | 21.819±5.71 B | 36.05±11.52 B |
| Organic | 16.118±5.71 B | 36.09±15.95 B |

[1]Means in a column followed by the same letter are not significantly different ($P$<0.05).

In terms of total yield, no significant difference was observed between the two cultivars included in this study. Total yields (marketable and unmarketable) for each treatment were not significantly different ($P$<0.05). A greater proportion of fruit from organic treatments were determined to be unmarketable. The most frequent source of damage resulting in fruit being rated as unmarketable was associated with hemipteran pest insects with piercing-sucking mouthparts such as stinkbugs and leaf-footed bugs. These insects are effectively controlled with conventional pesticides including carbaryl and malathion. Organic pesticides did not provide effective controls against these pests.

The value of tomatoes was calculated and costs of production were subtracted from that value. During the spring season, significantly greater economic return was obtained from Bush Early Girl IPM ($52) than for other Bush Early Girl treatments ($P$<0.05). Total return from the Celebrity IPM treatment ($62) was greater than that for the Celebrity calendar treatment but not the Celebrity organic treatment. When considered across both cultivars, the IPM management treatment resulted in significantly greater yields [14.5 kg

(32 lbs)] and total return ($57) than other treatments (Table 1). Although a greater value per pound was given (USA$ 2.80) for organic tomatoes than conventionally grown tomatoes (USA$ 2.00), the increased value was not sufficient to counteract the reduction in marketable yield associated with less effective controls from organic pesticides. Value of time spent was calculated at an hourly rate of $9.62 <http://www.bls.gov>. This value was effectively balanced by a reduction in time spent applying pesticides to plots as well as by a reduction in the value of pesticides applied.

The initial observations of this study suggest that the adoption of principles of Integrated Pest Management (IPM) would represent a potential for increased yields and economic return for small scale vegetable producers in Mississippi. However, adoption of IPM by small scale producers is limited. The identification and elimination of barriers to this pest management system would be beneficial for these producers.

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# Sterilization and In Vitro Growth and Development of *Arundinaria*©

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## INTRODUCTION

River cane, switch cane, and the newly identified hill cane, are the three species that make up the genus *Arundinaria* (Ohrnberger, 1999; Triplett, 2006). This genus of temperate woody bamboos is native only to North America and typically grows along waterways or in marshlands forming dense stands called canebrakes. These canebrakes have a dense system of rhizomes, which act as an effective riparian buffer to prevent excess nitrogen, in the form of agricultural runoff, from entering waterways. This dense network of rhizomes also helps to prevent erosion of river and stream banks. Beyond purely environmental benefits, ecologically, canebrakes form a unique habitat for many species of cane-obligate butterflies as well as many rare bird species (Platt et al., 2013).

Currently, the genus *Arundinaria* is sparsely distributed in 22 states of the southeastern United States. Although its distribution is wide, it is reported that the genus has suffered massive habitat loss due to altered burning regimes, conversion to farmland, and overgrazing. In fact, many historical accounts report canebrakes up to 20 miles long and ½ mile wide (Platt and Brantley, 1997); however, since European settlement of North America, the size of canebrakes has shrunken by an estimated 98% (Noss et al., 1995).

Successful large-scale propagation of *Arundinaria* would be of great interest to conservationists and to managers carrying out native plant restoration efforts, but large-scale propagation is fraught with many challenges. Biologically, seed-based bamboo propagation is not a viable option due to extremely long times to maturity and irregular flowering (Hughes, 1951; Janzen, 1976). Vegetative macropropagation is technically simple, but finding, harvesting, cleaning, transporting, and replanting rhizomes is extremely logistically difficult and very time sensitive. In vitro micropropagation would offer the possibility of generating large numbers of transplantable plants without the uncertainties in material acquisition, but bamboos are notoriously difficult to disinfest and any micropropagation system requires optimization. Our objective was to test procedures to successfully disinfest *Arundinaria* for in vitro micropropagation and to characterize its growth in vitro for later use in larger scale propagation experiments.

## MATERIALS AND METHODS

### Explant Material

Two types of propagation explant material were obtained for this experiment. In late January of 2014, rhizomes from a canebrake in Clarke County, Georgia were harvested, potted, and grown in a heated greenhouse on the University of Georgia campus. In March, the vigorously growing plants were treated with a systemic fungicide (Procure® 480SC, 8 oz/gal). These plants served as explant material for shoot disinfestation experiments conducted in May 2014 and July 2014. For these experiments, lateral shoots were disinfested either as multinodal branches or as single nodes. Additionally, the effect of leaf sheath removal to reduce contamination was investigated. For this, the sheath surrounding the stem was carefully removed with a scalpel down to the base of the node to expose the bud scale.

Unexpectedly, a second propagation material was provided. A local cane enthusiast and grower was able to provide seed from flowering plants he had scouted. The batch included several hundred seeds from a large canebrake in Arkansas. This larger batch was intended for nursery planting and unfortunately had been dusted with mycorrhizal spores beforehand. Due to the poor long-term viability of bamboo seeds, this batch served as the seed and embryo material for disinfestation experiments conducted only in May and early June. For these experiments, the seeds were disinfested as whole seeds with prophylls

(bracts) removed or as isolated embryos.

**Sterilization Procedures**
Sterilization procedures were improved iteratively over several trials. The initial procedure began with a rinse in soapy water to remove large debris, a tap water rinse, and a short dip in ethanol. During the ethanol dip, the explants were transferred to a laminar flow hood. A rinse in benzalkonium chloride (Lysol) and a subsequent rinse in bleach followed. Finally, the explants received three rinses with sterile water. A later series of treatments, adapted from Thakur (2006), were also tested. These treatments differed from the previous treatments in their handling of the explant material and had a long rinse with a combination antibiotic/fungicide solution (Rifampicin/Procure). Table 1 summarizes the lengths and concentrations of the rinses in the various sterilization treatments; the treatments are numbered in order of increasing harshness.

Table 1. Summary of sterilization treatments. Times are given in minutes or seconds. Bleach concentrations are given as concentration of sodium hypochlorite (NaOCl), and the ethanol used was 70%.

| Treatment | Soapy water (min.) | Ethanol (s) | Antibiotic/fungicide (min.) | Bleach (conc.) (min.) |
|---|---|---|---|---|
| 1 | 20 + rinse | 30 | - | 10 (0.53%) |
| 2 | 20 + rinse | 30 | - | 10 (1.05%) |
| 3 | 20 + rinse | 30 | - | 10 (2.63%) |
| 4 | 20 + rinse | 30 | - | 10 (2.63%) + 10 (0.53%) |
| 5 | 20 + rinse | 30 | 10 | 10 (0.53%) |
| 6 | 20 + rinse | 30 | 10 | 20 (0.53%) |
| 7 | 5 | - | 60 + rinse | 5 (4%) |

**Growth Conditions**
Based on the promising preliminary work of Baldwin et al. (2009), Murashige and Skoog (MS) media were shown as being comparable to WPM and superior to DKW media for river cane growth. Therefore, all media recipes used were based on MS media. The media were all made with 3% sucrose, gelled with 0.4% Gelzan, and brought to pH 5.8 before autoclaving. For initial growth conditions, the media was supplemented with 1.98 $mg \cdot L^{-1}$ BAP (6-benzylaminopurine) for seed-based explants and 3 $mg \cdot L^{-1}$ BAP for shoot-based explants.

**Data Collection**
For the first week after disinfestation, the explants were examined daily for signs of bacterial or fungal contamination. Thereafter, the explants were examined every other day. Additionally, the growth of the plants was observed. Times to root and shoot emergence were recorded as well as the timing of any lateral shoots that developed. For shoot-based disinfestations, results are presented for only the first six weeks, corresponding to the duration since the most recent trial; seed-based trials, however, have data for approximately 100 days.

## RESULTS AND DISCUSSION

**Shoot Disinfestation and Development**
The initial shoot sterilization procedure was conducted on single nodes with the leaf sheaths removed. Contamination was moderate. Treatment 5 showed 55% disinfested shoots after 6 weeks, but the harsher Treatment 6 showed only 33% disinfested shoots (Fig. 1A). A second round of treatments on the same type of explant material included Treatments 1, 5, and 7. Treatment 5 again showed similar results, 57% disinfestation,

suggesting the 'baseline' contamination of the plants had not changed between the two times. Treatment 1, which generates less waste material than Treatments 5, 6, and 7, showed an improvement with 76% disinfested shoots. Finally, Treatment 7 was conducted on single nodes with leaf sheaths removed as well as on multimodal segments with and without leaf sheaths. The multimodal segments showed similar results to the single nodes under Treatment 1 between 75% and 80% disinfestation. The best treatment by far, however, was the combination of Treatment 7, the single nodes, and the removal of the leaf sheaths; this treatment showed 100% disinfestation. It should be noted however, that for the shoot disinfestation experiments latent contamination was a severe problem. Many nodes did not show signs of contamination until 2 months after being treated; so long term evaluation will be necessary.

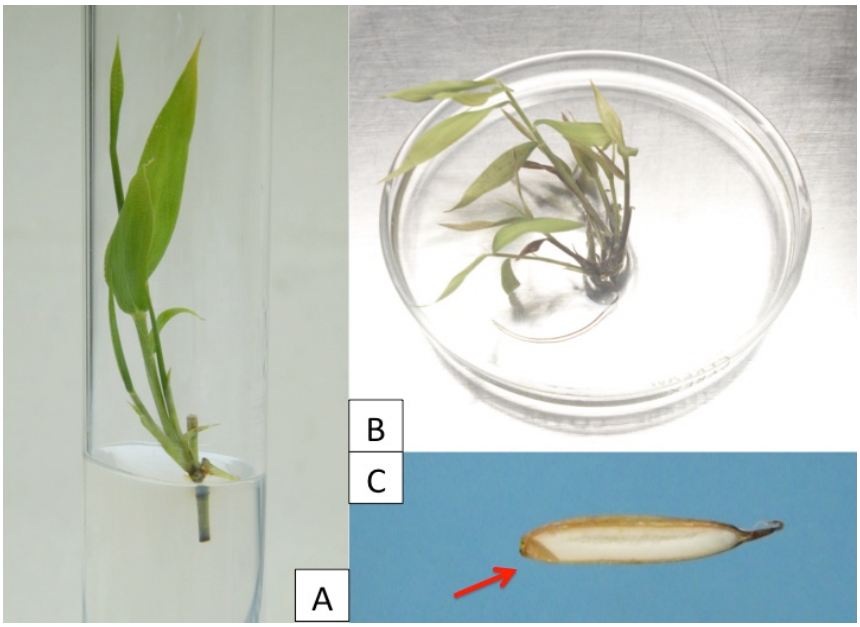


Fig. 1. (A) A sterilized nodal segment growing in vitro with lateral branches; (B) A developing plantlet with several later shoots and roots derived from a sterilized embryo; (C) A longitudinally dissected seed of *Arundinaria* showing the starchy endosperm and embryo (arrow).

Because of the prolonged fungicide rinse in Treatment 7, which has been shown in other plants to affect proliferation (Ruzić et al., 2009; Werbrouck and Debergh, 1996), the fold multiplication of the shoots and the time to first lateral shoot emergence were calculated. After 6 weeks, the shoots showed 1.41-fold (±0.75) multiplication. This rate was statistically equal for all dates and sterilization treatments. The average time to emergence of the first lateral shoot was 34 days (±7.7) days post sterilizations (DPS), however Treatment 5 showed a significant difference between trials. The explants showed lateral shoot emergence at 39 DPS versus 26 DPS for the earlier and later trials, respectively. The results for contamination percentages and growth are summarized in Table 2. Overall, these results show that Treatment 7 has a very high success for disinfestation of shoot material and that it has not been shown to significantly alter growth as compared to other methods tested.

Table 2. Results of the contamination and growth of the explant material. Shoot emergence times for nodes are note given because all growth from nodes is lateral growth. Numbers in parenthesis are times in days ± the standard deviation.

| Treatment | Explant | Disinfestation (%) | Shoot emergence (%) (days ± s.d.) | Lateral shoot emergence (%) (days ± s.d.) |
|---|---|---|---|---|
| 1 | Single node | 76 | - | 100 (33±7) |
| 2 | Embryo | 50 | 50 (35±28) | 45 (58±28) |
| 3 | Embryo | 28 | 46 (24±24) | 30 (52±26) |
| 4 | Embryo | 95 | 18 (29±20) | 21 (59±26) |
| 5 | Single node | 55 | - | 100 (32±6) |
| 6 | Single node | 33 | - | 100 (33±9) |
| 7 | Single node | 100 | - | 100 (34±6) |
| 7 | Multinodes | 75 | - | 100 (34±11) |
| 7 | Multinodes (w/ sheath) | 80 | - | 100 (38±9) |

**Seed-Based Disinfestation and Development**

Although over 200 whole seeds were sterilized, their response in vitro was limited to a small number of seeds, which failed to develop past the stage of root emergence. Because of this lack of response, experiments using the isolated embryos were carried out. In these experiments, the seeds were surface-sterilized using Treatments 2 or 3, and the embryos were aseptically dissected out and placed in culture vessels (Fig. 1C). There was an initial burst of contamination in the first five days after sterilization, and overall contamination was high. Treatment 2 had an overall success rate of 50%, with 61% of the contamination being attributable to bacteria. Treatment 3 had lower success; only 28% of embryos were successfully sterilized. In Treatment 3, 75% of the contamination was bacterial, the same trend as with Treatment 2. Subsequently, a harsher procedure, Treatment 4, was undertaken to surface-sterilize the seeds and then to sterilize the isolated embryos. This treatment successfully resulted in contamination rates of only 5%, stemming from a defective vessel, but unfortunately depressed development.

The embryo-based methods showed much higher response than the whole seeds. Development between Treatments 2 and 3 was similar but highly variable. The embryos showed shoot emergence as early as 6 DPS but had an average shoot emergence time of 26.4 DPS. Development of lateral shoots was similarly variable and occurred as early as 19 DPS, but averaged 54 DPS (Fig. 1B). For both treatments there was no significant difference in the percentage of embryos that showed shoot emergence, which averaged 47.2%; however, the percentage of those embryos showing lateral shoot growth was higher in Treatment 2, 45.2% compared to 29.8% ($p=0.062$). For Treatment 4, the embryos showed almost no response; less than 20% showed shoot emergence. Of the embryos that showed shoot emergence, 21% also showed lateral shoot growth, but this corresponded to a very small number of embryos ($n=3/14$).

Unfortunately, Treatment 7, the most effective shoot treatment, could not be evaluated on the embryos, due to the low viability of the seeds long term. Overall, these results show that the gentler Treatment 2 resulted in lower contamination than the harsher treatments and produced embryos with greater development of lateral shoots.

Further research investigating latent contamination rates as well as long-term growth responses will be necessary. In this report, each explant material received only one concentration of BAP, but further experiments will be necessary to determine the optimum concentrations and ratios of hormones and growth regulators for use in in vitro proliferation methods. As interest grows in large-scale native plant restoration in the southeast United States, a reliable supply of these plants will be necessary. The results presented here demonstrate that *Arundinaria* embryos and shoots can be successfully

disinfested and that these materials are amenable to growth in vitro.

**ACKNOWLEDGEMENTS**
Thanks are given to the State Botanical Garden of Georgia and Athens-Clarke County, Georgia for the use of their lands. Additionally, Justin Porter provided much help with the sterilizations of the material mentioned in this report. Finally, the bulk of this work would not have been possible without the advising, expertise, and generous donation of seeds provided by Thomas Peters.

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# Cutting Propagation of *Zelkova serrata*©

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## INTRODUCTION

*Zelkova serrata* is a deciduous tree in Ulmaceae from Japan, Taiwan, and eastern China. It is used for bonsai, shade tree, or park landscape because of its attractive habit, foliage colors, and heat and drought tolerance. Typically the plant reaches to 15-24 m tall with a spreading, upright-branching, vase-shaped crown (Fleme, 1983). *Zelkova* gained popularity because it was utilized to substitute American elm for its Dutch elm disease resistance and no elm leaf beetle (Dirr, 2011).

How to propagate this beautiful plant? Seed germination does not require pretreatment, and germination percentage would increase with prechilling at 4°C for 60 days (Ishii, 1979). However uniform *Z. serrata* seedlings can rarely be obtained by seed germination. Tissue culture had been successful, leaves and axillary buds were cultured on Murashige and Skoog (1962) medium containing half strength nitrogenous compounds to regenerate *Z. serrata* plants (Tomita, 1991), but tissue culture usually has high production cost and high technical requirement.

To regenerate uniform plants with lower cost for commercial production, rooting of stem cuttings is the most common application (Dirr and Heuser, 2006). Dirr and Frett (1983) rooted *Z. serrata* semi-hardwood cuttings treated with 0, 0.8, 1.6, and 3.2% IBA-quick dip and obtained rooting percentages at 32, 48, 62, and 54%, respectively. In our experiments, softwood and hardwood stem cuttings from 1-year-old seedlings treated with different types of rooting hormones at various concentrations were investigated in 2013-2014 hoping to regenerate *Z. serrata* all year round for market demand by rooting different types of cuttings.

## MATERIALS AND METHODS

### Plant Materials

*Zelkova serrata* softwood stem cuttings were obtained from full flush growth of container growing plants on 18 Sept. 2013 at Horticulture farm of University of Georgia. Cuttings were placed into water immediately after being removed from mother plants. They were trimmed to 10-15 cm and leaves of the bottom 3-5 cm were stripped, and then were treated with various concentrations of different rooting hormones. Hardwood cuttings were much easier to prepare. They were collected from 1-year-old seedlings and directly treated with rooting hormones on 18 Dec. 2013.

### Experimental Treatments

Both softwood and hardwood cuttings were treated with K-IBA at 1,000 ppm, K-IBA at 3,000 ppm, K-IBA at 8,000 ppm, Hormodin® 1 (1,000 ppm), Hormodin® 2 (3,000 ppm), Hormodin® 3 (8,000 ppm), K-NAA at 1,000 ppm, K-NAA at 3,000 ppm, K-NAA at 8,000 ppm plus control (no hormone). For the application of powdery Hormodin, cuttings were dipped into water first and then dusted with powder. For liquid hormone, cuttings were dipped into the concentrations for 10-15 s, then air dry for at least 10 min before placing them into the rooting media.

Treated softwood cuttings were randomly inserted into 32-cell flat trays filled with the rooting medium, which contained Fafard 3L Mix (main ingredients: peat moss and bark) and perlite at 1:1 (v:v). Treated cuttings were thoroughly watered before placing them on the mist bench. The mist bench was covered with 70% shade cloth and the mist system

was set for 20 s every 20 min at the first week, then 10 s every 20 min thereafter. Hardwood stem cuttings were rooted into the seedbed with bottom heat, which was filled with a mix of 1 sand and 1 Nature's Helper® Organic Soil (v/v) as rooting medium. All cuttings were completely covered with transparent plastic film and watered as needed.

**Data Collection**
Rooting percentage, number of roots, and average length of roots of cuttings were collected. Data of softwood cuttings were collected on 21 Nov. 2013 and that of hardwood were recorded on 9 May 2014. Root quality was indicated by total root length (= number of roots*average length of roots).

**Experimental Design**
A randomized complete block design was applied in the experiments with four replicates for each treatment and eight subsamples (cuttings) per replicate per treatment. All data were analyzed by SAS and mean separations were the least significant difference with alpha at 0.05 level.

## RESULTS AND DISCUSSION

**Softwood Cuttings**
Rooting hormones significantly increased rooting percentage from 6.3% (control) to 40.6% and total root length from 0.2 cm to 9.0 cm. Both the highest rooting percentage and best root quality were under Hormodin 2 (3,000 ppm) treatment.

Different types of hormones resulted in significant difference on rooting of softwood cuttings. Hormodin (IBA) treatments yielded higher rooting percentage and better root quality than K-NAA treatments. Under 1,000 ppm treatments, Hormodin 1 yielded double rooting percentage (25.0%) and about four times longer total root length (2.6 cm) than that of K-NAA, of which rooting percentage was 12.5% and total root length was 0.6 cm (Table 1).

Application methods did significantly affect the rooting. Liquid K-IBA (1,000 ppm) treatment yielded a rooting percentage of 31.3% and root length at 8.4 cm, which were much better than powdery Hormodin 1. As concentrations of K-IBA increased, the results reduced. While Hormodin treatments had the best result at 3,000 ppm, and both higher and lower concentration reduced the results (Table 1). It is possible that the liquid hormone had rapid effect than that of powdery hormone.

Lower concentrations of hormones (1,000 or 3,000 ppm) were helpful to the rooting. However, higher concentration (8,000 ppm) might be too strong for softwood cuttings without improving the rooting percentage (Table 1) even though the high concentration resulted in highest rooting percentage on semi-hardwood cuttings (Dirr and Frett, 1983).

Table 1. Impact of hormones on rooting percentage and total root length of *Zelkova serrata* softwood cuttings. Different letters mean significant differences at α=0.05.

| Treatment | Rooting (%) | Total root length (cm) |
|---|---|---|
| Control | 6.3d | 0.3b |
| K-IBA 1,000 ppm | 31.3ab | 8.4a |
| K-IBA 3,000 ppm | 12.5cd | 1.3b |
| K-IBA 8,000 ppm | 6.3d | 0.9b |
| Hormodin® 1 (1,000 ppm) | 25.0bc | 2.6b |
| Hormodin® 2 (3,000 ppm) | 40.6a | 9.0a |
| Hormodin® 3 (8,000 ppm) | 6.3d | 0.6b |
| K-NAA 1,000 ppm | 12.5cd | 0.6b |
| K-NAA 3,000 ppm | 15.6cd | 2.3b |
| K-NAA 8,000 ppm | 6.3d | 0.2b |

**Hardwood Cuttings**

Rooting hormone also did significantly affect the rooting of hardwood cuttings. Treatment K-IBA 3,000 ppm was the best rooting hormone for the rooting, which yielded rooting percentage at 40.6% (Fig. 1A) and total root length at 16.2 cm (Fig. 1B).

The K-NAA worked more efficiently than K-IBA. Under 1,000 ppm treatments, K-NAA yielded higher rooting percentage and better root quality than K-IBA. The K-IBA had a peak at 3,000 ppm, while K-NAA 3,000 and 8000 ppm had negative effect on root quality (Fig. 1B).

Application methods of hormone affected rooting as well. With concentrations of 1,000 and 3,000 ppm, higher rooting percentage and better root quality were observed under K-IBA treatments, and there was significant difference between K-IBA and Hormodin (Fig. 1). This might be the result of the difference in absorption between liquid and powdery hormone.

The lower concentrations of K-IBA and Hormodin treatments produced much higher rooting percentage than that of 8,000 ppm, and concentration at 3,000 ppm resulted in much better root quality than 8,000 ppm. The K-NAA at 1,000 ppm also yielded better rooting results than that of higher concentrations (Fig. 1).

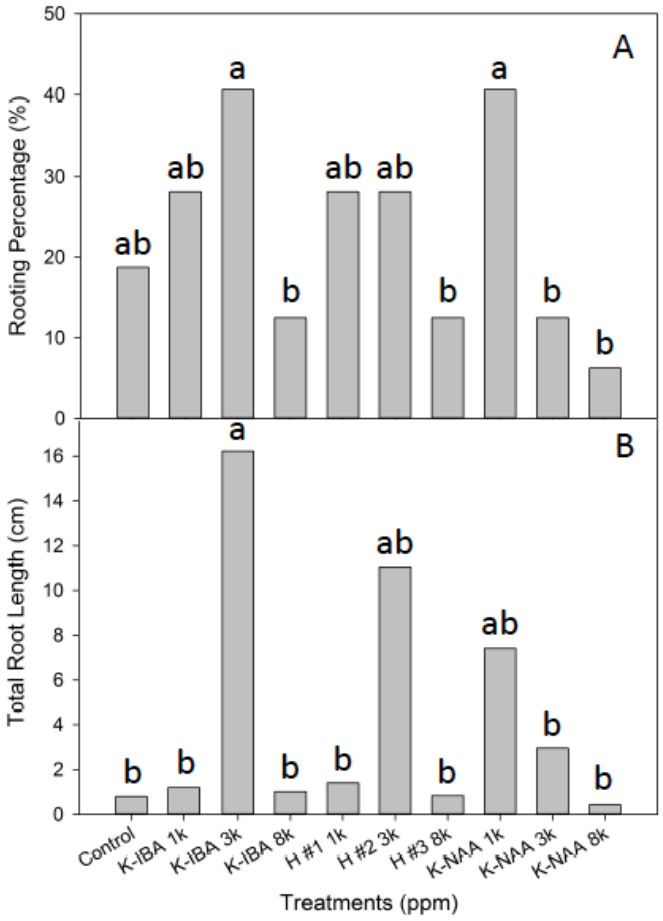


Fig. 1. Impact of hormones on rooting percentage (A) and total root length, (B) of *Zelkova serrata* hardwood cuttings. Different letters mean significant differences at α=0.05.

## CONCLUSION

Commercial production of *Z. serrata* could be regenerated from different types of stem cuttings treated by rooting hormone. Hormone types, application methods, and concentrations did significantly affect the rooting of *Z. serrata* cuttings. For better rooting percentage and higher quality of liners, Hormodin 2 should be applied for softwood cuttings, and liquid K-IBA at 3,000 ppm is recommended for hardwood cuttings.

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# Gardening for Wildlife: Are Native Plant Cultivars as Effective as Native Plants Propagated from Local, Wild Populations for Promoting Native Insect Diversity?©

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**Many gardeners concerned over recent declines in biodiversity in suburban areas are attempting to improve the ecological functioning of their landscapes by incorporating native plants. Native plants are important food sources for native herbivorous insects, and insects are in turn important food sources for animals in higher trophic levels. But do the native plants available in nurseries, typically cultivated varieties (cultivars) of a single genotype, fill an equivalent ecological role as the local, wild-type plants? For two herbaceous perennials, we observed significant differences in both total insect abundance and total number of insect species. However, there was a significant interaction between plant species and plant origin, suggesting that insect abundance and diversity does not depend on the source of the plant material per se, but rather on the particular characteristics of the cultivar that distinguish it from the wild form. We also observed significant differences in the insect communities among treatments, though only a small proportion of the total insect species collected contributed to these differences. Identifying which characteristics of cultivars might predict a loss of ecological function will not only help gardeners make the best choices of plants for their landscapes, but also will enable horticulturalists to select cultivars that potentially outperform the wild-type plants in terms of the ecological services they provide.**

## INTRODUCTION

Recent research suggests that the exotic species planted ornamentally in our suburban landscapes are inferior to natives in providing food for native herbivorous insects (Tallamy, 2004; Tallamy and Shropshire, 2009; Burghardt et al., 2010). Because herbivorous insects are important food sources for organisms in higher trophic levels, there is concern that a decline in abundance or diversity of insects in suburban areas could cause a concomitant decline in animals such as birds. This concern has spurred an interest in "gardening for wildlife" by replacing exotics with native ornamental plants in suburban landscapes. But are the native plants available in nurseries, typically cultivated varieties (cultivars) of a single genotype, equally effective as the local, wild-type plants in providing food for native herbivorous insects?

There are at least two reasons supported by research that suggest cultivars may differ from wild plants in their ability to support native insects. First, cultivars are usually asexually-propagated, and therefore contain less genetic diversity than wild-propagated plants for a given species. Because insect diversity is correlated with the genetic diversity of the host plants (Wimp et al., 2004; Johnson et al., 2006), several clones of a single genotype of a plant might support fewer insect species than multiple genotypes. Second, plant leaf chemistry determines which insect species are able to feed on a particular plant (Ehrlich and Raven, 1964), and some cultivars are selected for traits that alter leaf chemistry. For example, some plants are selected to have purple-colored leaves. The purple color is a result of increased concentrations of anthocyanins, a type of flavonoid known to function as a feeding deterrent in leaves (Harborne and Williams, 2000; Simmonds, 2003). In theory, this sort of change in leaf chemistry could affect the insects that normally feed on the plant, reducing the abundance or number of species of insects supported.

This research investigated whether these theoretical consequences of selecting cultivars actually affect herbivorous insects in a garden setting. We chose several native herbaceous perennials that occur locally in natural areas near the study site and have

cultivars available commercially. We determined whether the cultivars differed from plants grown from wild-collected seed in their ability to serve as a food source for native hemipterans (the true bugs), the dominant group of insects that feed on herbaceous plants.

## MATERIALS AND METHODS

The experiment was set up following a fully-randomized two-way ANOVA design at the Mimsie Lanier Center for Native Plant Studies at the State Botanical Garden of Georgia in Athens, Georgia. The first factor was Plant Species and included five levels: *Amsonia tabernaemontana*, *Coreopsis grandiflora*, *Monarda fistulosa*, *Oenothera fruticosa*, and *Schizachyrium scoparium*. The second factor was plant origin and included two levels: cultivar and wild-type. There were five replicates for each treatment, giving a total of 50 experimental units. Each experimental unit was a 2×2 m plot containing 16 plants evenly spaced, and plots were placed 1.5 m apart. All wild-type plants were grown from seed collected from wild populations occurring within a five-mile radius of the study site. All cultivars were purchased as liners from North Creek Nurseries in Landenberg, Pennsylvania. The cultivars were *Amsonia* 'Blue Ice,' *Coreopsis* 'Tequila Sunrise,' *Monarda fistulosa* 'Claire Grace,' *Oenothera* 'Cold Crick,' and *Schizachyrium scoparium* 'Prairie Blues.' Wild-type plants and cultivars were planted in April 2013.

We collected preliminary data from a subset of the plant species on 25 Aug. 2013. Insects were vacuumed from plots in the *Coreopsis*-Wild (CW), *Coreopsis*-Cultivar (CC), *Oenothera*-Wild (OW), and *Oenothera*-Cultivar (OC) treatments with a modified leaf vacuum. The order in which the plots were sampled was randomized to reduce any systematic bias caused by insects that escaped the vacuum and moved to other plots. Sampling began at 11 A.M. and ended at 2 P.M. to coincide with peak xylem flow. The insects were killed with ethyl acetate, sorted by species, and counted. Representative specimens of each species were pinned for subsequent identification.

We analyzed the count data in three ways. First, we determined the total abundance of adult hemipterans collected from each plot. Second, we determined the total number of species (i.e. species richness) of adult hemipterans collected from each plot. We analyzed both total abundance and species richness with a two-way ANOVA using function aov in R (R Core Team, 2013). Third, we determined the relative abundance of each insect species collected from each plot. These relative abundance counts were used to determine whether the insect community differed among treatments. The distinction between the insect community and species richness is that two treatments could have the same richness but with different insect species, hence the insect community would be different. The relative abundances were used to calculate a dissimilarity metric called "percent dissimilarity" or "Bray-Curtis dissimilarity" between all possible pairs of plots (Legendre and Legendre, 2012). This metric can be interpreted as the percentage of individuals *not* shared between two plots; i.e. a value of 0 indicates exactly the same community whereas a value of 1 indicates no species in common. The percent dissimilarity matrix was used to create an ordination plot using principal coordinates analysis with function capscale and to test for treatment effects using permutational multivariate analysis of variance (PERMANOVA) with function adonis (Oksanen et al., 2013). Principal coordinates analysis is an ordination technique that is a more generalized form of principal components analysis. It is used to visualize high-dimensional data in a 2-dimensional space. PERMANOVA tests for treatment effects by random permutation of the rows of the dissimilarity matrix, which are exchangeable under true null hypotheses. After each permutation, the F statistic is recalculated. After several thousand iterations, a pseudo-F distribution is generated that can be used to calculate an approximate p-value for the observed F statistic (Anderson, 2001).

## RESULTS

The results of a two-way ANOVA indicated a significant interaction between Plant Species and Origin for both total abundance and species richness ($F_{1,16}$=31.871, p<.001 and $F_{1,16}$=16.401, p<.001, respectively). The typical follow-up procedure after finding a

significant interaction is to break up the analysis into several one-way ANOVAs at each level of the other factor. However, our main interest was the comparison of wild-type plants with cultivars, so we chose to follow up with only a one-way ANOVA of Plant Origin at each level of Plant Species (i.e., we omitted the analysis of Plant Species at each level of Plant Origin). For total abundance, there was significantly higher insect abundance on wild-type *Coreopsis* vs. the cultivar ($F_{1,8}$=22.16, p=.0015), but there was significantly higher abundance on the *Oenothera* cultivar vs. the wild-type ($F_{1,8}$=11.48, p=.0095). For species richness, there were significantly more insect species on wild-type *Coreopsis* vs. the cultivar ($F_{1,8}$=15.36, p=.0044), but there was no significant difference in the number of insect species for wild-type *Oenothera* vs. the cultivar ($F_{1,8}$=2.53, p=.1501). A total of 68 insect species were collected across all plots.

The mean abundance for each treatment is shown (Fig. 1), as is the species richness for each treatment (Fig. 2). A species accumulation curve is used in lieu of a bar plot because it depicts more information. For example, when Replicates=1, the line is the mean species richness of each treatment and the error bars are ± 1 standard deviation (SD). Beyond Replicates=1, the line is the total number of insect species found in a random subsample of *i* plots (where *i* = 2, 3, 4, or 5). The error bars then represent the SD after repeating the subsampling many times. At Replicates=5, all the plots are sampled, so the line is the total number of insect species on all the plots within a treatment, and the SD is zero because there is only one possible combination of 5 replicates. The shape of the curve is useful for determining whether most of the insect species have been found or whether it is likely more will be found after further sampling. For example, after sampling 5 plots, the number of insect species found begins to level off for the *Oenothera* cultivar, but the slope is still increasing for the wild-type *Oenothera*, suggesting there are still more insect species to find.

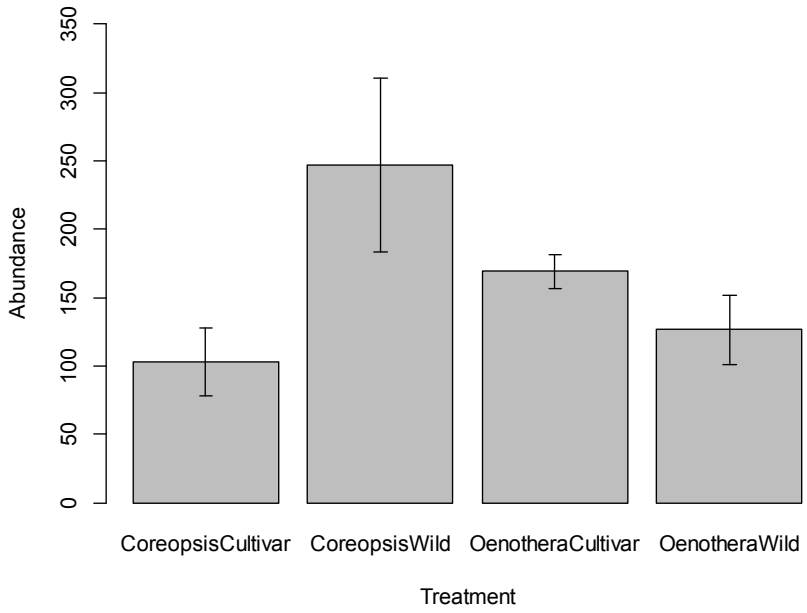


Fig. 1. Total abundance for plant species X origin. Error bars represent ± 1 SD.

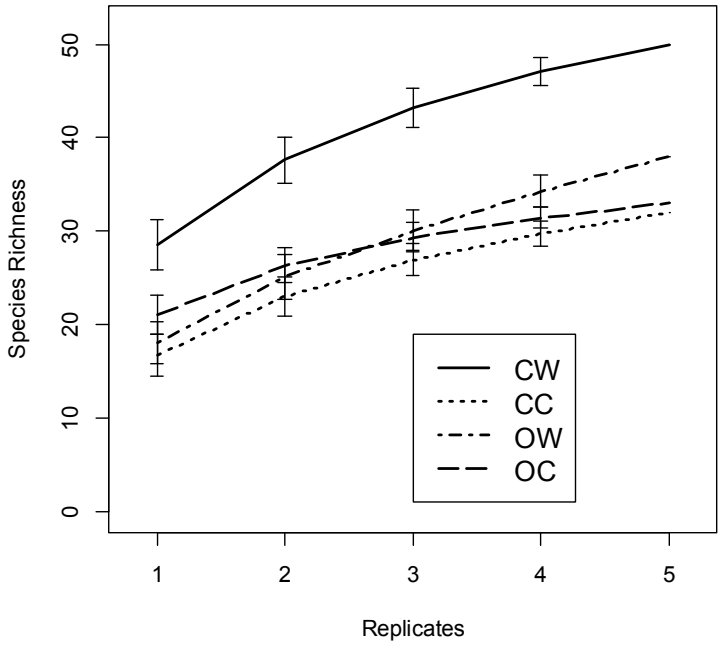


Fig. 2. Species accumulation curve for plant species X origin. See text for an explanation of the error bars.

An ordination of the treatments is shown below in Figure 3. The first axis explained 40.49% of the variation in the data and the second axis explained 27.04% of the variation in the data. The insect species that contributed most to the ordination are overlain as vectors. One notable feature of the ordination is that replicates from the same treatment tend to group together, and replicates from different treatments tend to separate. Another important feature to note is that only 6 of the 68 total insect species contributed most to the ordination; i.e. the next longest insect vector was substantially shorter than the shortest of these 6. The direction of a vector representing a particular insect species corresponds to the treatment that insect was most associated with, and the length of a vector indicates its contribution to the ordination, which in this case corresponds to the abundance of the insect. For example, the vector representing *Empoasca bifurcata* points between the replicates in the *Oenothera* cultivar treatment and the wild-type *Coreopsis* treatment, indicating that *Empoasca* is most associated with these plants. It is also the longest vector in the ordination, indicating that it was the most abundant insect collected. Also, the angle between two vectors can be interpreted as the correlation between one insect species and another in terms of their abundances.

Principal coordinates analysis is only a visualization technique for high-dimensional data, and therefore provides no information for hypothesis testing. We used PERMANOVA to test whether the insect community differed among treatments. Consistent with the univariate analyses, there was a significant interaction between Plant Species and Origin ($F_{1,16}$=19.45, p-value<.001). Again, we broke up the data and used a one-way PERMANOVA at each level of Plant Species to test for differences in the insect community between wild-type and cultivar. There was a significant difference in the insect community between cultivars and wild-type plants for both *Oenothera* and *Coreopsis* ($F_{1,8}$=16.042, p-value≈.007 and $F_{1,8}$=10.085, p-value≈.009, respectively). Although PERMANOVA assumes nothing about the distribution of the data, it does assume that the dispersion of the data is the same among groups, which is analogous to homogeneity of variances in univariate ANOVA. A test analogous to Levene's test did not indicate any violations of this assumption.

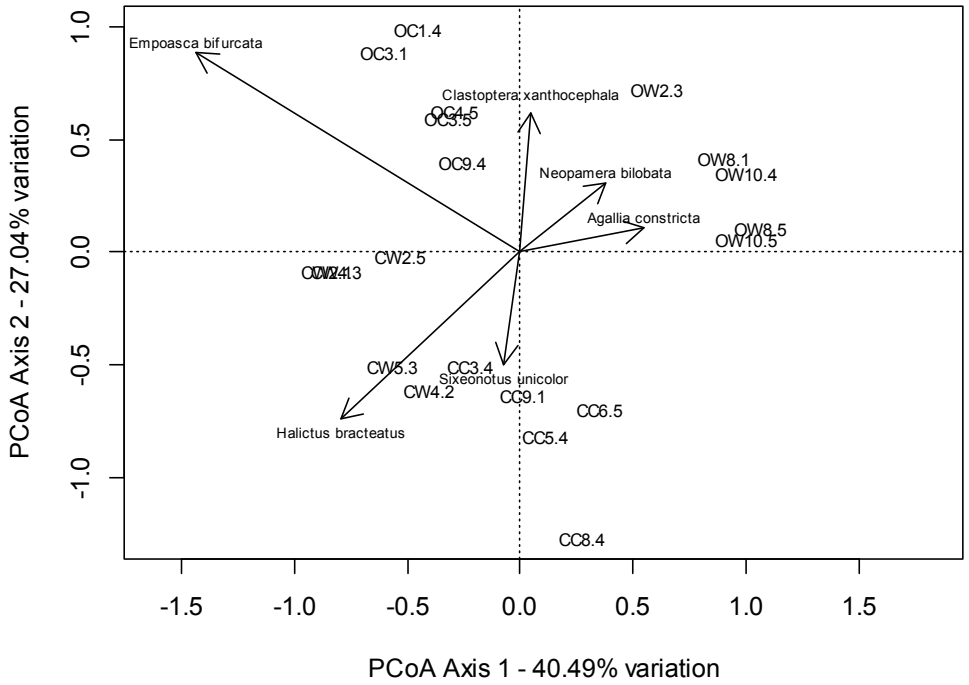


Fig. 3. Principal coordinates analysis biplot of treatments and insect species. Percent dissimilarity was used as the distance metric. Only six insect species are shown because the others contributed very little to the ordination. Replicates are identified by treatment and their location in the design (e.g., OC1.4 means *Oenothera* cultivar at row 1, column 4).

## DISCUSSION

The most striking result of this research was the interaction between plant species and plant origin. In the case of *Coreopsis*, the wild-type plants supported more individuals and more species of hemipterans than did the cultivar. In contrast, the cultivar of *Oenothera* supported more individuals of hemipterans than did the wild-type plants, though there was not a significant difference in the number of insect species supported. These results suggest that the ecological value of a plant species does not depend on whether the plant material is a selection (i.e., a cultivar) or wild-propagated, but rather on the particular cultivar that is chosen. In fact, these results suggest that some cultivars may provide a greater benefit to wildlife than their wild counterparts.

If some cultivars have more of a benefit to wildlife than others, the next obvious question is: Which characteristics of a cultivar might be used to predict how well it fills an ecological role in the landscape? The results of this research may provide insight into possible answers. *Coreopsis* 'Tequila Sunrise' is quite distinct from the wild-type plants. Wild-type plants are tall, structurally complex, and produce viable seeds. 'Tequila Sunrise' plants are variegated, clump-forming, apparently sterile (at least no viable seeds were observed during this research), and produce few branching stems. For gardeners who prefer a tidy garden with plants that do not grow tall and flop over, 'Tequila Sunrise' is far superior to the wild form. However, these traits that make it a superior garden plant appear to come at the cost of reduced ecological function. Determining whether the variegated leaves, lack of structural complexity, or some other characteristic is primarily responsible for its reduced ability to support herbivorous insects would require additional research.

It is more difficult to explain why *Oenothera* 'Cold Crick' supported a higher abundance of herbivorous insects than the wild-type plants. Unlike *Coreopsis*, the *Oenothera* cultivar and wild-type plants differ very little. Both are about the same height

and have similar structural complexity. Nurseries promote 'Cold Crick' as being more compact than the wild form of *Oenothera*, but this did not appear to be true for this wild population of *Oenothera*. The main difference between the wild-type plants and 'Cold Crick' is that 'Cold Crick' is sterile. This would explain why *Neopamera bilobata*, an insect that contributed significantly to the ordination and only feeds on seeds, was found in far higher abundances on the wild-type plants than the cultivar. A quantitative measure of structural complexity and knowledge of the phytochemicals present in the leaves could help explain differences in abundances observed for other insect species. An important caveat to note is that these data represent a snapshot of a single day during the first growing season. The patterns observed for both plant species could change depending on the season and the amount of time insects have had to colonize the plots. For example, the species accumulation curve in Figure 2 indicated that the number of insect species feeding on the wild-type *Oenothera* is probably much higher than the number suggested by the mean species richness for a single day. Although there were no significant differences in species richness between the wild-type *Oenothera* and the cultivar for the preliminary data, this pattern may not hold after repeated sampling.

We will collect data from all the plant species in the experiment multiple times in 2014. This should provide better insight into whether the patterns observed in the preliminary data extend to other plant species and other seasons of the year. The cultivars used for this experiment were chosen to represent a range of deviations from the wild forms, so data from the full suite of plant species should also provide more information about which characteristics of cultivars best predict their ability (or inability) to function ecologically in the landscape.

**ACKNOWLEDGEMENTS**

Funding for this research was provided by the Georgia Native Plant Society and the Garden Club of America. Thanks also to all the staff at the State Botanical Garden of Georgia that contributed to this project.

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# *Ilex* Embryo Germination Saving Your Time©

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## INTRODUCTION

Holly (*Ilex*) is a large genus in *Aquifoliaceae*, which is comprises of 400 to 600 deciduous and evergreen species. This genus is cultivated as important medicinal and ornamental plants in the temperate and subtropical regions (Galle, 1997; Hu, 1989). The great diversity and adaptability of hollies make them as the king in gardens and landscapes. They can be used as shade trees, dividing lines, hedges, and groundcovers. They have beautiful effects of fruits in autumn, masses of evergreen foliage, and bright glistening color of variegated cultivars (Robinson, 1984). *Ilex crenata* Thunb. is native to eastern China, Japan, Korea, Kuril, Sakhalin, Philippines, and the Himalayas. Now it is widely planted as an ornamental plant in the southeastern US for its dense evergreen foliage and various forms (Dirr, 2009). Many cultivars have been released for commercial production such as *I. crenata* (Fastigiata Group) 'Sky Pencil', which is popular in the landscape for its strongly upright habit and lustrous, dark evergreen foliage (Dirr, 2011).

Similar to the majority of *Ilex* species, seed germination of 'Sky Pencil' is inefficient as a result of low germination rate and long germination time. It usually takes 2 to 3 years to overcome the double dormancy from hard, impermeable seed coat and immature embryos (Dirr and Heuser, 2006). Normally, 'Sky Pencil' is propagated by rooting of stem cuttings with 1000-3000 ppm IBA (The United States National Arboretum). But for plant breeders, it is hard to select new cultivar from cuttings. New cultivars are from open pollinated and artificial cross. Therefore, seed germination is the key point to select new cultivars from I. crenata 'Sky Pencil'. To shorten the germination time and select new cultivars efficiently, we investigated the embryo germination of *I. crenata* 'Sky Pencil'.

## MATERIALS AND METHODS

### Plant Material and Culture Establishment

On 13 Jan. 2014, mature fruits from an 8-year-old plant of *I. crenata* 'Sky Pencil' seedling at the Horticulture Farm University of Georgia were collected and washed with running tap water for 20 min, then rinsed with distilled water. Surface disinfection was carried out with 75% ethanol for 5 min followed by immersion for 15 min in Clorox (included 8.3% sodium hypochlorite, Clorox Company, Oakland, California). Subsequently, they were washed five times with double distilled water and kept in sterile water until excision of embryos under a stereomicroscope in a laminar-flow hood. The immature embryos at heart-shaped stage (Fig. 1A) were placed into 6-cm petri-dishes containing various basic culture media plus 3% sucrose (Sigma-Aldrich, Co., Louis, Missouri) and 0.65% agar for germination. The pH of the media were adjusted to 5.8 with NaOH or HCl before adding agar (Fisher Science Education, Nazareth, Pennsylvania). A total of 12 ml of the media was transferred by pipette into autoclaved dishes. All dishes with embryos were cultured in a growth chamber at room temperature in darkness. After 2 weeks, on 28 Jan. 2014, germinated embryos were moved to a growth chamber with 14-h photoperiod under cool-white fluorescent lamps (115 $\mu mol \cdot m^{-2} \cdot s^{-1}$). Embryo germination rate and the height of seedling were recorded. Four weeks later, on 1 Mar. 2014, seedlings with at least two true leaves were transferred to a tray with 32 cells ($6.5 \times 6.5 \times 9$ $cm^3$) with a mixture of Aero-Soil perlite (Dicalite, Dicaperl Minerals, Inc., Bala Cynwyd, Pennsylvania) and a commercial substrate (Fafard 3L Mix, Sun Gro Horticulture Canada Ltd., Agawam, Massachusetts) in a ratio of 1:1 (v/v) and kept in greenhouse. Flats were placed under

intermittent mist. Misting frequency was controlled by a misting controller (Phytotronics, Inc., Earth City, Missouri) and set at 15 s every 10 min for the first 2 weeks. Mist system was on in the morning and off in the evening. No additional light was provided. Germination rate, seedling height, the number of leaves and number of roots were recorded before transplanting into a tray. After 2 months, plant survival rate was also recorded.

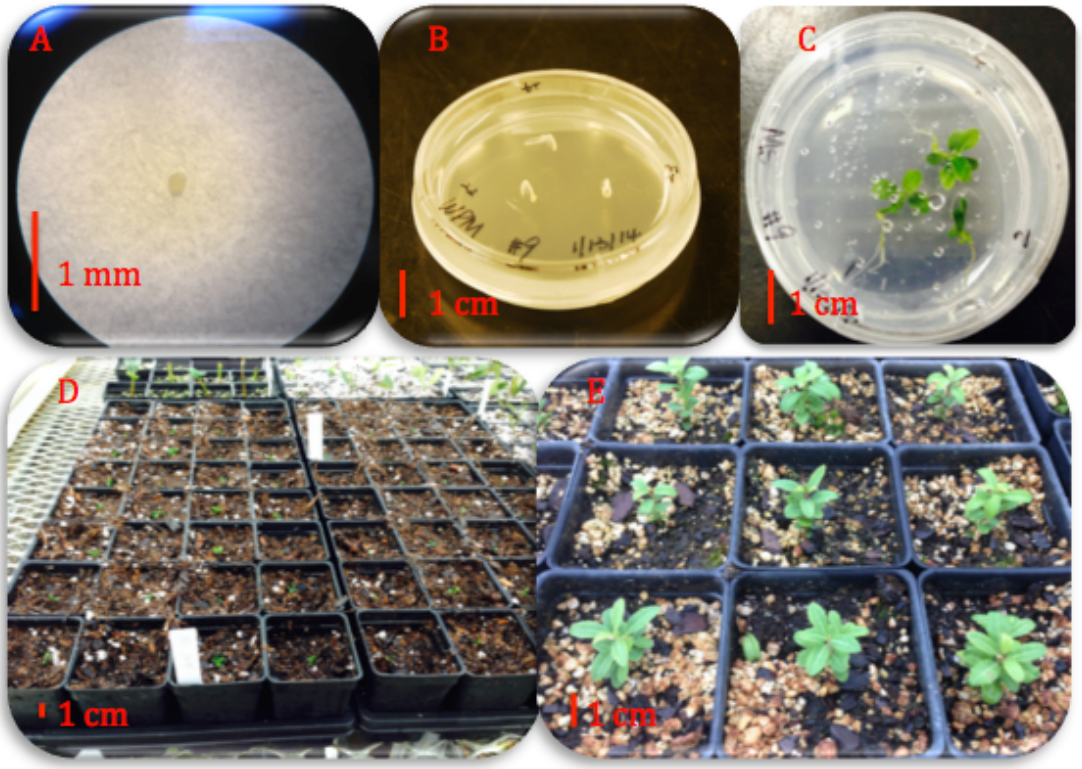


Fig. 1. *Ilex crenata* embryo (A); Embryo germination (B); Seedlings after growing four weeks in chamber (C); Transferred seedlings in greenhouse (D); Two-month old seedlings after growing (E).

**Medium Selection for Embryo Germination**
To determine the optimal conditions for embryo germination, quarter-strength Murashige and Skoog (1962) (MS) (¼ MS) (1962), half-strength MS (½ MS), full-strength MS, and Woody Plant Medium (WPM) (Lloyd and McCown, 1981) were tested in this experiment.

**Experimental Design and Statistical Analysis**
Randomized complete block design was employed in all experiments. Each treatment with nine embryos (subsamples) was repeated three times. Analysis of Variation (ANOVA) and General Linear Model (GLM) were performed using Statistical Analysis Systems (SAS Version 9.2; SAS Institute, Inc., Cary, North Carolina).

## RESULTS AND DISCUSSION

**Protocol for Holly Embryo Germination**
Instead of 2-3 years to germinate holly seeds, embryo germination only needs 2-3 weeks. The time you saved is very significant. Generally, we should collect fruits and harvested immature embryos from July to December. Embryos were excised under a stereomicroscope, and inoculate on embryo germination media. In 2-3 weeks, embryos germinated. The entire procedure is not difficult as we normally think. What you need is a

hood, a clean room, a stereomicroscope, and an autoclave. If you don't have an autoclave, you could buy sterilized customer designed media for your embryo germination.

**Effect of Media on Germination Rate**

We took germination data on 28 Jan. (Germination Rate 1) and on 1 Mar. 2014 (Germination Rate 2), respectively (Fig. 2). The embryo germination rate was from 45.8% to 79.2% in January. Four weeks later, the germination rate ranged from 58.3 to 91.7%. Obviously, majority of embryos germinated in 2 weeks and this trend still continued in the next 4 weeks. The highest germination rate, 91.7%, was obtained under the treatment of ¼ MS. It was significantly higher than that of ½ MS at 57%. From our observation, the culture media didn't have significant difference on germination rate in the first 2 weeks. But they had significant difference on germination rate after 6 weeks. From the above result, we concluded that the embryo germination of *I. crenata* 'Sky Pencil' took 2-3 weeks.

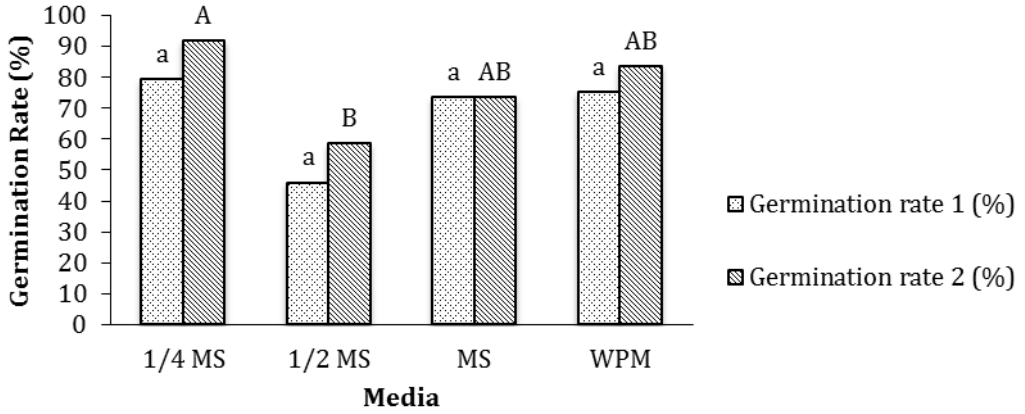


Fig. 2. Effect of media on germination rate. (Different letters mean significant differences at $\alpha$=0.05).

**Effect of Media on Seedling Growth**

We also took data of seedling height on 28 Jan. (Seedling Height 1) and on 1 Mar. 2014 (Seedling Height 2), respectively (Fig. 3). As shown in Figure 3, culture media had a significant difference on seedling height. The fastest growth of seedlings was under the treatment of ¼ MS. The tallest average seedling height was also under the treatment of ¼ MS on 1 Mar. 2014. In addition, the culture media had significant difference on number of leaves and number of roots (Fig. 4). Both under ¼ MS and WPM, we could get much better growth of 'Sky Pencil' seedlings.

**Effect of Media on Seedling Survival Rate**

Two months after transplanting (Fig. 1E), the survival rate was recorded. The culture media had no significant difference on 'Sky Pencil' seedling survival rate. All of treatments had high survival rate from 87.5 to 90.9%.

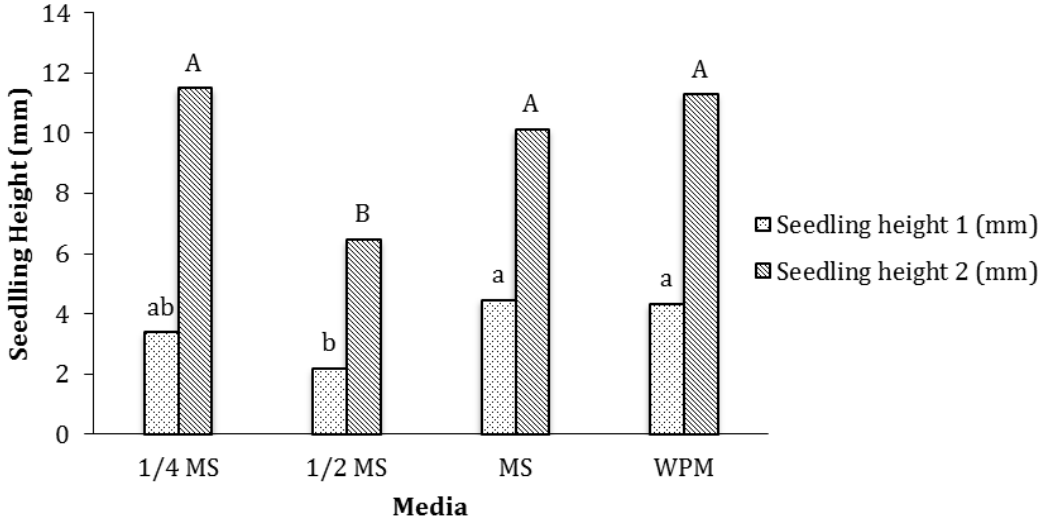


Fig. 3. Effect of media on seedling height (mm). (Different letters mean significant differences at α=0.05).

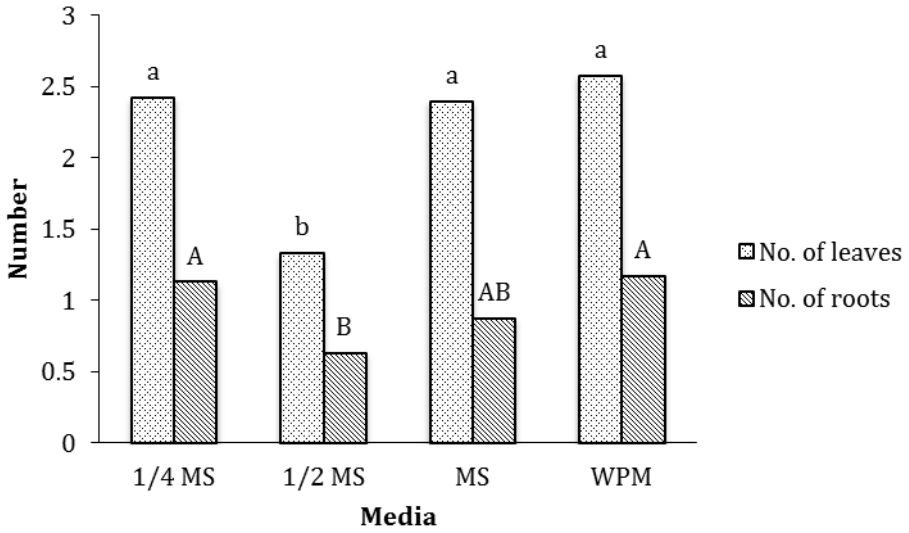


Fig. 4. Effect of media on quality of seedlings. (Different letters mean significant differences at α=0.05).

## CONCLUSION

A rapid seed propagation protocol for *I. crenata* 'Sky Pencil' is: collected embryo from surface sterilized fruits, inoculated on¼ MS medium with 3% sucrose, and grow them under dark condition. After embryo germination (Fig. 1B), moved them to light and grew 4 more weeks (Fig. 1C), and then washed seedlings and transplanted them into growing media (Fig. 1D).

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# All-America Selections for 2014: National and Regional Winners for Outstanding Garden Performance©

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Ten cultivars became All-America Selections (AAS) National Award Winners for 2014. All-America Selections includes a network of over 75 trial grounds all over North America where new, never-before-sold plants are "Tested Nationally and Proven Locally®" by skilled, impartial AAS judges. Only the best performers are declared AAS Winners. Once these new varieties are announced as AAS Winners, they are available for immediate sale and distribution.

An additional nine plants were selected as All-America Selections (AAS) Regional Award Winners for 2014. With heightened public interest in locally produced products and recognition that some plants can truly perform well in specific regional climates, AAS has established awards for plants with superior regional performance. Regional winners undergo the same trialing process as national winners.

## THE AAS NATIONAL WINNERS FOR 2014 ARE AS FOLLOWS

***Angelonia angustifolia* Serenita™ Pink $F_1$ Angelonia**
Elegant yet tough plants bring long-lasting color with very little maintenance. Plants look beautiful in mixed combos on the patio or create a soothing sea of soft color in the landscape. Plants are heat-tolerant and deer and rabbit resistant. Plants grow 12-14 in. tall by 12-14 in. wide and perform best in full to part sun locations in well-drained soil. This angelonia is tolerant of dry conditions, so less water is needed. Bred by PanAmerican Seed.

***Capsicum annuum* 'Mama Mia Giallo' ($F_1$ Pepper)**
Plants produce very early-maturing, yellow, sweet Italian peppers. Long tapered fruits have an easy-to-remove skin. Peppers have a nice sweet flavor that is excellent either fresh, grilled, or roasted. Bright yellow/gold fruit are pendant on sturdy, dark green, bushy plants with excellent coverage from sunburn. The somewhat compact, 24-in. plants take up less space and feature disease tolerance to tobacco mosaic virus. Bred by Seeds By Design.

***Capsicum annuum* 'NuMex Easter' (Ornamental Pepper)**
Plants are compact, well branched, and uniform in size, displaying small clusters of 4 to 6 fruits on top of the plant in a range from lavender to light yellow and (when fully mature) a light orange. The colors of the fruit resemble the pastel colors of Easter eggs. Plants perform well in pots, on patios, or for outdoor use. Bred by Chile Pepper Institute at New Mexico State University.

***Gaura lindheimeri* 'Sparkle White' (Gaura)**
Plants bring a touch of airy elegance to the garden with long slender stems sporting a large number of dainty white flowers tinged with a pink blush. Plants are perfect for mass planting in sunny landscape beds, in groupings with other perennials, or in larger containers. This season-long bloomer has excellent heat tolerance and a more uniform

flowering habit than other seed gauras. Commercial growers can utilize 'Sparkle White' as a first-year flowering perennial or as an annual. Bred by Kieft Seed.

***Impatiens hawkeri* Florific® Sweet Orange ($F_1$ New Guinea Impatiens)**
Plants produce masses of large, uniquely bicolored flowers in shades of light salmon to deep orange. Naturally branching plants quickly fill beds and are perfect for planting 'en masse'. With resistance to impatiens downy mildew, 'Florific Sweet Orange' is an excellent alternative for shade gardens where the disease is a concern. Bred by Syngenta Flowers.

***Osteospermum ecklonis* Akila® Daisy White' ($F_1$ African Daisy)**
Clear white flowers have a novel yellow center. Plants are easily grown from seed. Tidy, uniform plants produce non-stop blooms all summer long. Plants can continue blooming in the heat and have shown more drought tolerance than other African daisies. Bred by PanAmerican Seed.

***Petunia* × *hybrida* 'African Sunset' ($F_1$ Petunia)**
Plants produce an abundance of attractive, "designer color" flowers in shades of orange, an improvement over other orange petunias on the market. Plants grow evenly and uniformly in the garden and flower all season long. Mounded plants are 12 inches tall and spread up to 32 inches. Bred by Takii & Co., Ltd.

***Phaseolus vulgaris* 'Mascotte' (Bush Bean)**
The first AAS winning bean since 1991, this compact variety is perfect for today's small-space gardens. 'Mascotte' is a bush type bean that produces long, slender pods that stay above the foliage for easy harvest. Plants produce white showy flowers for ornamental value during bloom time. Root system size is ideal for patio containers and window boxes. The French "mascotte" (like its English translation "mascot") is a symbol of good luck and was chosen for the variety's gardener-friendly habit. Bred by Clause Vegetable Seed.

***Solanum lycopersicum* 'Chef's Choice Orange' ($F_1$ Beefsteak Tomato)**
Derived from the popular heirloom 'Amana Orange' (which matures late), 'Chef's Choice Orange' produces tomatoes in only 75 days from transplant. Fruits have a bright, internal color and superior flesh taste and texture. Orange fruit color does not fade when cooked. Average-sized fruits are 12 ounces, but can weigh up to 1 pound. Large, 5-foot-tall, indeterminate plants have leaves that protect fruit from sunburn. Bred by Seeds By Design.

***Solanum lycopersicum* 'Fantastico' ($F_1$ Grape Tomato)**
This variety is an early-maturing, high-yielding grape tomato with late blight tolerance. Bred specifically for smaller home gardens, this determinate tomato variety will perform quite well in hanging baskets, container gardens, and in small gardens. Long clusters of sweet tasty fruits are held toward the outside of the plant, making them easy to harvest, plus the fruits resist cracking. This bush tomato produces nicely flavored, half-ounce, grape-shaped fruit with up to 12 pounds of ripe fruit per plant. Plants are best grown in a cage for support, or in a large patio container or basket. Bred by Pro-Veg Seeds.

**THE AAS REGIONAL WINNERS FOR 2014 ARE AS FOLLOWS**

***Capsicum annuum* 'Giant Ristra' ($F_1$ Chili Pepper) (Region: Mountain/Southwest)**
Plants produce a heavy yield of bright red, very hot, 7-inch chili peppers with the appearance of a Marconi pepper, but the spiciness of a cayenne pepper. Fruits can be enjoyed fresh, roasted, or dried. Bred by Seeds By Design.

***Cucumis sativus* 'Pick a Bushel' ' ($F_1$ Cucumber)** (Regions: Heartland, Great Lakes)
This pickling cucumber has excellent heat tolerant and can be picked at the gherkin or spear stage for processing. The large yields from semi-bushy plants can be enjoyed fresh in salads and slaws. Gardeners can grow plants either in the vegetable garden or in containers on the patio. Bred by Seeds by Design and W. Atlee Burpee & Co.

***Cucumis sativus* 'Saladmore Bush' ($F_1$ Cucumber) (Region: Southeast)**
The first cucumbers mature in 55 days after sowing seed. This semi-bush vines set additional sweet crisp cucumbers as long they are kept harvested. Plants exhibit good garden performance due to their multiple disease resistances. Cucumbers can serve a dual use, with fruits harvested when small for processing as pickles or harvested later for fresh slices or spears. Bred by Seeds By Design.

***Cucurbita maxima* 'Cinderella's Carriage' ($F_1$ Pumpkin) (Regions: Southeast, Great Lakes, Mountain/Southwest)**
This bright reddish-orange pumpkin is the first hybrid Cinderella-type pumpkin on the market featuring a higher yield as well as powdery mildew resistance. Fruits are well suited for fall decorations and baking. Flesh is yellow, sweet, and has a nutty flavor. A surprising pale blue pumpkin may sometimes appear. Bred by Seeds By Design.

***Helianthus annuus* 'Suntastic Yellow with Black Center' ($F_1$ Sunflower) (Region: Great Lakes)**
These naturally dwarf, compact plants produce up to twenty 5- to 6-inch flowers per plant in three successive blooming periods. Plants will bloom in less than 65 days after sowing and can be enjoyed by gardeners as potted plants or in window boxes. Bred by Clause S.A.

***Raphanus sativus* 'Rivoli' (Radish) (Regions: Southeast, Heartland, West/Northwest)**
Plants have upright, healthy leaves with roots that are evenly colored and bright red Interior texture is smooth and dense with bright white color, even when roots get large. Uniform roots are very round and about 1½" inches in diameter with exceptional quality and taste when picked young, but still tasty if allowed to grow a longer time in the ground. Bred by Bejo Seeds, Inc.

***Solanum lycopersicum* 'Mountain Merit' ($F_1$ Tomato) (Region: Heartland)**
A superior, all-around tomato for the Heartland, perfect for slicing and sandwiches. With a 4- to 5-week harvest window, dark red fruits grow on compact, uniform plants that offer good resistance to multiple diseases that are common to home-grown tomatoes. Bred by Bejo Seeds, Inc.

***Penstemon hartwegii* 'Arabesque Red' ($F_1$ Penstemon) (Regions: Heartland, Mountain/Southwest, West/Northwest)**
This exciting new hybrid provides superior garden vigor and flowering for USDA zones 6-9. Large, bell-shaped, red and white bicolor flowers adorn well-branched plants. Bred by Syngenta Flowers.

***Solanum melongena* 'Patio Baby' ($F_1$ Eggplant) (Region: Northeast)**
This very early and highly productive eggplant has a compact habit, making it a great choice for containers or in the garden. Harvest fruit at 2 to 3 inches. Fruits are delicious roasted or in dips and salads. Thornless leaves and calyxes allow for painless (and child-friendly) harvesting. Bred by PanAmerican Seed.

**IN SUMMER 2014, TWO AAS NATIONAL VEGETABLE AWARD WINNERS WERE ANNOUNCED FOR 2015**

***Lactuca sativa* 'Sandy' (Oakleaf Lettuce)**
'Sandy' produces a multitude of sweet tasting, frilly, dark green leaves, is disease resistant, and is slow to bolt. Bred by Seeds By Design.

***Raphanus sativus* 'Roxanne' ($F_1$ Radish)**
Roots have a uniform, bright red color and a creamy white interior, with a great flavor and no pithiness. Bred by Bejo Seeds, Inc.

**IN SUMMER 2014, FOUR AAS REGIONAL VEGETABLE AWARD WINNERS WERE ALSO ANNOUNCED FOR 2015**
***Brassica oleracea* 'Hestia' ($F_1$ Brussels Sprouts) (Regions: Southeast, Mountain/ Southwest)**
This Brussels sprouts features a bright green exterior and smooth, dense yellow interior, with potential for a second season crop in many areas as this variety tolerates both warm and cool temperatures. Bred by Bejo Seeds, Inc.

***Brassica rapa chinensis* 'Bopak' ($F_1$ Bok Choy) (Regions: Northeast, Great Lakes, Mountain/Southwest)**
The first pak choi to receive an AAS award, plants mature early and the tender leaves and crisp sweet stalks have an excellent taste. Bred by Bejo Seeds, Inc.

***Capsicum annuum* 'Sweet Sunset' ($F_1$ Sweet Banana Pepper) (Regions: Southeast, Heartland, West/Northwest)**
These compact upright plants do not require staking and can be grown in a container, producing attractive, colorful, tasty peppers that can be enjoyed either fresh or canned. Bred by Seminis Vegetable Seeds.

***Cucumis sativus* 'Parisian Gherkin' ($F_1$ Cucumber) (Regions: Northeast, Mountain/Southwest)**
The numerous, black-spined, sweet-flavored cucumbers can be enjoyed fresh in salads and slaws, or picked at the midget size or small pickle stage for processing. Bred by Seeds by Design, Inc.

More information on AAS and AAS winners is available at: <www.all-americaselections.org or www.aaswinners.com>.

# What Time Is it: Propagation Scheduling at Bracy's Nursery©

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At Bracy's Nursery we grow over 650 different taxa of ornamental and fruit bearing plants. Bracy's utilizes 1.4 million liners to produce these taxa. Of these 1.4 million liners, Bracy's produces approximately one million liners in house.

Bracy's has two primary propagation structures that have a combined total of 2601 $m^2$ (28,000 $ft^2$) of area. Due to the area limitation and the fact that the structures are not heated for winter propagation, scheduling becomes crucial.

## BEGINNING PROPAGATION SCHEDULING

To begin propagation scheduling for a given year we compile a preliminary list of information:

1) Liners needed by type/group and size.
2) Time when liners are to be utilized.
3) The optimal time to root said liners.
4) The time range when liners can be rooted.
5) The cumulative time needed to acquire, prepare stick and finish the rooting process for each type/group.
6) Total area of propagation space available.
7) Man hours available to complete propagation.

## CALCULATING OUR MACRO DATA

With this list we move forward with calculating our macro data.

A. Plant/Group: (1) date liners needed, (2) cumulative time to propagate, and (3) determining how far in advance to schedule propagation.
B. Plant/Group: number units needed + liner size = Total area needed to propagate.
C. We now add up the total time needed to produce all liners required and the total area needed to produce all liners required. From this we calculate "C".
D. Total time needed × total area needed = Space time needs (STN).
E. We now take the total man/h available and the total space available to calculate "D".
F. Total space available times total man/hrs available = Space time available (STA).

## MAKING PROPAGATION DECISIONS WITH THE STN/STA RATIO

Using the ratio STN/STA ratio we can make managerial decisions. If the STN/STA ratio is less than or equal to 1, then our scheduling will be less complicated and critical. However, if the STN/STA is greater than 1, then scheduling becomes critical. At Bracy's the STN/STA ratio is typically 2 to 2.5.

At this point, we begin selecting high priority items from our liner needs. This high priority list is comprised of items that are difficult to root, are in large quantities that require significant man/hrs to produce or have a very narrow time period in which to propagate. Some examples include:

- Junipers: Late January and early February — time specific
- Crepe myrtles: June — large quantity and time specific
- Blueberries: July — time specific
- Dwarf yaupon: September — difficult to root

Once time slots are assigned to the high priority items, we begin filling in the schedule by grouping items by their optimal time to propagate. During this stage, we section off groups of plants in smaller time periods, typically 1 to 2 months. For each of these time periods we recalculate the STN/STA ratio. In these smaller time periods, the ratio must be 1 or less, or something will not finish propagation in order to open needed space for the next grouping period. If the ratio is greater than 1, then moving items around the schedule

will be necessary. In working the schedule, we try to place items as early as possible within their optimal rooting period. This allows more flexibility later in the propagation year for adjustments.

After the overall schedule is laid out the real work begins. The original estimates for completing the propagation for a given item or group rarely fall in line with what actually occurs. Constant monitoring of the propagation process is necessary to evaluate where we stand in regards to the original schedule. A crop failure, problems with the availability of cuttings and weather conditions all contribute to the schedule being off. New items being added to the needs list also creates the need to make adjustments. These occurrences make it necessary to reevaluate and rework the schedule. When reworking the schedule, we once again use our STN/STA ratio to ensure that we can complete the revised schedule. This is where early scheduling of items helps with our rescheduling by opening up available space for later items.

As we move through the propagation year, items that have completed the process are moved out from the propagation structures. This available space is then added into our STN/STA ratio for the next work period. If the propagation schedule is on track, the STN/STA ratio for the overall schedule should drop below 1 towards the end of the propagation year. If the ratio does not fall below 1, then a decision is made as to what remaining items to propagate have a high priority and which ones may need to be brought in as liners.