Interpreting Water Analysis©

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ALKALINITY

- Alkalinity is typically expressed in units of concentration of calcium carbonate ($CaCO_3$) or bicarbonate (HCO_3^-) equivalents.
- Units: $mol \cdot L^{-1}$, $mmol \cdot L^{-1}$, $mmol_c \cdot L^{-1}$, $mg \cdot L^{-1}$, or $meq \cdot L^{-1}$.
- Generally reported in $mg \cdot L^{-1}$ or $meq \cdot L^{-1}$.
- For $CaCO_3$ unit conversion: 1 $meq \cdot L^{-1}$ = 50.04 $mg \cdot L^{-1}$.
- To convert $mg \cdot L^{-1}$ HCO_3^- to $meq \cdot L^{-1}$ $CaCO_3$ divide $mg \cdot L^{-1}$ HCO_3^- by 61.
- 60–120 $mg \cdot L^{-1}$ $CaCO_3$ could be used as an adequate guideline.
- 180–240 $mg \cdot L^{-1}$ $CaCO_3$ acid injection likely required.

ELECTRICAL CONDUCTIVITY (EC)

Units: $mS \cdot cm^{-1}$ = dS/m = $mmhos \cdot cm^{-1}$
1 $dS \cdot m^{-1}$ = 10 $mS \cdot m^{-1}$

KEY TO EFFECTIVE WATER QUALITY SELF-ASSESSMENT:

- The establishment of well-planned and concise objectives for your sampling effort.
- Rinse bottles with sample water before you collect the sample.
- Use distilled water for rinsing after you complete the test.
- Perform test, or send to lab immediately after you collected the water sample.
- If not possible to test immediately, store sample at low temperature (4 °C).

Water Analysis Equipment©

Jackeline Dinwoodie
Seletech, Johannesburg, South Africa

BENEFITS AND APPLICATIONS OF PH, CONDUCTIVITY, AND SALINITY MEASUREMENT

Importance of pH. The pH is a measure of a liquid's acidity and alkalinity.

- pH is one of the most common parameters measured in a wide range of industries.
- The unit of measure for pH is the degree of hydrogen ion activity in a solution or aqueous base medium. The pH scale ranges from 0 to 14.
- Although litmus paper is a common method of pH measurement, it can only provide a rough indication, which might be insufficient in most applications.
- The most accurate method is by using pH meter and electrode with a hydrogen ion-sensitive glass bulb.
- The movement of ions across the membrane produces a voltage that is measured in mV and converted via the pH meter and reflected as a pH value
- Thus, depending on the concentration of the ions in the solution, the mV and hence the pH vary.
- Variations in temperature do have an influence on pH; it is thus important to have a pH meter with Automatic Temperature Compensation (ATC).

Calibration of pH.

- It is important to calibrate you pH meter and electrode before use. Always ensure that you use fresh pH buffers. These must be stored in a dark, cool cupboard at room temperature. This will ensure a shelf life of about 1 year.
- It is recommended to take 20 to 50 ml of the pH buffer, decant into a small container, and use this buffer for 1 month and then discard.
- Then take fresh buffer from the bottle. Never insert the probe directly into the bottle.
- When doing a pH calibration always start off with pH 7 buffer — the neutral point. Then do the calibration on pH 4 buffer followed by pH 10 buffer.
- It is recommended to do a three-point calibration, however it is possible to do a 2-point calibration. When doing a two-point calibration, always start with pH 7 and then pH 4 or pH 10 depending on the range of pH you are working in.

Sample Preparation When Doing pH for Soil.

- The ratio used when doing a sample for preparation on soils is 1:5, i.e., 10 g of soil to 50 ml of rainwater or distilled water.
- Mix the sample for 2–3 min and let stand for about 5 min so that all the salts can dissolve in the solution.
- It is recommended when doing a sample preparation to use $CaCl_2$ instead of rainwater or distilled water as the sample will be more representative of the conditions naturally occurring.
- It is however important to note that the pH will be 0.8 to 2 pH units less depending on the type of soil. The more grey the colour of the soil the greater the pH difference.

Care of pH Electrodes

- As electrodes are used and stored over a period of time, they will experience deterioration in performance.
- By doing a pH calibration at regular intervals (at least once a week), these errors can be corrected. If an electrode is able to be calibrated, is stable and responsive, it is still a functional electrode.

Storage/Shelf life of pH Electrodes.

- Since pH electrodes have a limited shelf life it is important to have a back-up electrode.
- Electrodes must be stored in electrode storage solution and not in water, as the hydrogen ions attach themselves to the bulb of the electrode and this can result in erroneous readings.

Electrode Maintenance

- pH electrodes are susceptible to dirt and contamination and need to be cleaned regularly depending on the extend and conditions of use.
- Wash electrode and reference junction quickly in de-ionised water. Always store the electrode in electrode storage solution.
- Selectech supplies a comprehensive pH electrode "Maintenance and Calibration Kit." This is highly commendable as this will not only ensure accurate and reliable calibrations, which in turn will result in reproducible results, but will also ensure maximum shelf life.

Types of pH Testers

- Pocket types — in a variety of models.
- Hand-held meters — different models to choose from.

THE IMPORTANCE OF CONDUCTIVITY/TOTAL DISOLVED SALTS/SALINITY

Conductivity. Also known as electrical conductivity (EC), conductivity is the capacity of ions in an aqueous solution to carry an electrical current. The basic measurements are milli-siemens·cm^{-1} (mS·cm^{-1}) and micro-siemens·cm^{-1} Conductivity is used widely to determine the level of impurities in the water.

Total Dissolved Solids (TDS). Is a mass estimate and is dependent on the mix of chemical species as well as the concentration of chemical species. The TDS can be measured in mg·L^{-1}, ppm (parts per million) or ppt (parts per thousand). The TDS concentration can be obtainable by multiplying the conductivity with a factor.

Salinity. Is the measure of the salt levels in the water. Salinity measurements are common in industries like agriculture, aquaculture, hydroponics, food, etc. The results are read as parts per thousand (ppt) or % (1 ppt = 1 $g \cdot L^{-1}$)

Conductivity Calibration Procedure. When doing conductivity calibrations it is important to use conductivity standards prepared for the same salts/chemicals. Select conductivity standards that cover the range you are expecting the conductivity readings to fall into — it is recommended to do a three-point calibration, however a two-point calibration is also possible, starting from the lowest conductivity standard to the highest value. The lifespan of conductivity standards, if stored sealed in a cool dark cupboard is about 1 year, however, once opened the life span is 6 months. It is recommended to take about 20 to 50 ml of sample in a small container. Use this for 1 month and then discard and replenish with fresh conductivity standard. Never place the electrode directly into the bottle of conductivity standard.

Conductivity Soil Sample Preparations.

- Place 10 g of soil in a suitable container and add 50 ml of distilled water or de-ionised water.
- Shake the container and let stand for a few minutes.
- Test the water above soil/sludge level.

Principle of Conductivity Measurements. The principal by which an instrument measures conductivity is via two plates being placed in the same sample and a potential is applied across the plates, and the current is measured. Since the charge of ions facilitates the conductance of electrical current, the conductivity of a solution is proportional to the ion concentration.

Conductivity Temperature Compensation. Conductivity measurements are temperature dependent. The effect of temperature on conductivity depends on the solution being measured. The effect is greatest in low conductivity solutions. A general rule to follow is there will be a 2% difference in conductivity per 1 ^{o}C increase in temperature. It is thus important to choose a meter with temperature compensation.

Conductivity Cell Maintenance. A polarised or fouled electrode must be cleaned to renew the active surface of the cell. In most cases hot water with a mild liquid detergent is an effective cleanser. Acetone easily cleans organic matter and chlorine solutions remove algae, bacteria, and moulds. Never use abrasive or sharp objects to clean an electrode. Care must be taken not to alter the distance between the cells of the electrodes.

Types of Conductivity/TDS Testers

- Pocket types — In various shapes and size and prices.
- Hand-held testers — Also various models available.

Other types of Testers

- Pocket and hand-held salinity testers.
- Combination meters — Measuring pH, temperature, and conductivity.

Efficient Plant Production and Cultivation©

Ben Geijtenbeek
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HOW TO BE AN EFFICIENT GROWER

Ask yourself the following three questions:

1) What is my problem?
2) What is the reason behind this problem?
3) What are some manageable solutions?

REASONS FOR PROBLEMS IN GROWING PLANTS

- Lack of fertilizer — resulting in poor growth
- Flower bud abortion and no colour by plant growth regulators — thickening of leaves and mis-formed growth points.
- Young plants exposed to stress — lack of fertilizer and fungal attacks result in poor plants, which starve and die off. Poor plants have no resistance under bad growing circumstances.
- Chemical over-kill with systemic fungicides. Young plants which are sprayed too often, stress!
- Lack of light and/or sunburn, resulting in poor growth.
- Bad soil mixes will hamper good growth.
- Poor quality seeds — seeds with low vitality and poor germination will produce bad plants.
- Growing areas — different growing stages growing next to each other — what is the risk?
- Poor climate control — a good climate is essential for growth.

Looking at the above, optimal growing conditions are a must!

HOW TO CREATE OPTIMAL GROWING CONDITIONS

It is not that difficult if:

- You know all involved growing factors and are able to deal with them.
- The main growing factors are: climate, light, temperature, nutrition, water.
- But the biggest growing factor is YOU!!
- Stop questioning — decide and act.

Where to focus? Management, information, production planning, calculations, plant selection, or sales.

PLANNING AND GROWING

Planning means: Who does what and when and where.

Order in time	**Organize in time**
Seeds/young plants	Production planning
Soil	Greenhouse/shade house space
Pots and trays	Labour
Fertilizers + advice	Sales
Chemicals	Finance — cash flow
	Green advice

MAIN REASONS BEHIND THE PROBLEMS

Unknown or not adapted water quality	Controlable?
Unbalanced fertilizer program	Controlable?
Excessive use of chemicals	Controlable?
Overdose of growth retardants	Controlable?
Shortage of attention — management	Controlable?
Lack of knowledge	Controlable?
Extreme climatic conditions	---

MAIN CONTROLLABLE TOOLS TO AVOID ABOVE PROBLEMS

- Right genetic/varieties
- Fertilization
- Water quality
- Growth regulation
- Climate

WATERING

- Watering from the bottom — reduces algae and black flies.
  - Avoids water-transmitted leaf diseases.
  - Very equal distribution — no dry spots.
- Watering from above — is very precise action only done by experienced growers.
  - Use fine drops and high pressure.
  - Be careful on sunny days.
    - To correct dry patches.
    - To give small amounts.

GREENHOUSE CONDITIONS

- High volume of plant population gives good climate.
- Air pruning of roots — when trays are off the ground.
- Clean area to avoid diseases.

BASIC ACTIVITIES OF PRODUCING YOUNG PLANTS

- Use a good soil, clean water, good seed.
- Follow sowing instructions such as temperature, covering, time to germinate.
- Use climate controlled room, avoid re-watering or drying out during germination process.

- Check phase of germination regularly — at least daily, but better twice a day.
- After germination put trays in greenhouse at desired temperature and light.
- Cover trays with plastic or acryl cloth to maintain humidity.
- Start fertilization as soon as first real leaves appear.
- Avoid temperature and humidity shocks.
- Start hardening off as soon as possible.
- Control diseases and insects.

IN SUMMARY: Avoid stress, avoid growing problems.

Optimizing Fertilization for Plant Cultivation©

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INTRODUCTION

Optimising fertilization requires up-to-date information on the composition of the growing medium and water. With this information one can do a calculated fertilization schedule according to the fertilizer requirements of the specific crop.

The key aspects to consider are the pH and EC of the substrate and the water.

KEY ASPECTS

Optimal EC and pH values are shown in Figure 1.

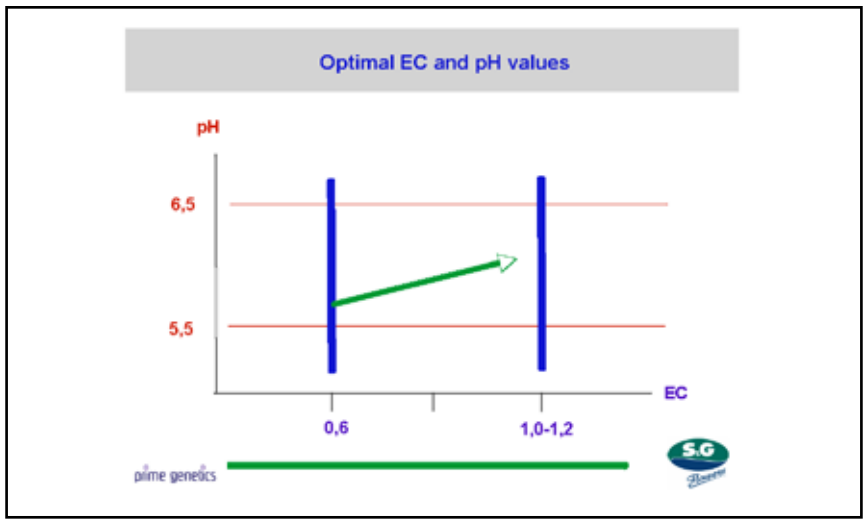

Figure 1. Optimal EC and pH values.

The pH (potential hydrogen) is the negative logarithm of the concentration H+, the acid value.

- The pH influences the solubility of nutritional elements and their availability to plants.
- A pH that is too low results in a poor uptake of phosphorous and calcium.
- A pH that is too high results in a poor uptake of the minor elements such as Mn, B, and Fe.
- High pH levels can be corrected by adding the right calculated amount of acid.

Electrical conductivity is the value of the total dissolved elements in the water or substrate, the salt value.

- The EC does not indicate the fertility of the substrate or water.
- The fertility can only be determined by analysing the chemical composition of the substrate and water.

Advantages of an A + B tank fertilization system.

- All elements are given in a balanced ratio.
- Flexibility to change quickly according to plant size.
- Relatively cheap.
- Water quality is taken into consideration.

Important: Keep calcium in high concentrations (A-Tank) always separate from sulphate and phosphate (B-Tank).

IMPORTANT FERTILIZATION ISSUES

- Never give plants water without nutrients.
- Use a balanced fertilization schedule that is based on the water quality.
- Monitor the pH and EC levels in the soil and water regularly to avoid surprises.
- When plants need more water (summer) lower the EC level per water application.
- When plants need less water (winter) raise the EC level per water application.
- For young plants start with an EC of 1.0 and as plant matures raise EC up to 2.5.
- Change EC levels, up or down, in small steps, 0.2 EC per time.

Jumping the Garden Fence©

Hildegard Klein
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INVASIVE ALIEN PLANTS

The presence of invasive alien plants in South Africa is due to human intervention. Many alien plants become naturalized and start to multiply and spread far from their original planting. Their invasiveness is harmful to the environment.

What Makes Some Alien Plants Invasive?

- These plants have no natural enemies.
- The rapid reproduction by means of seeds.
- Easily reproducing by vegetative means.
- Natural chemical defences.
- Hybrid vigour.

In South Africa there is not enough information available for accurate assessment of risks. Precautionary measures must be taken that sometimes clash with trade interests.

How Did the Invasive Alien Plant Get Into the Country?

- As garden ornamentals.
- As barrier plants — to prevent soil erosion, etc.
- As forestry or agro-forestry species.
- Unintentionally — people bringing in small quantities of seeds without declaring them at the border.

Main Proportion Invaders Among Different Users.

- Ornamentals 55%
- Barrier plants 13%
- Agriculture 11%
- Forestry 6%
- Not cultivated 9%
- Ground cover/binder 6%

Examples of Ornamental Plants That Have Been Declared Weeds or Invader Plants.

Ballon vine, *Cardiospermum grandiflorum*
Pompon weed, *Campuloclinium macroceplalum*
Yellow bells, *Tecoma stans*
Red sunflower, *Tithonia rotundiflolia*
Queen of the night, *Cereus jamacaru*
Rose cactus, *Cylindropuntia fulgida*
Yellow oleander, *Thevetia peruviana*
Mother of million, *Kalanchoe* (syn. *Bryophylum*) *delagoense*
Indian shot, *Canna indica*
Fountain grass, *Pennisetum setaceum*
Water hyacinth, *Eichhornia crassipes*
Parrot's feather, *Myriophyllum aquaticum*

Black locust, *Robinia pseudoacasia*
Jacaranda, *Jacaranda mimosifolia*
Syringa, *Melia azedarach*
Tipu tree, *Tipuana tipu*
Orchid tree, *Bauhinia variegata*
Pearl acacia, *Acacia podalyriifolia*
Singapore daisy, *Thelechitonia trilobata*
Sword fern, *Nephrolepis exaltata*

Risks Associated With Alien Plants.
Water pollution and obstruction of watercourses: *Acacia longifolia, Sesbania punicea*
Blocking of natural sunlight: *Melia azedarach*
Biodiversity: *Campuloclinium macrocephalum*
Soil pollution: *Acacia podalyriifolia*
Tourism/landscapes: *Jacaranda mimosifolia, Hakea sericea, Robinia pseudoacasia*
Agriculture: *Solanum elaeagnifolium, Cereus jamacaru, Cylindropuntia* (syn. *Opuntia*) *fulgida, Echinopsis spachiana*
Toxicity, injuries: *Nerium oleander, Thevitia peruviana, Opuntia aurantiaca*
Allergies: *Solanum mauritianum, Parthenium hysterophorus*
Forestry: *Lantana camara, S. mauritianum*
Pastures: *Campuloclinium macrocephalum, Cirsium arvense*
Allelopathy: *Eucalyptus camaldulensis, Acacia podalyriifolia*
Weight and smother: *Anredera cordifolia, Macfadyena unguis-cati*
Aquatic ecosystems: *Eichhornia crassipes, Azolla filiculoides, Pistia stratiotes*
Water utilization and boats: *Salvia modesta*, red water fern, and *E. crassipes*.

LEGISLATION ON INVASION ALIEN PLANTS IN SOUTH AFRICA

Conservation of Agricultural Resources Act (CARA)

National Environmental Management: Biodiversity Act (NEMBA) Act 10 of 2004

Unless you have a permit, you may not: acquire in any way; grow, breed, or propagate in any way; have in possession of, or physically control; convey, move, or otherwise translocate; import into the Republic of South Africa; sell, trade, give, donate, or dispose of; or carry out any other prescribed activity involving a specimen of an alien or a listed invasive species (extra-limital indigenous species = alien species).

Proposed Regulations.

- Alien species entering country are regulated.
- Provisions for unintentional introductions and pathways for invasion.
- Invasive species regulated to appropriate level, i.e., different categories.
- Alien species already in the country not regulated unless they are invasive.
- Extra-limital species only regulated where invasive.
- Notification only necessary for category 1a (see below).

CARA regulations.

- Category 1. Must control and eradicate.
- Category 2. Demarcate/permits to be issued.
- Category 3. Ban sale and further cultivation.
- Category X. Pending.

National Environmental Management: Biodiversity Act Regulations

1a. Strict control and eradicate.
1b. Management.
2. Demarcate/permits to be issued.
3. Ban sale and further cultivation.
4. Extra-limital species.
5. Pending/surveillance.
   X. Prohibited aliens.
   X. Exempted alien species.

Strict Control and Eradicate. Species requiring compulsory control:

- Crucial problem species.
- Effective control is practicable.
- Illegal to have a species on property, i.e., *Acacia paradoxa* (kangaroo thorn).

Management. Species requiring management:

- Effective control by individuals not possible.
- Must contain spreading.
- Integrated programme (typically managed by a local, regional, or national authority) will be required, i.e., *Caesalpinia decapetata* (Mauritius thorn).

Demarcate/Permits to Be Issued. Permitted in demarcated areas, e.g., woodlot, shelterbelt, or plantation.

- Permit required.
- Category 1b outside of demarcated area, i.e., *Acacia mearnsii* (black wattle).

Ban Sale and Further Cultivation. Regulated by activity.

- Certain activities are not permitted, e.g., sale or planting.
- Must contain spreading.
- Must notify purchaser of land.
- Can be declared 1a or 1b in certain area, i.e., *Grevillea robusta* (silver oak).

Extra-Limital Species.

- Listed extra-limital species.
- Indigenous species beyond their natural distribution ranges that are a threat to biodiversity (e.g., hybridisation).
- Permit required for possession, conveyance, etc., outside of natural range, i.e., *Protea neriifolia* cultivar.

Pending/surveillance.

- Alien or extra-limital species.
- May be listed after due investigations.
- Purchaser of species must be notified of status.
- Purchaser of land must be notified of the presence of such species, i.e., *Pyracantha coccinea* (firethorn).

Prohibited aliens.

- Species for which permits may not be issued.
- Species known to cause major problems.
- Not currently present in South Africa, i.e., *Eichhornia azurea* (anchored water hyacinth).

Current Situation

- Department of Environment and Tourism rejected proposal.
- Terminated involvement of task team.
- Public participation, i.e., Nurserymen's Associations, etc.
- The final outcome is in our hands.

Implications of the Biodiversity Act on the Nursery Industry©

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BIODIVERSITY ACT

Where Did It Come From?

- Nineteen drafts dating back to 1992
- Part of an International initiative
- Rio de Janeiro Earth Summit – 1992
- Johannesburg Earth Summit – 2002
- Gazetted as law in June 2004

Integrated Legislation to Protect Biodiversity: National Environmental Management Act (NEMA)

- Protected Areas Act – 2003
- Biodiversity Act – 2004
- Coastal Zone Bill

WHAT DOES THE LEGISLATION DO?

National Environmental Management Biodiversity Act (NEMBA). The purpose is to protect ecosystem integrity and the survival of species in the wild by:

- Institutional arrangements.
- Planning and monitoring.
- Protecting ecosystems and species.
- Introducing permits.

BIODIVERSITY ACT DEFINITIONS

Species. A kind normally not interbreeding with another kind, includes subspecies, cultivar, variety, geographic race, strain, hybrid, or geographically separated population.

Indigenous Species. A species that occurs or has historically occurred naturally in a free state in nature within the borders of South Africa — but excludes a species that has been introduced to the Republic of South Africa (RSA) as a result of human activity.

Alien Species.

- A species that is not an indigenous species.
- An indigenous species translocated or intended to be translocated outside its natural distribution range in nature.

Biodiversity Act. The law stated that unless you have a permit you may not:

- Acquire in any way, by any means, method or device, any specimen or derivative.
- Grow, breed, or propagate in any way.

- Have possession of or physically control specimens in any way.
- Convey, move, or otherwise translocate.
- Import plants into RSA or export from the RSA.
- Sell, trade, give, donate, or in any way dispose of plants.
- Any other prescribed activity.

INTERNATIONAL ACTION VS. LOCAL ACTION

What Are Green Industries Around the World Doing About the Problem?

St. Louis Declaration of 2001. Addresses the spread of IAP's by setting up voluntary codes of conduct for botanical gardens, nursery, and landscaping organisations – such as SALI, IPSA, LIA, and SANA – in South Africa.

Yellow Flag Declaration – June 2005

SA Landscapers' Institute Pledge. My company will have:

- A working knowledge of the IAP laws.
- Know how to remove IAPs.
- Shall never trade in IAPs.
- Know the alternatives to plant in place of IAPs**.**

A SALI Member Undertook to…

- Make clients aware of IAPs in writing.
- Fly the yellow flag on documentation and at my business.
- Conduct ongoing training into IAPs.
- Accept that Category 1 IAPs will result in disqualification in the SALI Awards.
- Abide by the spirit of the Yellow Flag Movement.

New Biodiversity Structures for South Africa — South African National Biodiversity Institute

- Management Flora of SA — National Botanical Institute.
- Management Fauna of SA — National Zoological Gardens.

International Trends — What Do the Green Industries Think?

- All imports undergo a risk assessment.
- "Polluter pays" principle.
- Government vs. industry regulation?
- Should authorities declare a "species" as an IAP?
- Species be declared — "guilty until proven innocent" or "innocent until proven guilty."

CONCEPTS UNDER DISCUSSION

The South African Scenario — What Does the Green Industry Think?

- Five categories vs. three categories?
- Yellow Flag vs. Green Flag?
- Voluntary vs. compulsory registration?
- Industry vs. government registration authorities?
- Government agencies with capacity to oversee the permit system?
- Indigenous seeds going abroad?

Five Versus Three Categories

1a . Prohibited species. Remove and destroy.
1b. Government control programme.
2. Control by area. No trade.
3. Control by activity. No trade.
4. Indigenous invaders. No trade.
5. Plants under surveillance; trade with a warning tag.

Category 5: Plants Under Surveillance, Labelling Ideas.

- Scientific and common name.
- Indication that the species is being assessed for potential invasive status and may need to be controlled in future.
- Landscaping plants — label in batches.
- Cut flowers do not need a label.

South African National Biodiversity Institute.

- National Botanical Institute.
- National Zoological Gardens.
- Invasive Species.

Plant Registering Authorities

- South African Nurserymen's Association (SANA).
- South African Landscaping Institute (SALI).
- And anyone else who applies.

Green Flag Registration — What Would Sellers of Plants Need to Provide to a Registering Authority?

- Name and address.
- Location of stock.
- List of nursery suppliers.
- You must display your Green Flag.
- Your licence to operate is valid for 1 year.

CONCEPTS UNDER DISCUSSION — INDIGENOUS SEED SALES

Suggestion That Seed That Is Potentially Invasive in Any Other Country Should Carry:

- A "colour" band around the perimeter of the label.
- A label that states that the purchaser must check for the potential invasiveness of the seed outside South Africa.
- A warning that a permit may be required by the receiving country for the seeds.

Cultivation of Southern African Succulents©

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INTRODUCTION

There are about 10,000 succulent species in the world of which 30% are native to South Africa. Main succulent plant families found in Southern Africa — 35 main plant families

1344	Mesembryanthemaceae	46%
392	Asclepiadaceae	14%
334	Asphodelaceae	12%
239	Crassulaceae	8%
180	Euphorbiaceae	6%
131	Asteraceae	5%
34	Portulacaceae	1%
28	Families (249)	8%

SOME FACTS ABOUT SUCCULENTS

- Southern Africa is home to nearly one third of the world's succulents.
- There are just over 4,000 succulent species found naturally in the Republics of South Africa and Namibia.
- With global warming and areas becoming drier, it is predicted that succulents will increase in numbers.
- Succulents are water-wise and are becoming increasingly popular in landscape design.
- Succulents are found on the highest mountains, on coastal plains, on the southern tip of Africa, and in the dry deserts.

PROPAGATION

Succulents can be propagated sexually (from seed) and asexually (vegetative—from cuttings).

Sexual Propagation—Why Propagate from Seed?

- Certain succulent genera and species are easier to propagate in this manner.
- Seed readily available.
- Plants develop faster from a seed than a cutting.
- Many caudiciform plants (plants with thick root stocks) can be propagated asexually but never form a thickened caudex.
- In certain cases stronger plants with a well-developed root system are produced.
- To strengthen genetic diversity within a species.

Some Types of Succulents Propagated by Seed.

Aloe seeds — Some aloes that are best grown on mass from seed: *A. angelica, A. broomii, A. comosa, A. dichotoma, A. excelsa, A. ferox, A. gariepensis, A. khamiesensis, A. marlothii, A. lineata, A. littoralis, A. microstigma, A. peglerae, A. pillansii, A. polyphylla, A. pretoriensis, A. ramosissima, A. speciosa, A. striata,* and *A. vryheidensis*

Other types of succulents propagated by seeds:

- *Dioscorea elephantipes*, elephant's foot.
- *Stapelia*, asblom or carrion flower.
- *Lampranthus multiradiatus*, Hout Bay mesembryanthemum.
- *Cotyledon orbiculata*, plakkie or pig's ear.

Asexual Propagation — Why Propagate Vegetatively?

- To copy a characteristic of a certain plant, for example a variegated form, a flower colour, a growth form, etc.
- Have large plants available in a relatively short space of time, for example *Crassula*, *Euphorbia*, certain bush vygies, certain aloes, etc.
- Some succulents do not produce much seed, for example cissus, haworthias, etc.
- Some succulents do not produce viable seeds, i.e., certain succulent senecios, othonnas, etc.
- A number of succulent plants can be propagated with relative ease and minimal propagation facilities

Asexual Propagation Techniques Used on Succulents.

1) Stem: stem succulents.
2) Leaf: leaf succulents.
3) Truncheon: branches.

Stem Succulents.

- *Adenium* — however it does not make a sizable caudex.
- *Aloe* species — *A. barberea, A. plicatilis, A. arborescens*, all rambling aloes, grass aloes, etc.
- *Anacampseros* sp.
- *Conophytum* sp. — Looks like lithops (beeskloutjies).
- *Cotyledon* sp., all "plakkies" can be propagated vegetatively.
- *Crassula*, nearly all crassulas can be propagated this way.
- *Euphorbia*, many of the tree euphorbias can be propagated this way.
- *Mesembryanthemum* (vygies), most of the colourful bush vygies are propagated in this manner.
- *Pachypodium* sp. (Kudu lilies), however, they do not make a sizable caudex.
- *Sarcocaulon*, bushmans's candles.
- *Senecio*, all succulent senecios are easily propagated vegetatively.
- *Stapelia* sp., all except a few are propagated asexually.

Leaf Succulents

- *Adromischus* — money plant — pieces of leaf, which fall on the ground, root easily.
- *Conophytums*, similar to lithops.
- *Cotyledon*, can also be propagated by stems.
- *Crassula*, can also be propagated by stems.
- *Gasteria*, grows easily.
- *Haworthia*, certain species, especially the window varieties.
- *Kalanchoe*, easy from a single leaf.
- *Lithops*, "beeskloutjies", living stones.
- *Sansevieria*, mother in law's tongue.
- *Senecio* can also be propagated by stems.

Truncheon Cuttings. This works for: Aloes, *A. barberea, A. plicatilis*; *Ceraria namaquensis*, Namaqualand pork wood; *Commiphora*, succulent types; *Cyphostemma*, Namibian wild grape; *Portulacaria afra*, karoo pork wood; *Tylecodon paniculatus*, botterboom; and *Sesamothamnus lugardii*.

Another Method of Propagating Succulent Plants.

Division. The following can be propagated by division: aloes, asclepiads — certain mat forms, crassulas, gasterias, haworthias, kalanchoes, mesembs — certain creeping forms, sanseverias, and senecios.

Propagating and Growing Media.

- Sieved coarse river sand, sieved loam, sieved well rotted compost, vermiculite, perlite.
- Bone meal, agricultural or dolomite lime.
- A well-drained growing medium ideal for cultivating succulents.

REQUIREMENTS FOR CULTIVATION OF SUCCULENTS

- Good ventilation — good air movement is essential.
- Correct placing of plants — do not over-crowd.
- Correct amount of light needed for optimum growing conditions — too much or too little light can be detrimental.
- Well-drained soils essential in most cases.
- Correct watering of plants — depending on winter or summer rainfall areas.
- Knowing where these occur in nature — thus understanding how they grow.
- Knowing when to sow seed and strike cuttings — depending on if winter or summer growing.

Mutation Breeding in the Hyacinthaceae©

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INTRODUCTION

Evolution.

- Constant, natural phenomenon.
- Caused by cosmic or ultraviolet rays.
- Faulty DNA replication.
- Can be encouraged or accelerated where needed.

Crop Improvement. Agricultural crops today have all undergone improvement by means of:

1) Selecting the best plants.
2) Crossings to combine good qualities.
3) Resorting to other sources of variation when existing germplasm fails to provide the desired recombinant.
   - By means of mutation techniques.
   - In vitro techniques.
   - Molecular techniques.

MUTATION BREEDING

Background. Induced mutations are used extensively in floriculture, e.g., *Streptocarpus* where five commercial mutants were obtained in 3 years from one cultivar. It is used in a number of different crops, i.e., it is standard practice to irradiate new chrysanthemum cultivars.

Induced mutations are carried out in order to: Improve yields, improve quality, disease resistance, pest resistance, increase attractiveness of flowers, and increase attractiveness of ornamental plants

Food and Agriculture Organization/International Atomic Energy Agency (FAO/IAEA) Mutant Database. There are over 2,200 officially released mutant taxa including:

- 47% cereals
- 24% ornamental plants
- 14% legumes
- 4% industrial crops
- 3% vegetables
- 3% oil crops
- 5% other crops

What Happens in Mutation Breeding.

- It alters genes by exposing seed or plant parts to mutagens.
- It changes the DNA (the DNA sequence can be changed).
- Parts of the chromosomes can be rearranged.
- An entire chromosome can be lost or duplicated.

How Does It Work? It requires three things, i.e., plant material, mutagen, and method.

1) Material – Seed, leaves, growth tips, etc.
2) Mutagen – Chemicals or irradiation.
3) Method – Combination of the above.

Chemical Mutagens. These are rarely used in vegetatively propagated crops because they are not very successful. This is due to poor uptake of mutagen and poor penetration of chemical compound. It is also difficult to repeat. The explants differ.

Radiation. This is preferred because it is easy to apply. It is reproducible and gives high frequency mutations. The disadvantages are that the mutations occur at random. Progeny has to be evaluated and selection is needed

International Floriculture Market Requires:

- Development of products that will appeal to consumer taste.
- Production methods at competitive prices.
- Ongoing introduction of new varieties.
- Floriculture market is fashion orientated.
- Colour and growth form variation is very important, i.e., yellow is good for Easter, red and white for Christmas, and softer colours for Mother's Day.

The Bulb Mutation Technology Project

Project started in April 2003 and ended Sept. 2006. The project is funded by the Innovation Fund and makes use of existing knowledge. It uses irradiation to induce mutants. The prime objective is to get new flower colour. A consortium consisting of the following partners runs the above project:

- ARC – Roodeplaat — research.
- Rural integrated engineering — project management.
- Vosbol — some research and commercialization.

Why Hyacintheceae?

- Mutation is a one-cell event.
- They are vegetatively propagated.
- Adventitious buds form on the leaf tissue.
- It is from single-cell origin thus mutations should be solid.
- Non-chimeral mutants.

Bulbs Taxa Used in This Project:

- *Lachenalia* — Produced beautiful mutations; especially new colour forms.
- *Ornithogalum* — Produced no colour change but increased flower size; good for cut flower industry.
- *Eucomis* — Produced bigger plant with leaves densely spotted; usual bad scent remained.

Regeneration capacity. Once a good mutant is found, the grower must be able to propagate it easily. Some mutants loose some regeneration capacity. Some do not grow and have to be discontinued.

CONCLUSION

We have the technology and expertise to induce mutations. Specific methods for the Hyacinthaceae have been developed and can be adapted to other crops. Currently at least four new cultivars have been identified in the Hyacinthaceae for multiplication and further evaluation.

Wheelie Green: The Development of a Mobile Unit to Produce Rooted Cuttings of *Eucalyptus* Tree Species©

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A first prototype of a mobile unit to produce rooted cuttings has been developed at CSIR NRE. The development of such a unit has two main objectives. Firstly to develop a low-tech unit in which cuttings can be rooted in infrastructure-poor conditions at nurseries based in rural areas. Such a unit needs to maintain the basic conditions conducive to the survival and rooting of the cuttings. The second objective is to develop the unit into a scientific experimental unit in which different conditions can be simulated to determine specific conditions needed to root difficult-to-root hybrid clones.

This paper reports on the progress of the development of the unit to date and the results obtained during the first rooting experiment. For this experiment hedge plants of an *Eucalyptus grandis* × *E. camaldulensis* clone were grown in the glasshouse at the University of Pretoria. Micro cuttings were placed in two media, namely a vermiculite medium and air to test for aerial rooting. The cuttings were "washed" in Benomyl (Benzidimazole) to prevent fungus infections and the cut edge was dipped in a rooting hormone, Seradix B2, before placement. Survival decreased rapidly within the first 5 days to about 54% plant survival. The first roots were observed 15 days after placement; at this stage plant survival stabilized at 44%. After 18 days the rooting percentage of the surviving plants was 6% for aerial rooting and 53% for the surviving cuttings placed in vermiculite. During this experiment the floor heating pads could not be used. However, the heat generated by the T5 Extra high output fluorescent tubes was enough to maintain an average temperature of 27 °C in the chamber. Temperatures never went below 25 °C or above 30 °C. The average relative humidity was 81%.

The results of this experiment indicate that there is sufficient potential for successful rooting of cuttings to warrant further development of this mobile propagation unit.

INTRODUCTION

Council for Scientific and Industrial Research's (CSIR) National Resources and the Environment (NRE) Tree Improvement group was tasked to develop an experimental mobile propagation unit for studying the conditions needed to stimulate root formation in difficult-to-root *Eucalyptus* hybrids. In this paper we report on the development of the first three prototypes, which will serve as the basis for the future development of a technologically advanced experimental unit.

The prototype in its current form has the potential to be used as a basic rooting environment in rural areas where the development of large infrastructures is too expensive. Not only will it be possible to root cuttings from *Eucalyptus* tree species but other tree species, e.g., *Sclerocarya birrea*, *Ximenia caffra*, *Uapaca*, *Parinari*, and *Podocarpus* sp.

DESIGN AND DEVELOPMENT

First Prototype. The original design and development of the first prototype (Fig. 1) was done by Dr. At Kruger. The unit has a metal framework with Perspex sides of which the front panel can drop down for easy access to the chamber. The size is 180 cm × 62 cm × 77 cm (L × H × D) and has the capacity for 4 × 128 seedling trays. The roof and bottom tray are made of aluminum. A single daylight fluorescent tube was attached to the centre of the roof.

The irrigation system is constructed of copper pipe extending in a T-formation in the center of the unit. In order to produce enough pressure to open the four non-drip copper fine-mist sprays, a single-phase high-pressure pump was attached to the copper pipe at the bottom of the trolley. A 20-inch hosepipe served as the water inlet and was attached to the pump. The irrigation is controlled by a timer system.

To generate heat from the bottom, four heating mats were placed within a polystyrene frame and covered with fine gravel. The temperature is thermostatically controlled.

Second Prototype. The irrigation system in the first prototype created a couple of problems. The high-pressure pump caused severe vibration of the copper pipe, which led to heat being generated and warm water being sprayed onto the plants. The vibration would also in time have led to the cracking of the copper pipe at the T connection. It was decided to replace the copper pipes with PVC pipe. The PVC pipes could be attached to the side of the chamber, creating space for an additional seedling tray (Fig. 2). This irrigation system did not need the high-pressure pump as normal tap pressure proved to be adequate enough to open the non-drip spray mist nozzles.

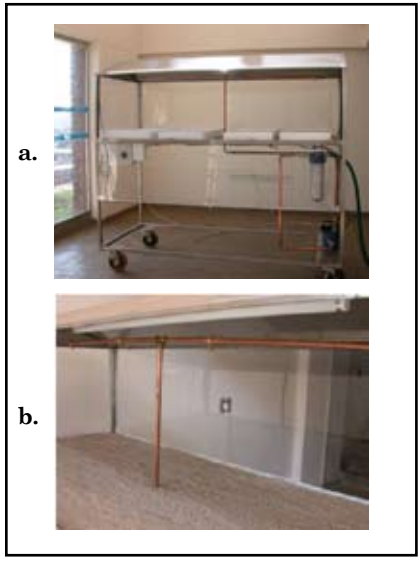

Figure 1. First prototype of Wheelie Green with high-pressure pump, copper pipe irrigation, and capacity for four seedling trays (a). Light source was a single daylight fluorescent tube (b).

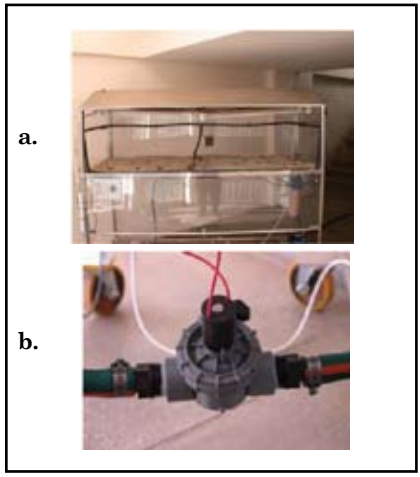

Figure 2. Wheelie Green 2 with PVC irrigation system attached to the chamber sides (a). The system has four non-drip mist spray nozzles. Normal municipal tap water pressure is adequate to open the nozzles. Irrigation is controlled by a solenoid valve on a timer (b).

The light quality (irradiance) generated by the single household fluorescent tube was not adequate to enhance photosynthesis. This tube was replaced by four T5 Plant Pro Fluorescent tubes (39W), which generates the correct light spectrum to enhance photosynthesis (Fig. 3). The tubes were attached to a wooden board suspended from the roof with two small chains. The idea was to allow for the light to be moved up and down should a change in the light energy at plant level be needed. However, this did not prove to be very successful as space was limited due to the positioning of the sprayers. They also created a safety hazard as, even though the board was painted with a water proofing layer, it started to bend after a couple of weeks under high humidity conditions in the chamber.

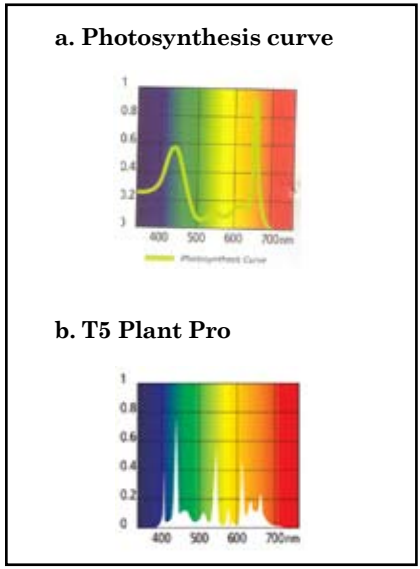

Figure 3. Wavelength produced by T5 Plant Pro Fluorescent tubes fall within the required light spectrum for photosynthesis.

Third Prototype. Only slight initial improvements were made to the second prototype. The lights were removed from the wooden board and attached to the roof (Fig. 4A). Irradiance at plant level was enough to ensure photosynthesis and it improved safety.

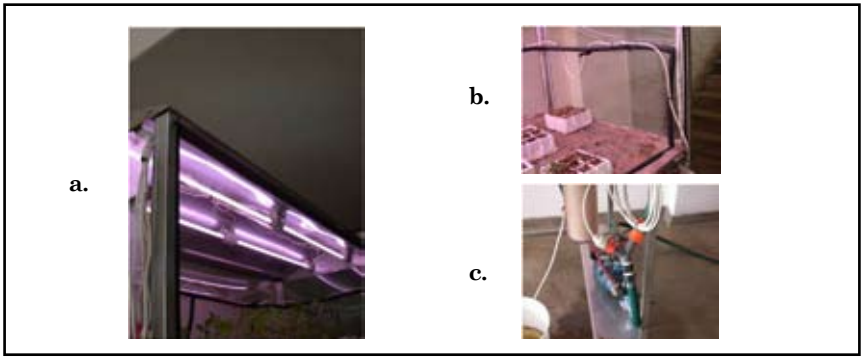

Figure 4. Prototype 3 with T5 Plant Pro Fluorescent tubes attached to the roof and a dual irrigation system.

The spray from non-drip mist nozzles from the PVC system was not fine enough. A cool mist spray system (Fig. 4B) that is commercially available was added to the PVC irrigation system. This increased the effectiveness of cooling down the chamber and a much finer spray drop was sprayed onto the plant leaves. This also created the opportunity for a dual irrigation system (Fig. 4C) with the possibility of using the PVC system for fertilization when the plants have rooted and fertilization

needs to be added to the system. A future idea is to replace the existing filter system with a fertigation filter system.

ROOTING EXPERIMENT

In order to test if environmental conditions conducive to rooting can be achieved in the current prototype (No. 3), a *Eucalyptus* hybrid clone, *E. grandis* × *E. camaldulensis*, which is known to be a good rooter, was chosen for the experiment. Hedge plants of this clone were kept in nursery bags in a glasshouse at the University of Pretoria. Microcuttings were harvested from these hedge plants and placed in two rooting media:

1) Vermiculite: Generally used in nurseries.
2) Aerial: Cuttings placed in up-turned seedling trays based on a method of Mike Kruger at Top Crop Nursery in Natal.

Before the cuttings were placed they were rinsed in Benomyl (benzimidazole 500 $g \cdot kg^{-1}$) to prevent fungus infection and the tips were dipped into a root-enhancing hormone Seradix B2.

The two different rooting medium treatments were placed in a randomized block design in the Wheelie Green (Fig. 5).

Figure 5. Experimental layout for rooting experiment.

Plant survival and rooting were monitored at weekly intervals. The temperature and relative humidity in the chamber were measured with an OakTon RH/TempLog instrument. Unfortunately due to the fact that the heating mats were not sufficiently insulated against water they had to be switched off after a week as they caused power failures. However, an average daily temperature of T = 25 °C ± 3 °C could be maintained across the experimental period. This was mainly due to heat generated by the fluorescent tubes. Irrigation was initially set for 2 h off and 60 seconds on. This was changed to 30 seconds on and 2 h off. The average relative humidity in the chamber was 81% ± 3%.

Initial plant survival dropped to around 54% within the first 5 days (Fig. 6), probably because conditions were initially too wet in the chamber. After 18 days the survival rate stabilized at 44% plant survival in both the vermiculite as well as in the aerial rooting.

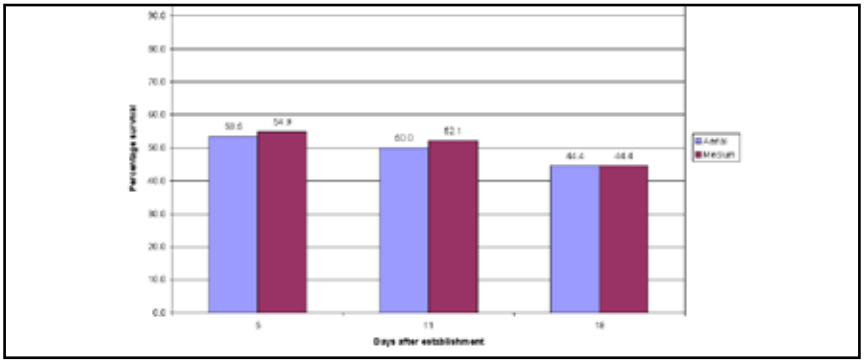

Figure 6. Survival of mini cuttings in the Wheelie Green at 5, 11, and 18 days after setting the cuttings.

Strong root development was obtained in both the vermiculite as well as in the aerial rooting (Fig. 7). However, substantially better rooting was obtained in the vermiculite (Fig. 8). Only 1.4% of the surviving cuttings rooted in the aerial medium while 30.7% rooted in the vermiculite. After 18 days only 6% of cuttings had rooted in the aerial medium while 53% had rooted in the vermiculite.

Figure 7. Strong rooting was observed in both the vermiculite and aerial rooting media.

At this stage it can be concluded that conditions suitable to enhance rooting can be obtained within the Wheelie Green. However, conditions are not conducive to aerial rooting.

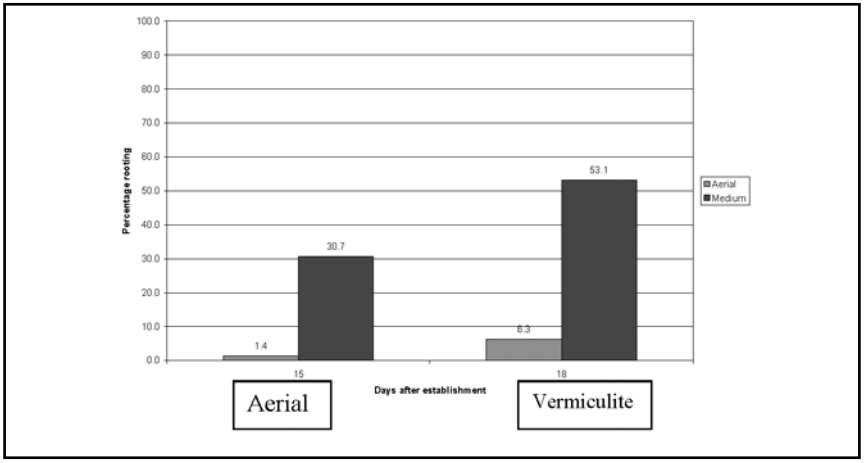

Figure 8. Percentage rooting of the surviving mini-cuttings in the vermiculite and aerial medium in the Wheelie Green.

FUTURE DEVELOPMENT

It can be concluded that at this stage we have developed the basic prototype for an experimental unit in which rooting experiments can be done. We do need to solve a couple of immediate problems, namely:

- Water and electricity problem.
  - Move heating pads to outside of chamber or replace.
- Better drainage of water from tray.
- Add fans for:
  - Better temperature control.
  - Slight air movement in chamber.

For the future upgrade to a fully controllable experimental unit we will need to obtain funding to develop a complete engineered design, which will include:

- Better insulation of the chamber.
- Addition of CO_2 system.
- Computerized control of the temperature (fans), irrigation, relative humidity, heating pads, and CO_2 system.

With the above mentioned technological improvements it will be possible to have an experimental unit in which research could be done to determine the specific conditions needed to stimulate rooting of cuttings from known difficult rooters e.g., *E. grandis* × *E. nitens* hybrids.

Acknowledgements. The development of the prototypes was funded as part of the ACIAR project: (FST/1996/124) — High performance eucalypts and interspecific hybrids for marginal lands in south and eastern South Africa and south-eastern Australia. The development was also partly funded from the CSIR's parliamentary grant.

The Use of Copper Compounds as Root Pruning Agents©

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INTRODUCTION

Melaleuca alternifolia, commonly known as "tea-tree," contains special oil in its leaves famous around the world for its antiseptic qualities. During the 1990s an elite clone of *M. alternifolia* ('Clone 88') was identified for its superior oil qualities and high oil yields, and my nursery was contracted to mass-produce this clone for a large plantation in north Queensland.

Tea-tree plantations are planted at a very high density of plants (25,000–30,000 plants per hectare), and because of the very large number of plants required for a plantation, there is considerable pressure on nurseries to supply the plants at the lowest price possible.

Between 1997 and 1999, my company produced by cutting propagation 10 million plants of *M. alternifolia* 'Clone 88'. We became very proficient at the production process, achieving an average strike rate of 95% across the whole project and 99% strike rate on the final 2 million plants. Because of the high labour cost involved in cutting production (every cutting is prepared and set individually by hand) and the low price demanded by the customer, the cuttings were set directly into the final container to minimise labour and handling.

The container chosen in which to grow the plants was the 'Hiko' V50 tray, comprised of 67 cells per tray, with a cell volume of 50 ml. This particular tray was chosen because it met several important criteria including ease of handling, strength, space efficiency, depth of cell (deep roots), strong internal ribbing to prevent root coiling, and its ability to be re-used.

Once the plants were produced, they had to be dispatched to the plantation. Because of the very large number of plants required to be delivered each day, the plants were pulled from the cell trays and packed tightly into polystyrene boxes in order to maximise the number of plants that could be delivered per truckload and to minimise freight costs. At the plantation, the plants were planted by machines comprising a device mounted on the back of a tractor with a shute down which the plants were dropped into the prepared ground. The plants were planted 300–400 mm apart, and due to the very large numbers involved, planting was at a very fast rate. Therefore, the plants we produced had to have robust root systems that could withstand the rigours of the handling, packing, transporting, and the planting process without falling apart.

Root system quality is of great importance to the plantation owner because of its impact on plant vigour and growth, and ultimately therefore on oil yield and profit. Furthermore, since the plantation is harvested by machines which slice the plants off at ground level, strong root systems are essential to anchor, and brace, the plants against the physical shock of the harvesting process and to ensure that the plants re-shoot to provide another year of growth.

COPPER

During the 1990s, there was widespread interest within the nursery industry regarding the quality of the root systems of nursery-grown plants and in particular root coiling, which could lead to poor performance or even death of plants some time after planting out into the field. As a result, copper compounds (which can be readily mixed with paint and applied to the insides of containers) were widely promoted as effective root-pruning agents in container-grown nursery plants. Such applications work by killing root tips as they make contact with the copper-based paint. This stimulates the production of side roots within the root-ball, which then grow to the outside where they are again stopped by the copper. This process thus prevents root coiling and leads to the production of a root-ball consisting of a mass of branching fibrous roots. However, while widely used in seedling and forestry nurseries, we could find no record of, nor information on, the use of copper compounds with *M. alternifolia* or in cutting (as opposed to seedling) production.

Consequently, we set up a trial to investigate the use of copper in our tea-tree production system to determine if we could make improvements on our existing root systems and also to see if there may be any detrimental effects on the production process such as impacts on strike rate, plant vigour and growth, and plant handling during packing, dispatch, and planting.

THE TRIAL

We selected Kocide® (a commercial product containing 400 g·kg^{-1} copper hydroxide) as our source of copper because it was readily available, inexpensive, and in wide use in other nurseries. We applied it to the internal surfaces of the cell tray containers by mixing with a water-based low-sheen white paint. The trays were left to thoroughly dry for 5 days before use. From communications within the industry, we determined that the generally recommended application rate of copper was in the vicinity of 20 g copper hydroxide per litre of paint. We therefore set up our trials with various rates above and below this level (Table 1).

Table 1. Application rates of Kocide[1] in water-based, low-sheen white paint.

Kocide (g·L^{-1} paint)	0	10	20	30	40	50	60	70	100	200	300	500
Copper hydroxide (g·L^{-1} paint)	0	4	8	12	16	20	24	28	40	80	120	200

[1]Kocide® is a commercial product containing 400 g·kg^{-1} copper hydroxide.

Two trays (134 cuttings) were set for each application rate and placed in the cutting-house under mist. At all stages of the trial we used our standard, well-established and successful procedures for the cutting production of *M. alternifolia*. After 6 weeks the plants were shifted to a hardening-up area under light shade, then to full sun at 10 weeks. At 20 weeks a visual assessment of the plants was made and the strike rate recorded. At 24 weeks a thorough assessment of the plants was carried out as described below. The results are recorded in Table 2.

Table 2. Effect of copper hydroxide on *Melaleuca alternifolia* cutting production.

Copper hydroxide ($g \cdot L^{-1}$ paint)	0	4	8	12	16	20	24	28	40	80	120	200
Strike rate (%)	96	93	94	93	96	81	70	81	82	93	87	78
Vigour[1] (1–5)	5	4	5	5	4	3	2	1	2	4	4	4
Colour[2] (1–10)	10	9	8	7	6	4	2	2	3	6	7	8
Shoot wt (g)	3.34	1.88	2.41	2.69	2.45	1.65	1.00	0.63	2.03	2.33	3.00	2.64
Root wt (g)	7.32	4.79	3.69	3.29	2.41	2.46	1.31	0.90	3.14	3.00	4.01	5.81
Handling[3] (1–10)	9.05	4.9	4.9	4.5	4.0	2.2	3.1	2.6	2.4	2.2	2.7	2.4

[1] Vigour was assessed visually on a scale of 1 (very poor) to 5 (very good) — see text.

[2] Colour was assessed against a colour chart on a scale of 1 (very yellow) to 10 (very green).

[3] Handling was assessed qualitatively on a scale of 1 (very poor) to 10 (very good).

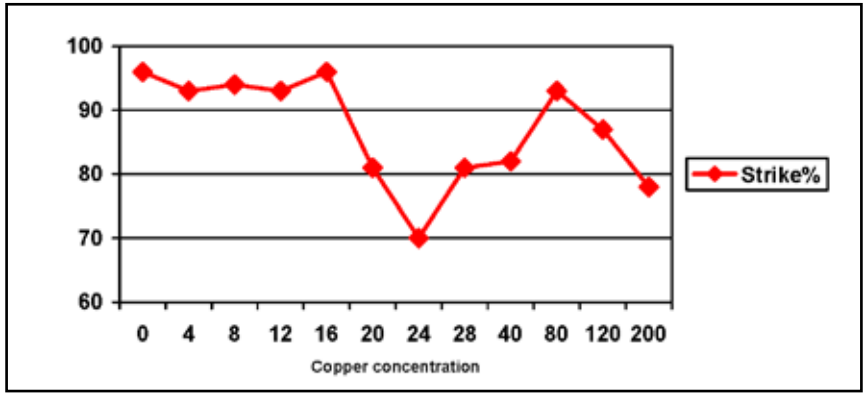

Figure 1. The effect of copper hydroxide[1] on the strike rate of *Melaleuca alternifolia* cuttings.

[1] Copper hydroxide concentrations are g·L^{-1} in water-based low-sheen white paint.

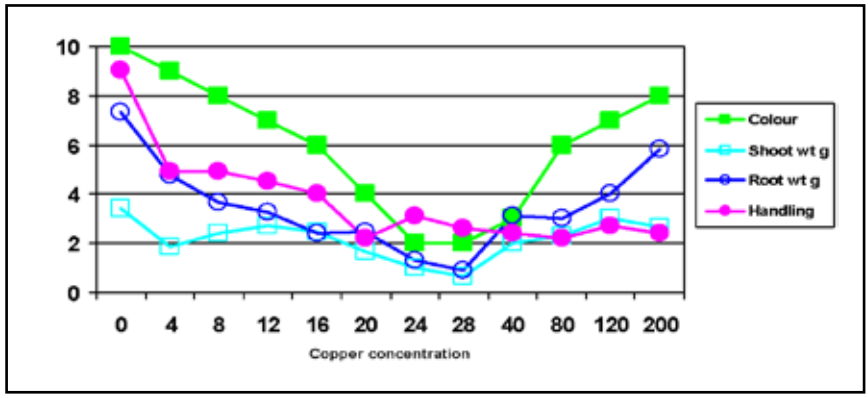

Figure 2. The effect of copper hydroxide[1] on the growth of *Melaleuca alternifolia* cuttings.

[1] Copper hydroxide concentrations are g·L^{-1} in water-based low-sheen white paint.

Strike Rate: The number of surviving plants was counted, and recorded as percent strike rate.

Vigour: The plants were visually assessed for vigour, on a scale of 1 (very poor) to 5 (very good), based on our experience of how the customer would assess the plants at sight.

Colour: The colour of the plants was assessed on a scale of 1 (very yellow) to 10 (very green) by comparing against a colour chart.

Shoot weight: Ten representative plants were selected from each application rate. The shoots were cut off at the base, at the junction with the root ball, dried of excess water (but not dehydrated), and individually weighed. The average shoot weight for each application rate of copper is shown in Table 2.

Root weight: The root balls from the plants selected above were then carefully washed to remove any media, dried of excess water (but not dehydrated), and individually weighed. The average root weight for each application rate of copper is shown in Table 2.

Handling: A further 10 representative plants were selected for assessment by our experienced dispatch staff for their ability to withstand the rigours of packing, handling, transport, and planting. Each plant was rated on a scale of 1 (very poor) to 10 (very good). The average rating for each application rate of copper is shown in Table 2.

CONCLUSION

It is clear from the data obtained in this trial that copper hydroxide is not suitable for use as a root-pruning agent in the cutting production of *M. alternifolia*. All application rates of copper hydroxide (including the recommended rate) adversely affected strike rate, vigour, colour, growth, and handling (Figs. 1 and 2).

Root Systems in Cutting-Raised *Eucalyptus* Species Are Influenced by Cutting Size and Stock Plant Treatment©

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INTRODUCTION

Conventional vegetative propagation of some *Eucalyptus* species has been carried out for some 50 years, although until relatively recently only on a small scale. The exploitation of the genera by countries other than Australia for the purposes of producing high-grade paper pulp have led to the development of a range of hybrids suited to particular environments and soil types.

The main concentration has been with subtropical hybrids particularly in Brazil and more recently temperate species in Chile, Uruguay, Portugal, and Spain. Selection of clones with high percentages of rootabilty combined with desirable growth rates, form, and fibre quality, is an ongoing process within the industry.

During the last 10 years, a great body of work has been undertaken especially in Brazil, where novel propagating systems have been developed to enable nurseries to mass produce clones. These techniques and some clones have been transferred to Australia and further adapted to suit local conditions.

STOCK PLANT PRODUCTION

When vegetative propagation of *E. globulus* in commercial quantities was first undertaken, stock plants were grown in the ground and kept juvenile and macro cuttings were taken from them. This practice still persists, in particular with *E. globulus* and to some degree with subtropical hybrids such as *E. grandis* × *E. camaldulensis*, *E. grandis* × *E. saligna*, *E. grandis* × *E. urophylla*, and a range of others.

In Brazil, during the last 10 years, a different method of growing and treating stock plants has evolved. This technique, which incorporates the use of irrigated sand beds or ebb and flow benches and stock plants grown at very high densities per square metre in so called "mini gardens," produce what are known as mini cuttings. With this system stock plants are again kept juvenile with cuttings being taken weekly to ensure that no lignified material forms on the small stump of each plant.

We have further adapted the system to incorporate the use of coir-filled bags rather than either sand beds or ebb and flow troughs and use a system of controlled, nonleaking drippers to irrigate the plants. Using this method, conventional benching can be utilised, and unlike an ebb and flow system, but similar to sand beds, nutrient solutions "run to waste" rather than being recycled.

NUTRIENT TREATMENT OF STOCK PLANTS

Using any of the systems described above, it is important to ensure a nutrient regime which will invigorate the stock plants so that they continue to produce vegetative material from which new cuttings can be taken. In addition, it is of particular importance to ensure there is a balance of macro- and micronutrients supplied to the stock plants, on a continual basis, to ensure their ability to produce vegetative material capable of producing roots.

In a number of Brazilian and Uruguayan nurseries, some of which produce cuttings as both macro and mini, no rooting hormone is applied to mini cuttings prior to sticking. With rooting percentages in the high eighties and low nineties being achieved from mini cuttings grown under this regime, it seems evident that proper stock plant management is negating the need for hormone application and thus another process in the system. At one nursery I have visited in Brazil, rooting hormone was injected via the drip irrigation system into the sand beds 24 h prior to cuttings being taken.

The use of supplementary lighting according to the particular latitude of the nursery as it influences day length is an addition that is still under review at the time of writing. Supplementary lighting may have an effect on cutting production and potential root ability; however there is a high capital and running cost involved. Further work is needed on this concept.

PROPAGATION AND ROOT DEVELOPMENT

Mini cuttings are taken from the stock plants and in our case made at the bench. They are stored in polystyrene containers containing frozen bottles of water and collected regularly by the "sticking" crew. They are then stuck into a seedling tray and placed under intermittent mist. Bottom heat is applied during cooler months.

Callus appears at between 12 to 18 days dependant on the clone and temperature conditions. At 28 days the cuttings are removed from the mist house, put through a transitional greenhouse, and then transferred to the final container.

DIFFERENCES IN ROOT DEVELOPMENT, MACRO VS. MINI

It is quite evident that mini cuttings taken from both *Eucalyptus* species and *Eucalyptus* hybrids and managed under a controlled nutrient regime at high densities per square metre produce a superior root system to those cuttings taken as macros from plants either grown in-ground or in other types of containers but without the benefit of an adequate nutrient programme.

We have also noticed that when partially lignified cuttings are taken from stock plants managed for mini cutting production, root development is inferior to those cuttings taken at the correct time and before lignification commences.

Comparisons of root systems between plants produced from mini cuttings, macro cuttings, and seed show quite clearly, if the seedling is used as the benchmark, that mini cuttings can produce a plant with a root system equal to that of a seedling and superior to that of a macro cutting.

CONCLUSION

The successful vegetative production of *Eucalyptus* species and hybrids is highly dependant on clone selection, stock plant management, timing of harvesting cuttings, and propagation processes.

Strong evidence now suggests that the use of mini gardens to produce mini cuttings, yield propagules superior to other methods of vegetative propagation and eventually plants with superior root systems, at least comparable to that of a seedling.

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Air Pruning Techniques©

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INTRODUCTION

In May 1985 I was Program Chairman of the Australian Region Conference held in Rockhampton, Queensland. One of the papers presented at that conference was prepared by Dr. Greg Moore of the Victorian College of Agriculture and Horticulture, Burnley Campus (now the University of Melbourne, Burnley). This paper, "Getting to the Roots of the Problem," was one of the most thought-provoking I have ever listened to. Greg outlined root development problems in an experimental planting of *Eucalyptus regnans* seedlings established by the Victorian Forest Commission. The seedlings planted in this experimental plot were some of the first forestry seedlings grown in nursery tubes, rather than being produced in outdoor field beds. Eight years after planting, the trees were approaching 20 m tall with a breast-height diameter of up to 35 cm. At this time large numbers of the trees began to fall over, and root system inspections revealed serious root system deformities.

Greg Moore concluded that the root system deformities had occurred as a result of the small, round nursery tubes used in their production and the poor nursery technique involved in the transplanting of the seedlings into the tubes. Here we had, for the first time, a researcher telling the nursery industry that the reasons why root system distortions occur in nursery-produced plants is directly related to the containers used for production and the sloppy techniques used in propagation.

Moore identified two types of root system distortion:

1) **Kinking.** This involves deflection caused to the developing tap root of a seedling due to the use of a very shallow tray for seedling germination. Many forestry organisations now shun pricking out of seedlings in favour of direct planting of seeds into deeper growing tubes to prevent kinking from happening.
2) **Circling.** Roots that come into contact with the side wall of a small, round tube will circle round the exterior of the root ball and eventually the root mass is spiralled inside the tube. Potting up of tubestock with circled roots into larger containers does not solve the problem. It merely hides the problem within a larger mass of potting mix. The 50-mm-round plastic tube that is still widely used in the production of tubestock in Australian nurseries is the greatest culprit of circling of the root system.

This paper outlines the concept of air pruning of the root system of seeds and cutting-propagated plants with the aim of preventing these types of distortions from developing.

A DEFINITION OF AIR PRUNING

Air pruning of tap or lateral roots involves the use of a zone of dry air positioned underneath the growing bench to cause a "shrivelling" or "burning off" of the root tips as they emerge through the base or the sides of the growing container. This pruning effect stimulates lateral root development from further back in the root system. An open-topped propagation bench encourages dry air around the base of the container.

Figure 1. Three examples of containers designed for air pruning.

This is especially the case where a bench heating system is incorporated into the bench. For effective air pruning to occur it is essential that the air underneath the bench is dry. Very moist air will prevent air pruning from occurring.

For successful air pruning of roots to occur we must have an appropriate size and shape of propagation cell and a style of growing bench that allows dry air to accumulate underneath the growing bench.

THE DESIGN OF THE PROPAGATION CONTAINER

Root system distortions that occur at the primary propagation stage will affect the plant for the rest of its life and must be prevented. There are many styles of propagation container that are very suitable for the prevention of root distortions. Some designs are based on an inverted pyramid cell shape, which deflects all roots downwards as they develop on the seedling or cutting and the roots grow out the base into dry air. Other styles of container have raised vertical ribs on the inside of the cell, which also act to deflect roots downwards. Some newer forestry seedling containers have vertical side slits in the walls of the cell, as well as an open base, so that air pruning occurs at the base and around the sides of the cell.

Where single tubes are used as the propagation container they must be unitised into a tray for ease of movement of the tubes. Plastic seed trays with a semi-solid plastic base are unsuitable as the base of the tray will be very moist and air pruning will not occur under these wet conditions.

The Design of the Propagation Bench. To enable air pruning to occur, the top of the bench must be open so that dry air accumulates under the propagation cells. Galvanised weldmesh bench tops are ideal for air pruning as the roots can grow through the base of the cell with no obstruction. Greenhouses with drop down side curtains below the bench tops will allow a good flow of dry air under the bench to assist air pruning.

At University of Queensland (UQ) Gatton Nursery Unit the propagation bench tops are open weldmesh design. At 100 mm below the bench top there is a warm water heating system comprising 12-mm black polyethylene pipes spaced 150 mm apart. The bench heating is designed to maintain 25 °C in the root zone. The warm air generated from the heating pipes optimises effective air pruning.

DEVELOPING A PRODUCTION SYSTEM FOR PROPAGATION OF A CROP

It is necessary for the propagator to develop a system of production that will effectively and efficiently produce a batch of high quality plants. For cutting propagation at UQ Gatton Nursery we propagate most of our cuttings in a 100-cell high-density plastic tray (see Fig. 1). The cell shape is based on an inverted pyramid shape with one single, large drainage hole in the base of the cell. The cell walls deflect emerging roots downwards and out through the drainage hole in the base. The dry air beneath the bench commences the air pruning process. By the time the rooted cuttings are moved up to the next stage of the production system, air pruning has already taken place.

The second stage in the production system is to tube the rooted cuttings into 50-mm square plastic tubes. These tubes have a large semi-open base and a series of internal vertical ribs that deflect roots downwards as they come into contact with the side walls of the tube. The square tubes are held in wire or plastic trays with an open base. They are grown on open weldmesh benches so that air pruning is an integral part of the growing on of the tubestock.

Irrigation Management©

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INTRODUCTION

Since man started production of cropping for food, irrigation and the addition of water to supplement the natural rainfall has endured evolution and innovation in both the harvesting of water and the application of water to the crop.

Water has been taken for granted for many years in that it has always been there and been in abundance, which in turn promoted wasteful techniques in the application of the water.

Water is shaping up to be one of the 21st century's greatest challenges due to climate change, coupled with the increased demand of municipalities, industry, horticulture, and agriculture and the new requirements of environmental flows required to sustain the environment. This is evident in Australia, with initiatives being put in place with the Murray/Darling River system.

We are currently in a cycle being referred to as a 1- in 100-year drought, with below average rainfall being experienced in a large portion of the Australian continent for the last 5 years. As primary producers we are going to be under increasing pressure to ensure that our application techniques and use of water in producing our crops is achieving best practise and undergoing constant continuous improvement. Otherwise we will face the prospect of justifying how we can access water and conduct our business in irrigated cropping.

Under the current water restrictions, which are gripping a large part of Australia, this is also important in demonstrating to the community surrounding our business that we are efficient in managing our water. A large proportion of water being applied on ornamental pot plant production and horticulture is still applied by conventional overhead sprinklers.

APPLICATION TECHNOLOGY

The traditional brass sprinklers look impressive when in operation, but brass is a high wearing compound and if not correctly maintained and managed will soon lose efficiency. Advances in sprinkler technology by the Israelis and the Americans using plastics, which are more resistant to wear than traditional brass sprinklers, has been a major breakthrough in efficient application techniques.

After experiencing 2 years of below-average rainfall and with water storages dropping rapidly, a strategy was developed to better manage this resource as follows:

- Upgrading above-ground spoon drains to capture and direct storm water runoff;
- Developing a linked subsurface drainage system to capture the daily return water from irrigation and direct it to a central pond;
- Trialing of new application technology of overhead sprinklers between the Nelson R 2000 and Namcad sprinklers;
- Looking at more efficient water harvesting.

In changing brass moss sprinklers which, at new, average 10 $L \cdot min^{-1}$ compared to new generation Nelson R 2000 sprinklers operating at 8 $L \cdot min^{-1}$, we were able to achieve a 30% reduction in water being applied to the crops. Other significant side benefits, such as improved crop quality and health, have become more apparent over time. For example, foliage production in *Philodendron* was experiencing bacterial leaf disease in the winter that, on closer observation, was starting directly under the sprinklers and spreading out through the crop.

On following through with catch can tests, as per the Nursery and Garden Industry of Australia Water Works guidelines, it demonstrated that we were literally flooding the crop under the sprinklers due to the nozzle wear, which in turn was the catalyst for the disease commencing. Since changing the sprinklers over to Nelson rotators in 2004 we have not experienced the same disease issue.

The addition of pressure-regulator nondrain valves has also had a major bearing on the efficiency of the system in two main areas. It ensures that the sprinklers operate at the optimum pressure, which in turn means that the droplet spectrum produced by the sprinklers is producing a more even application of water to the crop. It also prevents the draining of the lines at the completion of the irrigation which then needs to be refilled at the commencement of the next irrigation cycle.

At our Orchard Road property, which operates fully with pressure regulators, irrigation shifts were cut back by 5 min, which saved an additional 40,000 L of water per day. Setting pressure valves on all remaining taps/toilet cisterns at the optimum pressure at which the pumping system is designed to operate is another operational efficiency to be gained and will further save running costs.

Irrigation and water management is not just about applying water onto crops—it needs to be approached as a holistic system understanding the process and relationships and creating the correct balance.

It is best summed up in the following:

- Water requirements to promote crop growth;
- Correct water regime to prevent disease;
- Cost relationship of applying water in efficiencies in harvesting and applying water.

Irrigation is a key production process, and cost inputs should promote growth but can easily inhibit growth and financial success.

MEASURING AND MONITORING

There is a direct relationship between energy consumption and harvesting and applying water by pumps. Any efficiency gained in applying water creates a direct saving and cost benefit in reducing energy costs.

In using variable-speed-drive pumps with pressure starts, the pumps are designed to operate like a manual car and ramp up to the water demand, rather than traditional centrifugal pumps, which start and go to full operational pressure. We have found power consumption to be reduced with the initial installation, having a pay back period of 5 years. The gradual ramp up of water supply to match demand has the added benefit of not putting the system under additional pressure, reducing the risk of blowing up mains.

Having the irrigation pumps on pressure starts, as opposed to electric starts linked to open valves, has the added fail-safe in that if a short circuit or a valve fails

to open, the pumps won't still be pumping, which also reduces the risk of blowing up water mains.

In installing pumps, matching the correct pump to the correct duty is important for operational efficiency and lowering operational costs. With the new technology pumps now available it is worthwhile to keep monitoring the performance and running costs of the equipment to understand the process. In an exercise that we completed in 2005 in upgrading a water harvesting pump, it highlighted how important this process was to keep monitoring. The example, the table below shows that the new technology pump is half the kilowatt size and has the ability to pump 20% more water, with a saving of 60% in running costs. The investment in the pump was $1,000 for a saving on running costs of $864 per annum.

Table 1. Orchard Road water-harvesting pumping upgrade April 2005.

Pump Size	Pumping capacity ($L \cdot h^{-1}$)	Aver. daily run time to harvest (150,000 $L \cdot h^{-1}$)	Electricity cost/day ($0–12 kwh)	Power consumption per annum based on ave. pumping (240 days/yr)	Estimated power saving per annum
4.0 kw	12,000	12.5	$6.00	$1,440	
2.2 kw	15,000	10	$2.40	$576	60%
					$864

GROWING MEDIA

The advances in growing media with composted barks have improved aeration in growing media along with readily available water for potted plants. The addition of wetting agents to assist in the rewetting of growing media assists in better utilising irrigation water.

Copra or coir peat is a useful product as an additive to growing media at up to 10% of volume. Coir fibre has a unique wicking ability with readily available water for the crop as well as good air-filled porosity. In trials conducted with potted product we have been able to achieve up to 10 days before wilting with flowering potted azaleas as opposed to 4 days prior to this.

On foliage production of *Philodendron* under 50% shade cloth in the winter of 2006, with the addition of coir fibre to the growing medium we were able to further reduce irrigation by 30%. This was a direct water saving, increased crop quality, and reduced foliar fungal or bacterial disease — all major benefits.

Coir fibre is a renewable resource; therefore it is also environmentally friendly. It is important, however, to monitor the coir fibre for salt contamination depending on where the it is sourced from.

THE FUTURE

The next stage of advanced technology, the development of field data stations, is exciting. These units will have the ability to measure the growing media moisture in the container and EC levels. Coupled to a weather station monitoring rainfall, solar radiation, temperature, and wind speed the information is then transmitted via GPRS (mobile phone chip) back to a dedicated web site where the information

is collated and interpreted via interactive soft ware to then graphically represent what the real-time demand of the crop is at that point of time.

Advanced technology has been used in the intensive greenhouse industry in Europe for many years. This technology will give the ability for broad acre container production to use science to better manage irrigation cycling and, lower running costs and nutrient leaching.

This will produce a better crop that is not stressed, by either too much or not enough water, but importantly prevent a lot of potential disease issues, use less water, and reduce nutrient leaching from containers.

Triple bottom line and environmentally sustainable production is the way of the future in achieving better profitability, better outcomes for the environment and the community, and ultimately producing a better crop.

Propagation of *Chamelaucium uncinatum* Cultivars by Grafting©

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INTRODUCTION

Geraldton waxflower is one of the most spectacular wildflowers of Western Australia. Flowering occurs during the early spring wildflower season. The native flower and nursery industries have selected a range of superior colours and forms, and these have been introduced to the flower and nursery industries across Australia. The mass flowering effect creates a large, spontaneous demand from the flower- and plant-buying public.

The University of Queensland Plant Nursery Unit has propagation licences in place with the breeders in Western Australia, and these licences enable us to supply plants to flower growers and nurseries across Australia.

WHY GRAFT GERALDTON WAXFLOWER?

The native soil profile of Western Australia is a very deep, sandy soil with free-draining properties. The soils of south Queensland are predominantly heavy clay with relatively poor drainage. The high summer humidity and rainfall in south Queensland contribute to the soil-borne fungal problems frequently experienced here. *Phytophthora cinnamomi* is the major killer of Geraldton waxflower. The University of Queensland has assessed the disease resistance of a number of selected forms of waxflower as rootstocks, and a selection code named B4C4 is the rootstock principally used for grafting the phytophthora-sensitive selection on to.

PRODUCTION OF THE ROOTSTOCKS

- The cutting material for our B4C4 rootstocks is collected in July during the plant's most dormant stage of growth. The cutting material responds quickly once placed in propagation.
- The soft shoot tips are collected with sharp secateurs and placed in a Styrofoam box. The cuttings are moistened in the box, and an ice pack is placed in the box.
- The shoot tips are placed in chlorinated water for 1 min to eliminate any surface pathogen problems.
- The cuttings are prepared by selecting the tips that are semi-hardened and cut to 8 cm in length; the leaves are stripped from the bottom 4 cm of the stems.
- The cuttings are dipped in a 4000 $mg \cdot L^{-1}$ IBA solution for 5 sec.
- The cuttings are stuck in a propagation medium comprising: Canadian peat moss, vermiculite, and perlite (3 : 3 : 4, by volume) plus 2 $g \cdot L^{-1}$ mini Osmocote.
- 100-cell plastic trays with root trainers are used for high quality root development.

- The trays of cuttings are placed on open weldmesh benches in our fog propagation house.
- The propagation house has warm-water basal heating of 25 °C; 90%–95% humidity is maintained by the fogging system.
- The cutting trays are hand-watered as required.
- A strict fungicidal spray program is carried out weekly with a rotation of five different fungicides applied as a preventative spray.
- After 8 weeks an average 90% strike rate can be expected. The struck cuttings are then tubed into 50 × 50 × 100-mm native tubes.
- The native tubes have internal root trainers for optimum root quality.
- The trays of tubed rootstocks are placed on benches in a growing-on greenhouse with 30% shading on open weldmesh benches to be grown on for a further 8 weeks. They are hand-watered every day. The tubestock continues to be given the same fungicide spray program as the cuttings under propagation.
- This brings us to September, and the rootstocks are ready for grafting. The stem of the rootstocks should be 2 mm of more in diameter.

THE GRAFTING PROCESS

- The scion material should be collected fresh on the day chosen for grafting.
- The scion material should be healthy and in a semi-hardened condition.
- One grafter can achieve an output of 250 grafted plants in a 7-h working day comfortably.
- Once the scion material has been dipped in a chlorine solution for 1 min, the moist material should be placed in a Styrofoam box with an ice pack until used.
- A sharp grafting knife, Parafilm™ tape, a water spray bottle, and small cutters are required for grafting.
- Parafilm is the preferred tape used because of its stretching qualities as it binds on itself, eliminating the need for knots.
- All of our grafting work is carried out in an air-conditioned room to eliminate wilting of the scion material and for operator comfort.
- Selecting a strong, straight-stemmed rootstock ensures that a strong graft union will develop.
- The top of the rootstock is removed approximately 12 cm up the stem to eliminate the apical dominance of the rootstock. This will ensure that the growth of the scion shoot is promoted.
- A side splice graft is used to fasten the scion of the side of the rootstock stem.
- A 3-cm slice of bark is removed vertically from the stem of the rootstock, exposing the cambium layer. The rootstock is now ready for the scion to be attached.

- A healthy shoot tip of the scion material is selected, and a corresponding cut is made in the basal side of the stem to expose the cambium layer. The tip of the scion shoot is removed to overcome apical dominance and the basal portion of the stem has the leaves removed.
- The scion material is positioned on the side of the rootstock, and the Parafilm tape is used to bind the two together, ensuring that no moisture can penetrate into the graft union.
- During the grafting process the grafted rootstocks are kept moist with the spray bottle. When a tray of grafted plants is full it is placed in the same fog propagation house in which the cuttings were rooted. Hand-watering is done as needed.
- A period of 2 weeks is needed for the graft union to form, and then the top of the rootstock can be removed to stimulate scion shoot growth.
- After cutting back of the rootstocks, the grafted plants are held under fog for a further 2 weeks. They can then be moved into another greenhouse with a lower humidity and higher light level to grow on.
- By November there should be vigorous growth of the scion shoots, and the scion shoots are tip pruned to promote a bushy habit. Any regrowth shoots from the base of the rootstocks should be removed
- Eight weeks of growing on in the greenhouse will bring the grafted tubestock to a saleable size. The grafted plants are then moved outside into full sun for at least 2 weeks before sale. Nursery customers are supplied with plants in February, and cut flower growers are supplied in April.

Environmental Factors Affecting Plant Tissue Cultures©

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INTRODUCTION

Environmental factors have many effects on plant growth and development. Indeed, plant propagators often take great care in managing the nursery environment to optimise plant propagation and growth. The environment includes physical or chemical (abiotic) and biotic components. In the nursery the biotic factors include not only insects and microorganisms but also other plants, including weeds. What may be less obvious in the nursery is that plants in turn may affect their environment. This interaction between the plant and its environment is the scientific discipline of "ecology." The main message of this paper is that plants growing in plant tissue culture (or in vitro) are also subject to these same interactions, hence the research field of "in vitro ecology." In this short paper I am going to focus on two aspects of the culture environment, light and gas exchange (ventilation).

Light can be described and measured by several characteristics, each having various effects on plants: quantity (intensity × duration), photoperiod (light-dark cycles), quality (colour or wavelength), and direction. Each of these parameters of light are associated with particular aspects of plant growth and development.

PHOTOSYNTHESIS AND PHOTOAUTOTROPHY

The best known effect of light is as an energy source for plant growth via photosynthesis. Light of particular wavelengths is absorbed by the pigment chlorophyll to convert carbon dioxide and water to carbohydrate. The importance of photosynthesis for plants in vitro has gone full circle from the early assumption that it was insignificant and unnecessary, because sugar is provided in the media, to current recognition that it is not only possible but can provide substantial benefits, under the right conditions. Photoautotrophy, the ability of cultures to obtain their sugar (carbohydrate and energy) through photosynthesis, has been demonstrated for many species and is routinely practiced in micropropagation laboratories. It requires a reduction or removal of sugar in the medium, higher light intensity, and aeration (venting) of the containers to enable gas exchange, particularly the supply of carbon dioxide. When used during the final culture cycles, the reduced humidity inside the container has the additional advantage of hardening the plants ready for deflasking. This aspect of light in vitro has been well covered at previous I.P.P.S. meetings, e.g., the article by Chieri Kubota (Kubota, 2002).

Photosynthesis is dependent on the total input of light within the photosynthetically active radiation (PAR) range. This is a function of the light intensity and duration of exposure of the cultures and is best described by the term PPFD (photosynthetic photon flux density) — a measure of the total number of photons (units of light energy) supplied to the plants. In practice it depends on the output of the light source, the distance from the plant surface, and the material of the culture vessel. The PPFD required for efficient photosynthesis is higher than that usually supplied in growth rooms (Table 1).

Table 1. Typical light intensities.

Light source	µmol·m^{-2}s^{-1}
White fluorescent tube	10–50
Compensation point	20
Autotrophic cultures	65–250
Glasshouse	100–1500
Sunlight	>2000

PHOTOPERIOD

Photoperiod, the relative duration of the daily periods of light and dark, is a well established phenomenon in the control of plant growth. It is particularly known for its effects on control of flowering but may also influence vegetative growth cycles and the occurrence of dormancy. A related but distinct effect is that the total duration of light also affects the cumulative light input for photosynthesis.

LIGHT QUALITY

The term "light quality" refers to its colour or the range of wavelengths. Light, or more correctly radiant energy, occurs across a wide spectrum of wavelength only part of which is visible to humans (Fig. 1). Plants respond to light because particular pigments in the cells absorb light at certain wavelengths. White light includes the radiation across the visible spectrum but may be accompanied by invisible wavelengths, including infra red and ultra violet (UV). Radiation in the invisible bands contributes to the heat load and particular wavelengths may also be toxic to plants.

There is considerable interest in the use of various shade cloths and screening materials to modify the light input to plants in the nursery and even in the field. The type of light source and the light transmission characteristics of culture containers affect the quality of the light reaching plants in vitro (Fig.1). Modifying the spectral composition can alter the growth rate or morphology of the plant. It can promote or inhibit flowering. The actual response varies widely between plant species. Some general responses are listed in Table 2, but there are many exceptions with individual plant species.

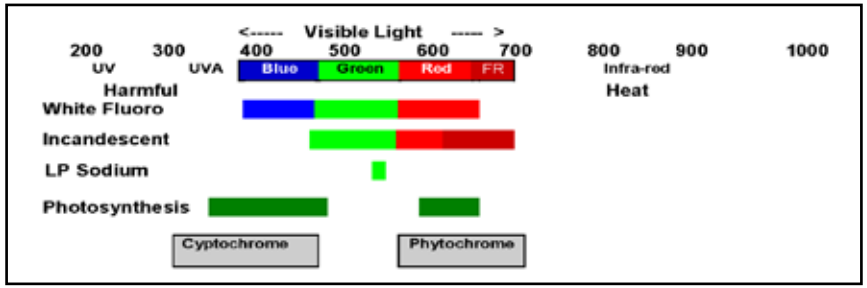

Figure 1. The radiant energy spectrum with bands of light that affect plant growth.

Table 2. General responses of plants to light quality.

Red + blue	Increased net photosynthesis
Blue or blue + far red	Reduced photosynthesis
Red or red + far red	Increased stem length by internode elongation not leaf number
Blue or blue + far red	Reduced internode elongation
Red + Far red	Reduced leaf area

Growth responses to light (photomorphogenesis) are mostly regulated by the relative supply of light in the blue, red, and far-red bands of the spectrum. Note that fluorescent lights lack light in the red-far red range and therefore an additional light source (incandescent globe) is required for photomorphogenic responses. Photomorphogenesis is regulated via specilised chemicals that are activated or de-activated by specific wavelengths of light. Only small quantities of light are required.

The spectrum of light can be manipulated using assorted filters or screening materials; however a more precise method is now becoming economic for small-scale purposes, such as in tissue culture growth rooms, using light emitting diodes (LEDs). These solid-state electronic devices produce light in very specific wavelengths. They have the added advantage of a low energy requirement and conversely produce very little heat but because the light output is small, large numbers may be needed to get adequate coverage.

Research recently published on chrysanthemum (Kim et al., 2003) illustrates the type of responses to light quality using LEDs (Fig. 2). The shoots are elongated and leaf size is reduced under red or blue light but growth is more normal under blue + red. Note also the differences in root growth. With strawberry 70% red + 30% blue gave the best dry weight and increased leaf number (i.e., internode number) whereas 100% red gave the longest internodes (Nhut et al., 2003). The principle here is that the shape of the plant can be manipulated by varying the mixture of red and blue in the light source.

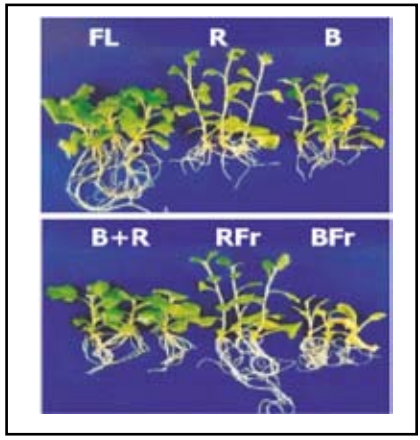

Figure 2. Light quality affects *Chrysanthemum* plantlet form.

FL=fluorescent; B=blue; R=Red; FR=FarRed light. From Kim et al. (2003).

Overall plant growth is dependent on the supply of carbohydrate and energy. Perhaps more importantly, the survival of plants during that critical period following deflasking is dependent on the supply of carbohydrate stored in the plant tissues. Traditionally this has been supplied to in vitro plants as sugar in the medium but, as discussed above, autotrophy is possible under the right conditions. However, the quality of light can also affect net photosyn-

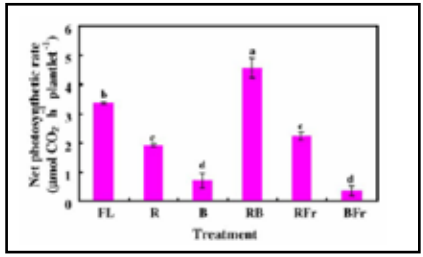

Figure 3. Effect of light quality on photosynthesis in chrysanthemum cultures. From Kim et al. (2003).

thesis. In particular, exposure to red + blue increased photosynthesis of chrysanthemum plantlets in culture (Fig. 3) and more importantly, these plants still had 30% more dry weight 45 days after planting out.

VENTILATION

Tissue culture containers are traditionally sealed to exclude microorganisms and to conserve moisture, but we need to reconsider. Firstly, as mentioned above, one factor limiting photosynthesis in vitro is gas exchange to maintain the carbon dioxide levels in the headspace of the container, e.g., with grapevine cultures (Shim et al., 2003) (Fig. 4). The conundrum is that increasing ventilation of culture vessels increases water loss. Secondly, it has been amply demonstrated that reducing the humidity in the culture vessel in the culture cycle before deflasking helps to harden the transplants against water stress. How do we manage this conundrum?

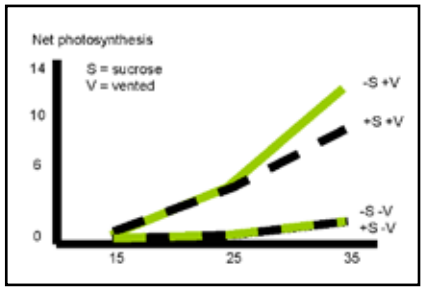

Figure 4. Ventilation effects on grapevine shoot cultures. From Shim et al. (2003).

Fortuitously, for autotrophic culture we can (need to) delete sugar from the medium. This alone greatly reduces the risk of microbial contamination. The balance between gas exchange and conservation of water can be maintained by the use of semi-permeable enclosures that allow gas exchange but limit water loss. There are various films and membrane vents that allow good gas transfer but little water. There are custom-made culture vessels incorporating this technology. In practice, small changes in the sealing of culture containers can have a significant effect. Often just leaving the lids slightly loose is sufficient.

Note also that the extent of ventilation can also have marked effects on the growth pattern of the plantlets, e.g., with *Annona* (Zobayed et al., 2002) (Table 3).

Table 3. Ventilation effects on *Annona* cultures.

	Sealed	Natural	Forced	N + F*
Days to initiation	6.0	8.5	13.5	
No. shoot + buds	0	48.7	25.5	39.2
Shoot length (mm)	-	5.0	17.0	12.0
No. nodes	-	1.1	3.0	1.6
Leaf area/shoot	-	0.5	2.0	1.2

*N-2 weeks then F-5 weeks

From Zobayed et al., 2003.

THE MESSAGE

I have only briefly covered selected aspects of "in vitro ecology" and the implications for plant tissue culture practice. An important practical message here is that often subtle differences in technique of handling the cultures can make a difference to the performance of the plants. Often these differences go unnoticed, but they may well explain some of the variability laboratories and nurseries experience between batches of plants.

The quality (and intensity) of light can change as the light source ages. Stray light from a window or the glow from a nearby warning light (that new exit sign above the door!) may be sufficient. What about the paint on the culture room walls? This could affect the quality of reflected light. Changes in the composition or colour of containers or lids affect the light transmitted into the plants as well as the pattern of gas exchange.

The tissue culture environment is complex and dynamic and has marked effects on plant growth both during culture and after planting out. Different plant species also respond differently. We still have much to learn but we can start by being aware of the possibilities.

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In-Slab Bench Heating Improves Propagation Hygiene and Cuts Maintenance Costs©

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INTRODUCTION

The Australian National Botanic Gardens (ANBG) is dedicated to growing, studying, and promoting Australian plants. It currently holds around 6,500 species of Australian plants, many of which are new to horticulture.

In June 2004, a new production nursery was opened. Major features of this modern facility include: twin-skin polytunnels, a computerized Building Management System (BMS), and "in slab" bench top heating.

The twin-skin polytunnels provide maximum light throughout the year and insulation for additional warmth in the cooler months to optimize growing conditions. The BMS computer controls and monitors the irrigation and ventilation within the polytunnels and growing areas.

"In-slab" heating bench tops are used to provide bottom heat to maximise root growth throughout the propagation and young plant development phases. These bench tops have been constructed to replace "in-sand" benches and heated cold frames in the old nursery. In this case, electric heating cables have been installed in concrete slabs 3 m long, 900 mm wide, and 75 mm thick and placed on prefabricated steel benches. The use of electric cables to heat buildings has been around for a long time, but using them in this way in a nursery may well be a first.

From a production point of view, the combination of these three features has significantly improved the growth of the plants.

From a propagation point of view, the use of in-slab bench top heating has solved most of the hygiene problems associated with the in-sand bench heating in the old nursery.

BACKGROUND

The ANBG nursery grows between 10,000 and 15,000 plants each year, and all these plants are used in new gardens or as replacements. The ANBG nursery differs from most commercial nurseries in that:

- Many of the plants are "new" to horticulture, and striking them may require a range of different treatments and/or methods.
- The number of plants required is often between 1 and 20 as opposed to 100s, if not 1000s, in commercial nurseries.
- Most of the plants grown in the nursery are propagated by cuttings or grafts from mother plants where the provenance is known and documented and the propagation history recorded.

COMMENTS ON HYGIENE

Staff at the ANBG nursery has a philosophy of getting the basics right to begin with, and this starts with nursery hygiene. Good hygiene practised throughout the propagation cycle results in higher strike rates for cuttings with more healthy roots and concomitantly stronger plants.

The majority of hygiene practices at the ANBG nursery have not changed with the move to the new nursery. These are:

- Pots are washed and steam sterilized, and all propagation and potting mixes are pasteurised.
- All pots and materials are transported on trolleys, and there is no contact with the ground in any part of the process.
- All hoses are stored off the ground.
- There is regular maintenance in propagation tunnels, i.e., removal of dead leaves and cuttings.
- All growing mixes are formulated to encourage healthy plants with a good balance between air-filled porosity and water-holding capacity.
- Cuttings are placed in 100-mm square punnets with uniform spacing to allow adequate air movement.

However, despite these practices there were major problems with the maintenance of the in-sand heating benches. To get an idea of the significance of the in-slab bench tops it is necessary to discuss the propagation conditions in the old nursery and compare them with those in the new production nursery.

COMPARISONS

Old Nursery.

Propagation Structure.

- Glasshouse.
- Light control—partially removable 70% shade cloth.
- Southern end non-ventilated set up for fog propagation—cuttings and grafts.

Hot Beds.

- 3×10 m^2 bench tops.
- Heat supplied by electric heating cables in 100 mm of washed river sand.
- Weight unknown.

Temperature Control.

A single thermostat was placed in the corner of each bed and was set for 23 °C.

- Tests using data loggers revealed that the system was unable to supply the required temperature especially at night in winter.
- Removal of 50 mm of the sand improved the heat transfer, but the system still could not consistently deliver the required temperature.

Irrigation/Humidity.

For propagating cuttings and grafts:

- "Dann" foggers were used to maintain humidity and were controlled by a "Jefferies" mist controller with light sensor.
- Using fog as the source of humidity means that the sand in the hotbeds dried out quickly, resulting in uneven heat distribution and the media in the cutting punnets drying from below. To counter this all benches were watered daily.

Hygiene/Pests and Diseases.
The control and elimination of pests and diseases in the propagation phase was a time-consuming factor in the old nursery. Some comments:

- Uneven distribution of the fog caused wet spots and dry spots, and these areas could not be used.
- Moss and liverwort quickly became established in the wet spots, and the spores began to germinate in any punnets where cuttings were slow to root. Moss and liverwort are also a haven and food source for slugs and fungus gnats.
- Fungal diseases like botrytis were difficult to control.
- Cleaning up media spills on the sand was difficult.
- A sheet of Marix weed mat was placed on the benches, but it also became infested with moss and liverwort.
- Ants also invaded the sand beds, making nests and then farming/spreading insects like scale and mealy bugs.

Safety.
With electric wires in sand there is always a risk that they may be damaged.

New Nursery.

Propagation Structures.
Twin-skin polytunnels are used to provide optimum growing conditions with maximum light. There are seven tunnels, each contains five benches with concrete in-slab bench tops.

Environmental Controls.

- Humidity is supplied with Dann foggers controlled by a combination of the BMS and balance arms.
- Light is moderated by the use 70% shade cloth and whitewashing in summer.
- The BMS also controls the temperature via evaporative coolers and opening roof vents.

Benches.
The benches used throughout the nursery are made from prefabricated galvanised steel. They range in height from 900 mm–950 mm.

In-Slab Concrete Bench Tops.
In this case each bench top:

- Is 3 m long × 900 mm wide × 75 mm thick.
- Can supply heat in a range from 0–30 °C.
- Weighs 640 kg.
- Has been treated with cream-coloured epoxy paint.

Testing and Performance.
Testing with data loggers in punnets of cutting mix on these benches indicated that the heat transfer over a 24-h period is consistent with little drop of temperature during the night.

Bench-Top Hygiene.

Each bench:

- Is sloped towards the drainage line on the floor, and all surface water runs away freely.
- Has improved drainage, and with the elimination of sand there is no moss or liverwort and nowhere for slugs to hide.
- Is easily cleaned, and any spills can be easily swept up. When a bench has been cleared of punnets, it is sprayed with sodium hypochlorite and lightly scrubbed and then washed down. It is then ready for re-use.
- Can be isolated to minimise the risk of contamination.

Additional Maintenance.

Because there is still a risk that the cuttings may dry out, all the benches are still watered daily, and some of this water is trapped under each punnet.

Safety.

Having the electric heating cables fully enclosed in concrete means that there is no risk of their being punctured.

CONCLUSIONS

- In-slab bench tops are easy to keep clean and are virtually maintenance-free.
- No fungicides or pesticides have been used in the propagation tunnels in the new nursery.
- Bench space is able to be used more efficiently.
- Staff has more time to concentrate on other facets of the production process.
- Benches tops can be used for experimental purposes to establish optimum temperature for root development.

Tapping Our Biodiversity: The Future of Native Plants in Horticulture in Queensland©

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INTRODUCTION

Because Australian native plants originate from the Australian bush, they are inextricably tied to the Australian landscape, and so the growing of Australian native plants has always been about not only propagating and growing Australian plants in gardens, but also about getting out into the bush collecting propagating material and understanding the plants in their natural habitats.

Historically the plants most extensively collected, studied, and grown in gardens and landscapes have tended to focus on eight main genera in the "big 3" Australian plant families: Mimosaceae (acacias), Proteaceae (grevilleas, banksias, and hakeas), and Myrtaceae (callistemons, melaleucas, leptospermums, and eucalypts). This is no doubt because these are the genera and families that, more than any others, put that particular Australian stamp on the Australian landscape and that most Australians identify with typifying all things Australian. So, if you want to create a garden that looks Australian and that reminds you of the bush, these are the obvious genera to use.

By the end of the 1970s the native flora surrounding the major cities and regional centres (which are located in the southern part of the continent) was pretty well explored, and to a large extent most of the species had been tried and tested in cultivation, while the much more sparsely populated tropics remained largely unexplored botanically. Only a handful of north Queensland rainforest plants, such as *Buckinghamia celsissima* (the ivory curl) and *Syzygium luehmannii* (small-leafed lilly-pilly), had entered cultivation.

So during the 1980s and 1990s the focus finally shifted further afield into the more remote regions of the continent. Thus began a very exciting era for native plants in Queensland — the exploration of the north Queensland Wet Tropics rainforests and the wilderness of Cape York Peninsula — and what a wonderland of new and exciting species was revealed.

THE PRESENT

By the year 2000 over 1,000 new tropical Australian native species had been introduced into cultivation by my nursery (Yuruga), and native plant lovers were starting to get their tongues around seemingly unpronounceable names like *Syzygium, Geissois, Opisthiolepis*, and *Blepharocarya*. What a long way from acacias, banksias, callistemons, and eucalypts!

Certainly in my part of Australia (that is, north Queensland), there is a tremendous underlying feeling for the habitat and landscape from which the natives grown in gardens originate. People grow native plants for the multitude of benefits they bring: not only for the beauty of the plants themselves and their magnificent flowers, foliage, and fruit; but also for the birds, butterflies, and other wildlife they attract and harbour. People grow natives because they care about the environment.

As well as their role in gardens, landscapes and revegetation, there is also an emerging and very important role for tropical Australian native plants in other areas such as the cut flower and foliage industry, bush foods, and timber production.

BREEDING AND SELECTION

In the global forestry industry, eucalypts are a very important timber. In Australia, eucalypts have traditionally been harvested from native forests, but this is now recognised as unsustainable and is no longer palatable to the Australian public, and the industry is rapidly moving to plantation establishment. Selection and breeding of superior trees to enable increased yield from the existing plantation estate is already occurring, and plantations of elite clones of eucalypt hybrids are already established. Clonal forestry is the way of the future.

The bush food industry is rapidly developing, and it is well recognised that plantation establishment, as opposed to wild harvest, is essential for a viable, sustainable, and profitable industry, especially since for some species tonnes of fruit are harvested annually. Hand in hand with plantation establishment comes the selection of superior individuals for clonal propagation and plantation improvement.

Similarly, there is a growing cut foliage industry based on some of our stunning native foliage, but the quantities currently harvested from the wild are in the hundreds of tonnes annually in southeast Queensland alone, and so there is increasing pressure for plantation establishment and the development of improved selections in response to market pressure. The beautiful new foliage selections *Stenocarpus* 'Forest Lace' and 'Forest Gem' are stand-out examples of the role of breeding and selection in our native flora.

ACCESS TO SEED

It is easy to forget that the huge range of native plants so readily available today is totally dependent on the access we have enjoyed to the bush in the past for our source of seed and propagating material. Such access is essential since it not only results in native plants being available for gardens, landscapes, revegetation, etc., but also has the additional benefits of accumulating vast amounts of knowledge about our native flora and its habitats and distribution patterns, maintaining the genetic vigour of our cultivated plants, and allowing that essential connection between the land and the plants, the habitat and the landscape. The conservation outcomes from access to the wild are immense.

Unfortunately, with expanding cities and agriculture, the pressure on our bush has never been greater. The response in recent years has been to declare more and more National Parks in an endeavour to protect what remains, and this is desirable and admirable. However, there is a down-side that urgently needs to be acknowledged, discussed, and addressed.

THE IMPACT OF LEGISLATION

Current legislation in Queensland restricts access to and prevents the removal of anything from National Parks, and that includes seeds and cuttings even though the quantities required for propagation are small and invariably inconsequential to the conservation status of the species being collected. In addition, the collection of any propagating material from the wild in Queensland (outside of National Parks) is currently so grossly over-regulated that there is very little collection from the

wild any more at all. To put this in context, for my nursery (Yuruga Nursery) to collect propagating material from the wild, I am currently required to have five (yes, five!) permits. The compliance costs in terms of money, time, and effort are enormous. From both an Australian and a global perspective, this ranks with some of the most restrictive management legislation in the world. Needless to say, most commercial operators, when faced with this absurd degree of bureaucratic red tape, take the easy way out and grow exotics instead, and that is exactly what has been happening in Queensland over the last 12 years or so. The quantity and range of native plants now offered for sale in commercial nurseries across Queensland has declined dramatically, with enormous implications for conservation.

In my part of the world, we are surrounded by wonderful National Parks, State Forests, and World Heritage rainforests. Landholders in the region need to plant gardens, windbreaks and screens, and they need to stabilise creek banks, plant shade trees for cattle, and create corridors for wildlife. It is crucial that they can readily obtain suitable native plants so that the genetic integrity of the surrounding native forests is not inadvertently placed at risk by seedling recruitment from, or cross-breeding with, nearby plantings.

This means that it is essential that local forests be accessible for the collection of propagating material. For instance, the flame tree, *Brachychiton acerifolius*, occurs over a huge geographical range right down the east cost of Australia, and obviously there are genetic differences between populations over such an extensive range. It is therefore very important that trees planted in north Queensland are grown from seed obtained in the region and not from seed of southern stock or from assorted garden collections of unknown origin. However, without access to local forests for seed collection, this is exactly what will happen. Or even worse, nurseries will take the easy way out and sell exotic substitutes such as the African tulip tree with its enormous potential to invade the precious forests.

WEEDS

This brings me to weeds. If landholders cannot obtain native plants, they will plant exotics instead if that is all that is available. The threat to our forests from exotic species becoming weeds is extremely serious, and once a plant has become a weed it is too late.

It is now widely accepted that a large proportion of our serious weeds in Australia are garden escapes, i.e., exotic plants that have been introduced into the country for their ornamental value. While quantity of seed produced and method of seed dispersal are useful indicators of potential weediness, as are hardiness and speed of growth, the weed potential of a plant is not always all that easy to evaluate in advance, since it may take years of natural selection over multiple generations before a plant suddenly is able to escape and create havoc on the environment. Thus a serious side-effect of the current Queensland legislation is that there is likely to be a huge weed problem in the future as a result of the current decline in native plants sold in nurseries and the increase in numbers and variety of exotics.

GENETIC VIGOUR AND IN-BREEDING

But why is it so important to have continuing access to native forests for seed when there are so many plants in cultivation from which seed could readily (and more easily) be harvested? The answer lies in an understanding of genetic diversity and vigour and of inbreeding, and the ivory curl (*B. celsissima*) is a text-book example.

Buckinghamia celsissima has been in cultivation for decades. It was one of the earliest collections from north Queensland's rainforests, and it is grown extensively in gardens and landscapes virtually right around Australia. It can be propagated from cuttings, but it flowers and seeds prolifically and so most propagation is by seed, which germinates readily. And therein lies the problem. All the hundreds of thousands of plants in cultivation around Australia can be traced back to the original couple of wild collections, and with no further wild collections to re-invigorate the genetic base, the cultivated plants have become more and more inbred over the years. The deterioration in the vigour of cultivated plants has become a serious issue. At Yuruga Nursery, on the other hand, we collect our propagating material from the wild, and of course we collect *B. celsissima* as well. The vigour, colour, and general appearance of our wild-sourced plants compared to cultivated material is so stunning and remarkable that for quite a while many people were convinced that Yuruga's plants were actually a different species!

In our work at Yuruga we have noticed the effects of inbreeding and genetic decline on many occasions and across a wide range of species. The valuable cabinet timber species Queensland maple *Flindersia brayleyana*, for instance, is another text-book example where inbreeding in isolated seed-trees is resulting in a rapidly decreasing germination rate and an alarming increase in deformities in germinants. This species is an important commercial timber, so maintaining genetic vigour is essential not only for broader environmental reasons as discussed above, but for the health and prosperity of emerging industries as well.

Because the effects of inbreeding often develop slowly or over many generations, it is easy not to notice or recognise that it is happening. But happen it does, and this is why continuing access to wild seed from native forests is so important, to keep our cultivated populations re-invigorated and genetically healthy. Maybe it does not matter so much if we were only growing the plants as street trees in the city centre, but it is significant when the plants are being used in broader landscapes across our countryside, and especially in sensitive locations adjoining, abutting, buffering, and extending our precious native forest estate.

CONCLUSION

The future of native plants in horticulture in Queensland will be bleak indeed unless the current legislation, which so severely, and unnecessarily, restricts access to propagating material in the wild, is substantially revised.

The Effects of Mulch on Soil Temperatures for Field Growing Conditions©

Ian S. Tolley
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THE ORIGINAL CHART

Figure 1 was photographed by Ian Tolley at the University of Florida, Lake Alfred Research Station, U.S.A., during his Churchill Fellowship in 1966.

It was an old record stuck high up on an office wall, and current researchers, at that time, were unable to provide the author's name.

Other Data Sources

- At this time I am unaware of any current trial evidence of this nature.
- The unknown researcher used commonly available cotton trash (mulch).

Relevance of the Charts

- I thought this information was particularly important to tree crop production in hot, dry climates.
- Technology to accurately convert the information (distorted by a parallax error) was not available at that time.
- Thirty-nine years later, I still felt the information was useful to enhance support for mulching, as a permanent tool towards sustainable soil management.

The Converted Charts

- Each chart has five integrated, scaled segments.
- For clarity three charts, each of five graphs have been produced to include the following: U.S.A. (Northern Hemisphere) summer months (in Fahrenheit and in Centigrade) for June, July, August, September, and October (Figs. 2 and 3). Conversion to Australian (Southern Hemisphere) summer equivalents (in Celsius) for December, January, February, March, and April (Fig. 4).

Each chart in the figures demonstrates the following:
The top chart shows:

- Summer maximum / mean air temperatures at the time of trial.

The other four charts are constructed to:

- Show data for different soil depths.
- Show temperatures for three soil surface conditions.
- Black plastic sheeting (top line).
- Bare soil (centre line).
- Mulch – cotton [gin] trash (bottom line).

Sources of Mulch

- Import mulch materials to field.
- Permanent cover crops that can be mulched in situ.

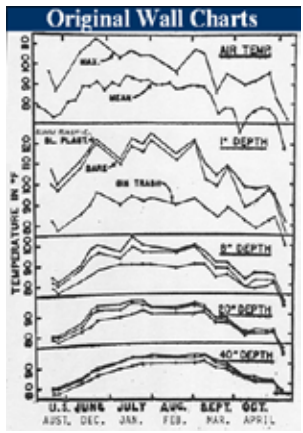

Figure 1. Original graph of effects of mulch on soil temperatures for field growing conditions.

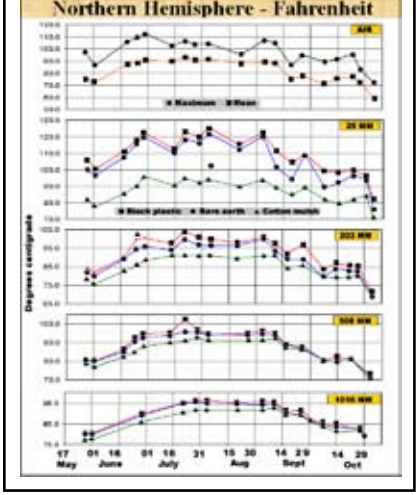

Figure 2. U.S.A. (Northern Hemisphere) summer months (in Fahrenheit) for June, July, August, September, and October.

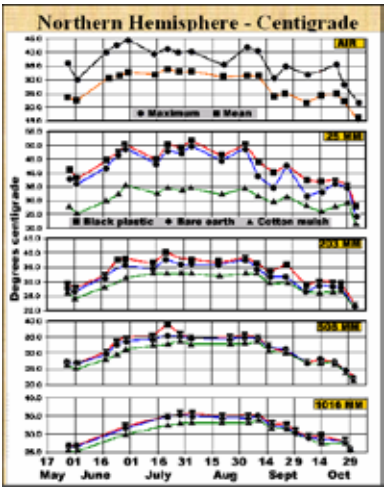

Figure 3. U.S.A. (Northern Hemisphere) summer months (in Centigrade) for June, July, August, September, and October.

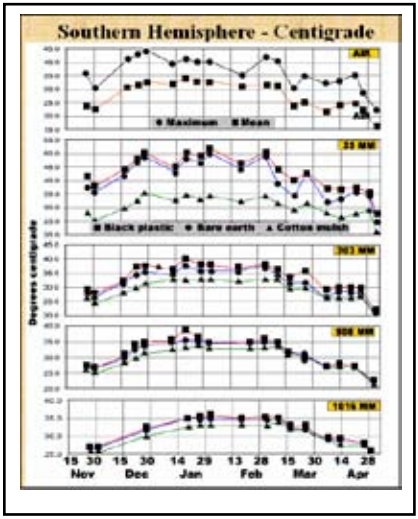

Figure 4. Conversion to Australian (Southern Hemisphere) summer equivalents (in Celsius) for December, January, February, March, and April.

Permanent Mulch

Mulch can also be regularly thrown under the tree crop canopy by offset slashers, for benefits of

- Further soil protection.
- Enhancement of carbon /nitrogen ratios.
- Improved shallow root growth and fertilizer uptake.
- Reduction of insect pressure on tree crop.

Soil temperatures at a depth of 25 mm.

Results: As much as a 15 °C reduction under mulch.

Requirement: Optimum root-zone soil temperatures should be between 20 °C and 27 °C.

The Individual Charts for Northern Hemisphere (Centigrade)

CHART 1: Maximum / mean air temperatures
CHART 2: Soil temperatures at 25 mm depth.
CHART 3: Soil temperatures at 203 mm depth.
CHART 4: Soil temperatures at 508 mm depth.
CHART 5: Soil temperatures at 1016 mm depth.

The Shady Side of Fern Propagation©

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PROPAGATION METHODS

All ferns at our nursery are propagated by either vegetative material or spore. In the case of the vegetative material we do a range of material depending on the species. Some are from pieces of rhizome; some bulbils are removed and direct stuck; and some are from bulbils along the rachis and we layer these fronds onto mix. These bulbils over time will root into the mix and can then be picked off and plugged out. Of the approximately 40–60 fern species we grow, approximately five would be vegetatively propagated. Vegetative propagation is relatively simple, but in the case of some species, we have found that better plants are obtained through spore propagation.

SPORE COLLECTION AND PROPAGATION

Over the last 12 years or so, the main focus of Fern Factor has been to develop techniques and procedures to propagate ferns by spore. This starts with the collection of the spore. There are over 10,000 spores per gram, so we are dealing with a dust-like material. Every sporangia case (that's the spots on the back of the fronds) has 64 spore in it, so you can see with a healthy fern there is no shortage of spore. Right from the start cleanliness is paramount.

Collecting. Our spore collection season generally starts in November or December (late spring to early summer), and the first genus to become ripe is the *Polystichum*. I am collecting spore right through to approximately May (late autumn). I collect the spore by collecting fronds with sori (spore cases) on them which are ripe. These ripe sori fronds are then put into paper bags and hung somewhere warm and dry. Generally over the next day or two the sporangia cases will pop open. I then try to sow this fresh spore as soon as possible.

Growing Media. The medium we have come to use is a peat, pumice, and perlite [peat, 1-4 mm pumice, medium perlite (75 : 13 : 12, by volume) plus 600 g slow release fertilizer N15–P3.5–K8.3 + trace elements and 1000 g dry trichoderma bio-innoculant per cubic metre] mix with very low fertiliser input. At one stage in the early days we got trays of prothalli burning off, caused by fertiliser guttating through the prothallus and causing the prothalli to burn. We quickly learned not to add too much fertilizer, restricting the rate to approximately 1 $kg \cdot m^{-3}$. After many problems with scarid fly larvae (*Lycoriella* species) in the mix, we now steam all our propagation mix. Scarid fly larvae love to eat the fine roots of the prothallus. The steaming is preformed by a boiler in combination with a fan that blows hot air through the mix at 60 °C for 30 min. The idea is to not sterilize the mix but to pasteurize it, that is, kill the baddies but leave the goodies. Our mix has fertiliser added when cooled and then it is wet down and ready to be sown with the spore.

Sowing, Germination, and Growing-On. There are many ways to do this, but the hard thing is to not over-sow the trays, remembering how fine the spore is. We add the spore to water and spray it over the trays with a hand spray bottle. After

the trays are sown they are straight away put into plastic bags, sealed, and put into the growth room or under benches in greenhouse one. Here they stay for, depending on species, 3 to 7 months. When we notice the prothalli are well developed we will then shift the trays out of the growth room, take them out of the plastic bags, and place them into a plastic tent in greenhouse one or put a plastic lid over the tray.

What makes ferns so unique is that they first develop into a prothallus, which has the sexual parts on it. As long as the right conditions are provided, with sufficient water over the prothallus to help the sperm swim from the male part to the female part on the prothallus, the prothallus will fertilize and form the true plant, that is, what we see and know as a fern. Often in the forest what you think is moss or lichen could actually be a mass of prothalli.

This stage in greenhouse one is crucial, as we are taking these very soft, vulnerable prothalli and trying to harden them up and get them to fertilize. Too wet and they will rot; too dry and they will not fertilize and will possibly die. We have a computer to monitor and operate a significant part of the cooling, humidity, and irrigation in both greenhouse one and two. This crucial stage is mainly controlled by the computer, but vigilant observation is also carried out. After fertilisation has occurred in greenhouse one, plants are then clumped out into plug trays and finally moved into greenhouse two, which is run at a lower level of humidity. From spore to a plug, depending on species, is generally a full-year process. We either sell them at this stage or grow on for our own production.

The New Zealand Native Plant Collection at Dunedin Botanic Garden: "Our Treasure"©

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INTRODUCTION

Welcome to a brief glimpse of the treasure that is the New Zealand native plant collection at Dunedin Botanic Garden. What I would like to do this morning is to tell you a bit about how the native plant collection is arranged and show you some of the plants I think of as special. The collection covers approximately three hectares and we've got about 20 minutes, so it's a whirlwind tour and I would like to think you will be inspired to go and see it for yourself.

BOTANICAL ORGANISATION OF THE COLLECTION

The collection is grouped with a number of ideas in mind, one of the main ones being taxonomic relationships. We have collections based on genus, such as the *Hebe* collection. *Hebe* is a species-rich genus, with a great diversity in plant form and habit. Our collection of *Hebe* is historically important to the botanic garden because it originated from a donation of plants in the early 1900s that formed part of the basis of the native plant collection. Our collection displays whipcord forms such as *H. annulata* and larger-leaved species such as *H. bollonsii,* a species from the Poor Knights, Mokohinau, and Hen and Chickens islands off the coast of northern New Zealand.

Another historically important collection is New Zealand flaxes (*Phormium*), including the Rene Orchiston collection as well as the early flax plantings from the 1900s. While there are only two species of *Phormium*, *P. tenax* and *P. cookianum*, Maori recognise over 60 named forms, and it is the Rene Orchiston Collection that represents many of these.

Other genera-based collections include *Coprosma* and *Pittosporum*, which are both displayed in their own borders. Recently the *Pittosporum* border had drainage put in on the roadside and the soil level raised to overcome a high water table, and we are also increasing the diversity of the species we display. A couple of my favourite plants here are *P. cornifolium* and *P. patulum*, a nationally endangered subalpine species found in the South Island. We also have a *Pseudopanax* collection.

Family-Based Collections. Still on the taxonomic track, we have collections based on plant family, with Myrtaceae, Fabaceae, and Asteraceae represented, each with their own border.

Metrosideros carminea, a climbing rata, is represented in the Myrtaceae collection. Another plant in this collection is *Syzygium maire*, a tree of swamp and bog forests throughout the North Island and the north of the South Island.

The Fabaceae collection contains good-sized specimens of some of our native broom species, such as *Carmichaelia odorata* and *C. williamsii*, interesting plants with relatively large, pale yellow flowers with purple markings, making it one of my favourites. We couldn't go past the iconic *Sophora* species when talking legumes, and neither could we ignore the kaka beak (*Clianthus*), which has been adopted as the logo for the Dunedin Botanic Garden.

The Asteraceae family is the most species-rich family in New Zealand. Again there is a great diversity in plant form, size, and habit. The collection here represents the smaller herbaceous genera such as *Leptinella* and *Celmisia*, as well as the tree daisies such as *Olearia fragrantissima*, which has the most delightful peachy scented flowers. An unusual member of the family is *Brachyglottis sciadophila,* a liane of lowland forest margins that also occurs on the Otago Peninsula.

The last taxonomically based collection is that of the order Coniferales, or more simply put—our conifer collection. The conifer border displays plants from each of the four families that represent conifers in New Zealand. The Araucariaceae family has *Agathis australis*, which is growing well out of its natural range and is even producing cones; the celery pine *Phyllocladus trichomanoides* belongs to the Phyllocladaceae family; *Manoao colensoi* of the Podocarpaceae family; and *Libocedrus plumosa* of the Cupressaceae family.

THEMES AND HABITS

In the last 20 years there have been a couple more collections added to the Native Plant Collection, and these have been based on representation of a natural habitat. The wetland pond, located by Lovelock bush behind the Botanic Garden Centre, was dug out of a boggy piece of ground. Rather than trying to represent one particular wetland type, the outer plantings are designed to represent the natural succession seen in wetland communities, from emergent species in the pond to the trees and shrubs associated with wet areas. A peat mound was also developed to cater to alpine species that occur in mountain wetlands. Most of our other alpine natives are grown in the alpine scree garden, which was developed in the late 1980s. *Bulbinella angustifolia* is flowering right now [April], which probably shows you how reliable the seasons are here in Dunedin. *Myosotis colensoi* occurs in the east of the South Island from south Marlborough to Canterbury and is currently listed as nationally endangered. *Leucogenes leontopodium,* known as the North Island edelweiss, also occurs on some South Island mountain ranges. This is a dynamic and ever-changing garden due to the fact that many alpines can be difficult in cultivation, and if they survive they are treasured!

The final grouping concept I'll mention today is based on plant attributes or characteristics. The native cultivar collection falls into this category, and there are some wonderful foliage colours on show in this border. *Parahebe* 'Snowcap', a cultivated variety of the species *P. catarractae*, and *Hebe ochracea* 'James Stirling', a recipient of the Royal Horticultural Society's Award of Merit and one of my favourite plants, are both displayed in this border.

We have a collection of plants with a divaricating habit. This is a border that has interest all year round but really comes into its own at this time of year. This is also where we tell the story of plants that have a juvenile form and habit that is sometimes remarkably different from their adult forms such as *Elaeocarpus hookerianus*, which at the moment looks for all the world like it has some other plant growing up through the centre of its twiggy divaricate stems but is simply going through puberty.

Coastal plants are an important part of the collection because there are many that are now rare or endangered due to the increasing pressure people put on these areas in the way of coastal development. Sometimes they have a very limited distribution such as *Gunnera hamiltonii*, which only occurs on the south coast of the

South Island and on Stewart Island. *Euphorbia glauca* and the native pikao *Desmoschoenus spiralis* are listed as being in decline, and *Gentianella saxosa* isn't rare but it is a sweetie.

We have a collection of plants from our offshore islands, which include plants such as *Myosotidium hortensia* from the Chatham Islands, both the blue- and white-flowered forms. *Myosotis capitata* is a blue-flowered forget-me-not from the Auckland and Campbell Islands, and Kermadec Island nikau palm (*Rhopalostylis baueri*) does well with shelter.

Lastly there are the tree and shrub borders. Ferns are represented within these borders; a couple of examples are the silver fern, *Cyathea dealbata*, and *Marattia salicina*, which does well with a mulch of pea straw over winter. With the shelter provided by many mature trees and shrubs we are able to grow some plants that would not normally do so well this far south. *Meryta sinclairii* is a tree that doesn't like frost or cold wind, and another plant from the north that does well is *Rhabdothamnus solandri*. This plant has flowers for many months of the year even here. While these borders cater to trees and shrubs, there are also a number of plants with habits that rely on trees and shrubs. *Parsonsia* and other lianes are grown throughout the borders. Epiphytes such as *Earina autumnalis* are placed in the forks of trees, and the hemiparasite *Ileostylus micranthus* or green mistletoe, has made itself quite at home in many trees and shrubs throughout Dunedin, to the point where it is difficult to explain that it is rare in parts of the country. To finish off today I'd like to show you my favourite plant, *Dracophyllum traversii*, and, just because he was there when I had the camera out, a kereru (New Zealand wood pigeon) in a *Cordyline*.

A Few Observations on Misconceptions: Rot 'n Rush©

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SAWDUST AND ITS MANY USES

It's amazing how the soil we have treated so badly continues to bless us with food, clothing, and beauty. To see whole areas stripped and dumped into huge anaerobic heaps and sold off as top soil is at the least depressing! To have spent hours double digging and "Bastard Trenching," was for me a waste of youthful exuberance if not character building. To have learned that mulching and no digging is the way to grow is a blessing in old age; it takes much time for soil to recover from poor husbandry and the mixing up of its vital ecological components. "Never use sawdust" an age old adage was and still is, the cry being that it robs the soil of nitrogen, a huge hangover from the trenching and bury it brigade. We use tons of sawdust with not a trace mineral or other deficiency. Thick mulch over gardens and tree areas keeps the soil cool, full of organisms, and rich in humus with few weeds; the type of sawdust (untreated) can be from any species. The only drawback is that it is soon gobbled up and needs another layer. The large trees soon send up masses of roots with their assistant mycorrihiza (a symbiotic association of a fungus and the roots of a plant) and become healthier and more insect- and fungus-resistant. The perennials planted grow at a fast rate, producing dark green foliage and richly coloured flowers. Ferns grow to perfection, while the young native seedlings are produced in overabundance.

Sawdust used as a heeling in media produces strong root formation even on so-called dormant deciduous trees, and masses of new white roots soon grow. Divisions of evergreen species such as *Astelia* sp., New Zealand (NZ) flaxes (*Phormium* sp.), and a host of perennials soon grow strong roots, far better than when being potted into cold, soggy potting mix, over winter, ready for potting up in early spring with few losses.

I have observed in the past and more recently huge logs fallen or felled, covered in healthy young trees forming a native mixed hedge, the tree providing the media and mycorrihiza the food. Putting observations into nursery practice, we (nursery persons) are trying to produce good healthy plants, and I believe the use of sawdust mycorrihiza can help us. There are a number of NZ native trees and perennials hardly ever seen for sale because they are tricky or slow to grow. We have managed to grow some of them by using sawdust with *Podocarpus* root and mycorrihiza in a sandy mix for cuttings that are hard to root and grow on.

Dracophyllum – twenty or so species to try. Some rooted in 12 weeks and are growing well 2 years later as still small plants. Others include tree species such as *Ixerba brexioides, Litsea calicaris, Quintinia serrata, Archeria*, and *Epacris* and perennial species such as *Ourisia* and *Euphrasia*, with possibly many more to be tried. Experiments with sawdust continue, possibly as mulch over potted trees for revegetation to give them a boost before planting out in situ.

RUSH

With the advent of wetlands as part of revegetation and subdivision of land there has been a rush to produce plants suitable for planting. While *Phormium* and *Cordyline australis* are a mainstay, the many Cyperaceae are also valuable genera. Most are easily identified although they do somewhat all look the same, and most plant growers do not seem to have a clue what they are producing. We have been producing reeds and rushes, exotic and native, since the late 1980s. The last 5 years have been a steep learning curve to be able to grow from seed and division our native forms. Production has gone from a few hundred in the early days to many thousands at present. A useful key to identification can be found in the Flora of New Zealand (Moore and Edgar, 1970), good line drawing and sketches in Field Guide to Stewart Island Plants (Wilson, 1982), and good photographs in The Cultivation of New Zealand Native Grasses (& Rushes) (Metcalf, 1998).

The following is a list of rushes using a visual description, not a botanical description.

- The rare and elusive *Sporadanthus traversii* (originating in the Chatham Islands) and *S. ferrugineus* (originating in the Waikato) have very erect bright green stems with joints and scales to 3 m tall, are slow growing with brown flower heads at the tip of stems, with male and female plants separate. Both species grow on peat bogs and sphagnum moss.
- *Bulboschoenus fluviatilis,* very open leafy foliage, 100–200 cm tall, green in summer and then goes dormant. Rampant and very untidy with hard rhizomes that can be eaten when in fresh growth and grows in shallow water or boggy ground.
- *Machaerina articulate* (syn. *Baumea articulate*), very strong growing, rampant, bright green, 100- to 200-cm-tall plant with ridges on the stem that can be felt by running fingers up the stem. Fluffy brown seed heads and grows in shallow water.
- *Machaerina rubignosa* (syn. *Baumea rubignosa*), large clumps, 30- to 80-cm-tall, blue green stems, slightly oval in appearance with flower heads at top of stem which seeds light golden brown and grows in boggy conditions.
- *Machaerina tenax* (syn. *Baumea tenax*), clumps but spreads slowly, stiff grey 30- to 50-cm-tall stems forming seeds with hard grey-black tips, often growing on clay banks and poor soils.
- *Eleocharis acuta,* makes thick clumping mats, 20–80 cm tall with stiff wiry leafless stems coloured green with base reddish brown. Small cylindrical seed heads coloured pale brown.
- *Eleocharis sphacelata,* rampant, very strong growing usually to 1 m tall with soft green stems that crush and will grow in shallow water to 30–40 cm deep. Pointed cylindrical papery seed from heads which break up easily.
- *Juncus gregiflorus*, clumps to 60–150 cm height, with wiry shiny green stems and multi-stemmed almost fluffy seed head. The tip of the stem is about 10 cm above seed head. Grows in dry to bog conditions.
- *Juncus pallidus,* strong growing to 100–200 cm tall with blue-grey stems that are full of white pith. Multi-stemmed seed head usually close to the stem and about 20 cm from the tip. Grows in dry to bog conditions.

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Whistle Stop Chelsea 2005 Experience©

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AN OVERVIEW

The Chelsea Flower Show was the highlight of a short visit back to London, the city of my birth. Visiting Royal Horticultural Society (RHS) Chelsea on one of the Members Only days was exceptional. The area was lightly populated, allowing good viewing of the exhibits. The exhibits and exhibitors were fresh and sparkling.

The new Great Pavilion at RHS Chelsea contained a mix of show gardens, floral, and plant exhibits. Although our visit was on an overcast day, the light conditions in the marquee were excellent, and the colours almost natural. Walking in, we were overcome by the vastness of the Great Pavilion and by the sights and the scents held within its walls.

Outside, the show gardens, allied traders, floral arts, and horticultural displays drew much attention from all visitors. It was interesting to observe the medals system, in that excellence of display to a certain standard gave awards and that more than one medal could be awarded in each class if each exhibit met the strict judging criteria. It was good to note that timber products displayed or sold must have been harvested from sustainable forests and that alternatives to peat products were used in the displays. Exhibitors were also prohibited from using or showing non-native invasive plants in their displays.

Most of the exhibits gave the impression that the plants had been growing in their displays for years, defying the logic that all had been a grassy site just a few days before.

The first ever exhibit by the Chelsea Pensioners drew much interest. Depicting the soldiers' dreams of their homeland whilst serving in the Second World War, the exhibit included the village pub, village green complete with duck pond, and the home vegetable patch. Poppies and other wildflowers grew in the meadow alongside the pub.

The display of medal winning vegetables by Medwyn Williams, his ninth year and last display at Chelsea, and another Gold, drew much attention. The display included over 45 different vegetables, many grown in long containers and displayed with long roots intact. All were in neat bundles, perfectly even and unblemished, displayed to perfection.

Cascading mountains of mouthwatering, fragrant strawberries exhibited by Ken Muir Ltd. left the taste buds tingling.

CLEMATIS

Clematis exhibited at Chelsea were superb. Different styles of display by each grower highlighted their plants. Many excellent new cultivars of clematis were displayed by Raymond Evison's Guernsey Clematis Nurseries. Plants displayed from staging up the walls of the Great Pavilion on a large corner site were flowering prolifically, resulting in wall-to-wall clematis flowers. These dwarf and very floriferous patio-style clematis are the result of Raymond Evison's intensive breeding program and so worthy of a place in the modern smaller garden. Clematis displayed

by both Thorncroft and Sheila Chapman Nurseries were on pergolas and frames, as they would be growing in the home garden. Immaculate displays, their hard work rewarded by medals yet again. The displays by various societies, institutes, and retailers were a source of both knowledge and articles for purchase. Everything from Wellington boots to watering cans, bumble bees, books, and RHS colour charts, and all things horticultural.

CONCLUSION

In all, this was an experience to be repeated at a later date, this being only a sample of what was on offer. We can only imagine what the Saturday plant sales were like, when the numbers of people were far in excess of those allowed in on the priveledged "RHS Members Only" days. We left in awe of the sights we had just experienced, vowing "We'll be back."

Question Box©

An open forum, in the spirit of Seeking and Sharing, for all participants to respond to and discuss the written questions submitted during the Conference on any subject.

When is the best time to take *Pittosporum* and *Metrosideros* cuttings?

Pittosporum: Half-ripe terminated wood, mostly April-June/July (mid-autumn to mid-winter)
Metrosideros: Half-ripe terminated wood, mostly March into May (autumn)
Seradix™ 2 (Bayer Crop Science) (4-indol-3-ylbutyric acid 3 $g \cdot kg^{-1}$) can be used but if in doubt go down to a lower strength.

Is there a biological control for damping off (*Fusarium* species) on seed trays?

Natural sphagnum moss (*Sphagnum* species) can be placed on top of the media with seed sown into the moss. For larger seed, gravel chip may be better.
Trichoderma species are available in a range of commercial products that can be incorporated in to the media.

Has anyone had problems with nematode infestation of *Astelia chathamica* 'Silver Spear' and *A. nervosa* 'Westland'? This shows symptoms of rotting in the centre of the crown.

A few people have seen spasmodic problems; however no real solutions were put forward. If anyone has any suggestions please email Ann Fair, Naturally Native New Zealand Plants, Tauranga.

The assessment of apprenticeships is currently carried out by those employing them. Is there any move by the Horticultural Industry Training Organisation (HITO) to change that?

This opened up a discussion on horticultural training. Points discussed included:
HITO would like students to be able to go to one of the Centre of Excellence training schools.
Roving assessors are not as widely available or as accessible as they say they are.
It is not always ideal to assess people you work with and who you have also taught.

How are the assessors themselves going to be assessed?

Moderation is a concern, and HITO is working to address this. Trainees need to pass because they have earned it and deserve to, not because the system says so.
The recognition of prior learning is available for those people who have already worked in the industry; however the cost is not user friendly and this must be looked at. The cost could be as much as $1000.

Chris Hughes as HITO board member representing the Nursery and Garden Industry Association noted these comments and will investigate further.

How do you propagate weeping myrtle (*Syzygium floribundum*)?

Young stock is preferable, but it is a difficult species and perseverance is called for. Grafting may offer the best success.

How do you put in successful applications to Department of Conservation (DOC) for seed collecting?

Not an easy question to answer. DOC appears to have trouble realising the difference between commercial and noncommercial (e.g., revegetation) programmes. They should readily give permits for seed collecting for noncommercial projects. However, at the same time we need to continue to push the need to allow seed collection for commercial purposes to keep native plant species alive and growing. If native species are not helped by nursery propagation then we could end up without them at all.

Where can you buy sieves for seed sifting?

Otago Wireworks in Dunedin.

Where can you purchase Seradix™ (Bayer Crop Science) (4-indol-3-ylbutyric acid) in the strengths not available?

This product range is only available in some strengths. However, you can make your own, and Jeff Elliot gave a paper on this subject at the 2002 New Zealand Conference, which is in Volume 52 of the I.P.P.S. Combined Proceedings.

Overview of Annual Meeting of IPPS Japan Region 2006©

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On 15 and 16 July, the 13th Annual Conference of the IPPS Japan Region took place in Wakayama Prefecture. Professor Nito, the International Director for IPPS Japan Region, served as the Executive Secretary of the Wakayama Conference and obtained cooperation from Kinki University to develop a successful conference.

On the first day, we had a keynote presentation from IPPS Japan Region member Mr. Mamoru Noguchi, who was formerly of National Institute of Hygienic Science in Osaka; the subject of his address was "Search for Medicinal Wealth" (Fig. 1).

He discussed a new method that is used to evaluate for positive effects of herbal dishes using radar charts and discussed its theoretical background in detail. He compared the radar charts for some Kampo medicines (Chinese herbal medicine) as well as herbal dishes that have been prescribed for the same disease. He also introduced cooking recipes for the herbal dishes. Additionally, he showed similar patterns in most cases, and it is concluded from the results that radar charts may be used to assess the biological activities of herbal dishes in comparison with Kampo prescriptions.

Next, we had presentations from other I.P.P.S. members. Copies of these presentations will be published in the *Combined Proceedings* (black book) so the I.P.P.S. members will be able to read and study them.

Unfortunately, we did not have enough time to exchange the members' information because the presentations filled the conference time. Therefore, members were

Figure 1. Mr. Mamoru Noguchi making his presentation.

Figure 2. Kinki University research farm.

not able to talk about what they are doing and what the expectations are for the IPPS Japan Region in front of the members. I feel that it is not enough to only have presentations for the audience at the conference. There should also be conversation and communication between the I.P.P.S. members. Sometimes we find that attendees do not know what kind of background each member has.

A general business meeting was also held. A problem facing the IPPS Japan Region is that the number of members is decreasing every year. To try to solve this problem, we maintain the home page on the Internet web site and send a newsletter to members. During the business meeting we introduced the location for the next annual conference to the membership. The 14th Annual Conference in 2007 will be in Miyazaki Prefecture. The dates of the conference will be the 17th and 18th of November. Dr. Tetsumura, who is a professor at Miyazaki University, will be the executive secretary of the Miyazaki conference. After the business meeting, we had a great time at the banquet with food and drink at a restaurant. It was great time to exchange information and have conversations.

The next day, we toured a grower, Nakatsu Bio Center, and the Kinki University research farm. At the Nakatsu Bio Center we visited with the grower, Mr. Koike. The grower is required to produce a high-quality, safe product and must achieve a stable supply of product. To achieve these requirements, he invests in agricultural growing systems to improve plant production. At Nakatsu Bio Center, they propagate a special kind of lily bulb. In Wakayama prefecture, they are trying to become the leader in the propagation of this special product.

At the Kinki University research farm (Fig. 2), Professor Nito, the director of the IPPS Japan Region and the Secretary of the Executive Committee of the13th Annual Conference, discussed his research (Fig. 3). Professor Nito is well informed in the field of citrus (orange, mandarin, etc.). They conduct special breeding at the Kinki University research farm. In addition, they grow and conduct research

Figure 3. Professor Nito discussing his research.

Figure 4. Mango research greenhouse at Kinki University.

Figure 5. Research plants in a greenhouse at Kinki University.

on mango (Figs. 4 and 5). Kinki University has a brand and supplies the fruit to the market.

We hope that many members who attended the 13th Annual Conference in Wakayama were satisfied with the conference. Once a year, IPPS Japan members attend the conference from all parts of the country. It is very valuable chance to exchange information among the members. When we attend the annual conference, we hope we will obtain new ideas and they will be helpful in our business or study.

Our industry has been changing day by day. IPPS Japan Region should also be changing day by day. If not, the members will not be satisfied with IPPS Japan Region. The next annual conference will be in Miyazaki prefecture. The most important meaning of I.P.P.S. is the spirit of "SEEK AND SHARE." We hope that the 14th Annual Conference also keeps the spirit of "SEEK AND SHARE" when they develop the conference. The IPPS Japan board hopes that our members make the most of the conference and the meeting.

Field Trip in Wakayama Prefecture, Japan©

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The 13th Annual Conference of IPPS Japan Region was held in Wakayama on 15 and 16 July 2006. There were 35 participants, and eight papers were presented in the session.

On the 2nd day, 16 July 2006, participants enjoyed the field trip in Wakayama area. It was a very fine day and exceptionally hot for the rainy season in July. The group drove to the south from Wakayama city and visited Koike Nursery Co. Ltd. (Fig. 1A, B, and C). Koike Nursery is one of the biggest in the western part of Japan and propagates seedlings of vegetables and flowers. The products are sold to farmers and wholesalers as well as DIY shops for amateur gardeners. The seedlings are propagated under an enclosed environmental systems controlled by computers.

The next visit was to Bio-Center Nakatsu (Fig. 2), which is run under the subsidy of Nakatsu village municipality. Seedlings of *Gypsophila* and *Lilium japonicum*, which is indigenous to the Kii peninsula, Japan, are propagated by tissue culture methods. *Lilium japonicum* is propagated not only for horticultural use but also for the rehabilitation of environment and germplasm conservation in this area. In addition, the center produces unique ornamentals, which are called "flask-plants." Plants are grown on the medium with some colors in the small vials as same size as 100-ml flask under aseptic condition.

Finally, the group visited the experimental farm of Kinki University (Fig. 3A, B, and C). About 200 cultivars and strains of *Citrus* species are maintained in the orchard. The conservation of indigenous species such as *C. junos, C. tachibana, C. unshiu* and so forth is tremendous. Some variegated strains and dwarfed strains will be used for ornamentals. These plant materials are used for the taxonomical study of *Citrus*, which is still controversial. New chemicals will be found from fruits for dietary purposes.

Participants went back to Wakayama station, said good-bye and promised to meet again next year in Miyazaki.

Figure 1A. Discussion at Koike Nursery Co. Ltd. The third person from the left is Mr. Koike.

Figure 1B. Soil and compost mixer at Koike Nursery Co. Ltd.

Figure 1C. The incubator for grafted plants. Temperature, humidity, and light intensity in the incubator are automatically regulated. Grafted plants are acclimatized for a couple of days in the incubator before shipping.

Figure 2. The long way to Bio-Center Nakatsu under strong sunshine.

Figure 3A. Citrus germplasm at the experiment farm of Kinki University.

Figure 3B. Nursery field of citrus plants. Plants are grafted on trifoliate orange rootstock.

Figure 3C. Variegated fruit (chimera?) of satsuma mandarin found in the collection. The taste of fruit is absolutely satsuma mandarin. Some variations of variegated types are found.

Plant Type Variation Induced by Grafting and the Related Genes Analysis in Pepper©

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Investigations into the variant characters of graft-induced pepper strain "Peaton" (*Capsicum annuum* L.) have been carried out in our laboratory for many years. Although the high branching character of Peaton is an important horticultural character, the mechanism causing high branching is unknown. From previous studies, plant type such as branching pattern could be regulated by plant hormones. Specifically, the interaction of auxin and cytokinin could be a good clue to understand the mechanism of Peaton's high branching ability.

A decrease in auxin sensitivity was found by two kinds of auxin sensitivity tests. Therefore, two genes, *AXR1* and *PIN1* that relate to auxin-signal pathway, were isolated and sequenced, and G specific sequence was seen in *PIN1*. Future studies investigating the expression and sequencing of these genes would be important in understanding this phenomenon.

INTRODUCTION

The graft-variant line of pepper "Peaton" was induced by Yagishita around 50 years ago (Yagishita, 1964). Firstly, 'Yatsubusa' (Y) pepper was grafted as the scion on Spanish paprika (Sp) understock by the "mentor grafting" technique. Seeds that were derived from the fruit of the scion were sown. To increase the variation ratio, "repeat grafting" was carried out. After repeated grafting (five times), we could obtain the graft-induced variants and finally establish the stable line Peaton (G). In this study, we used a G line that has been maintained for more than 45 generations.

Graft-variant line G has wide intermediate phenotypes between Sp and G such as fruit shape, capsaicin content, sugar content, length of stoma, etc. (Yagishita, 1979). However we could observe not only such intermediate phenotypes but also G specific characters that include a high-branching character, larger number of nodes, and ability of regeneration from young cotyledon that we have not observed in Sp and Y.

Characteristics of axillary branch number and node number would be principal factors of "plant type" that construct the spatial arrangement of plant organs. A typical practical introduction of such plant types into agriculture is in the breeding of the semi-dwarf rice cultivar "IR8". In addition, we can see a deceased number of culms in the process of domestication of wild maize species by South American natives. The decease in number of culms enhances sink function of grains and enlarged the edible portion of maize. Therefore, plant type breeding has been playing an important role in breeding from ancient times to the present.

Inheritable graft-induced variation has occurred in other plants, such as eggplants and soybean (Hirata, 1979); however, such graft-induced variation is rarely

applied to agriculture breeding today. Therefore, understanding the genetic basis of G specific character that is horticulturally important would have great value in the near future. Because it will have a significant effect, we not only searched for useful genes but also the mechanism of graft-induced variation and its application in breeding science.

It is well known that plant growth regulators (PGRs) have large effects on plant morphology; especially, auxin and cytokinin in apical dominancy. Therefore, different branching patterns may be due to the difference in amount of synthesized PGR or PGR sensitivity. In fact, auxin-resistant mutant *AXR1* (auxin resistant1) of *Arabidopsis* has high branching phenotype (Lincoin, 1990).

Through molecular biological studies the teosinte branched1 gene (*TB1*) that controls number of culms was identified with QTL analysis of maize and teosinte (Doebley, 1995). Zinc finger protein *PetSPL3,* whose over-expression in plants induces a high-branching character, was found in petunia (Takatsuji, 1999). In addition, the *max* mutant in *Arabidopsis* and *rms* mutant in pea, which control branching, were investigated, and the source genes were identified. With the above research as a background, the present study was carried out to examine the hormonal involvement in the high branching character with genetic and physiological research methods.

MATERIALS AND METHODS

Plant Material. In this study, we used a G line that was purified and maintained by 47 times selfing of the graft-induced variant. In the experimental lines of Sp and Y, we also maintained their pure lines that had been used for making graft-induced variant (Figs. 1 and 2) by repeat selfing.

Investigation of Number of Axillary Branches and Nodes in Each Line. We surveyed axillary branch number and nodes in Sp, G, Y, and F_1 progenies resulting from their crosses in 2004 and 2005. Investigational time was the stage when plants stopped their vegetative and generative growth. The stem that had the largest number of branches was determined and evacuated as a main stem.

Microscopic Observation of Axillary Bud. The fourth nodes of plantlets 8 weeks after seed sowing were observed under a microscope. First, the part of the nodes was excised and embedded into an agarose gel. Agarose blocks were sliced into 60 μm widths by a micro slicer. Using these segments the growth degree of the axillary meristem was determined.

Auxin Sensitivity Test. We carried out two kinds of tests to investigate auxin sensitivity. One was the "decapitation test" and the other the "culture reaction test."

Decapitation Test. Plantlets of G and Y, 12 weeks after seed sowing, were used in the decapitation test. These plantlets were cut just under the 6th node, and a Vaseline paste containing 0, 0.1, and 0.5 $mg \cdot L^{-1}$ NAA was applied. Cut surfaces were covered with plastic caps. The number of branches was counted after 2 weeks to determine auxin response.

Culture Reaction Test. Seeds of each line were sterilized and sown on an aseptic medium in the auxin reaction test. After 1 month, cotyledonary nodes were cut around 5 mm from the upper and from the down part of nodes. These nodes were put between two kinds of media with cutting surface touching each medium (Fig. 3).

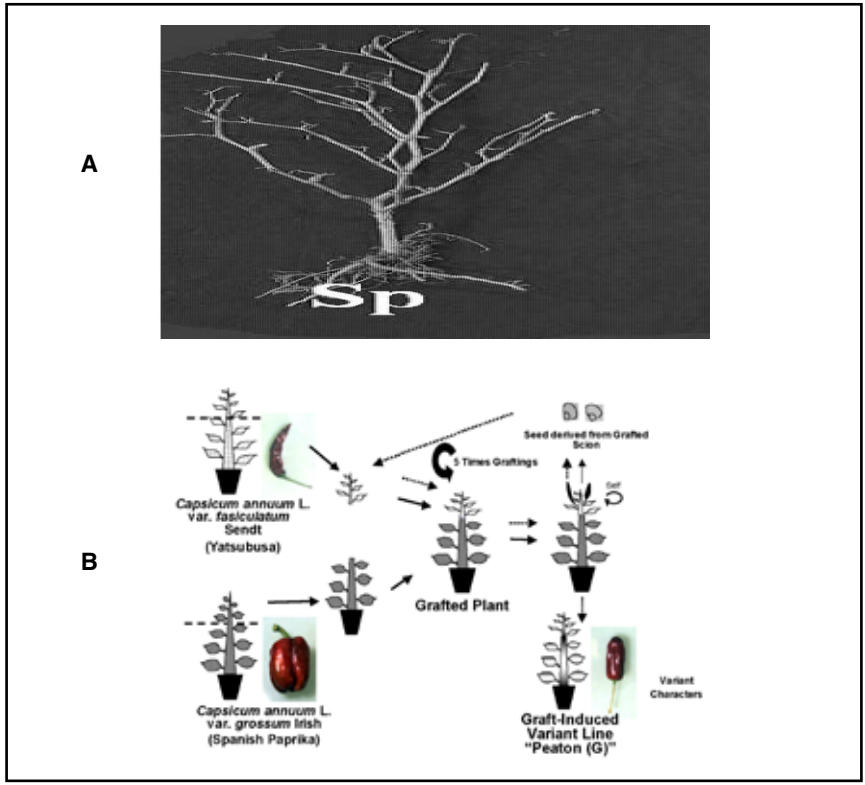

Figure 1. (A) Plant type difference of final growing stage in each line. Left to right; Sp, G, and Y. (B) Proceeding of graft-variant strain Peaton (G).

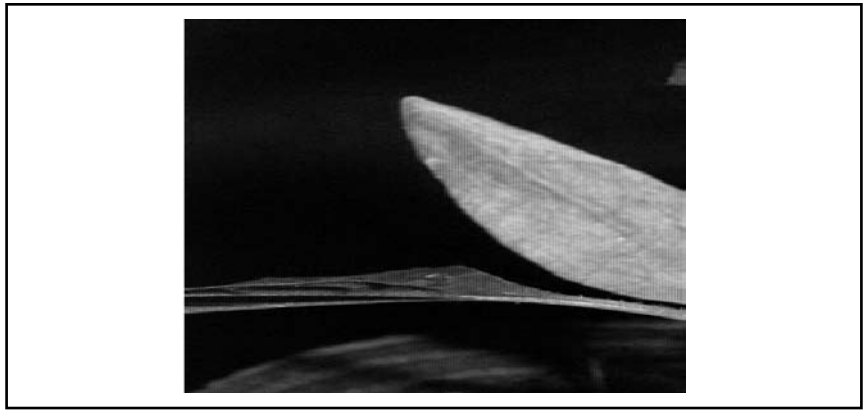

Figure 2. NAA application method in decapitation test.

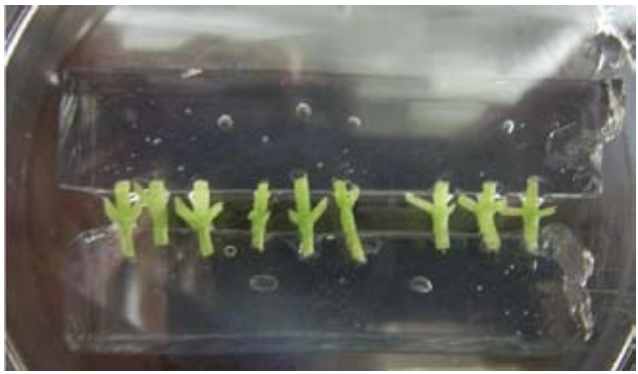

Figure 3. Auxin sensitivity test by using tissue culture. Apical medium: Murashigi and Skoog (MS) solid medium containing 0, 0.02, and 0.1 mg·L^{-1} NAA; basal medium: hormone free MS solid medium.

Solid Murashigi and Skoog (MS) medium containing 0, 0.02, 0.1, or 0.5 mg·L^{-1} of NAA were used as upper (side of shoot tips) medium. And hormone-free medium were used as lower (root side) medium.

Isolation of Auxin Signal Pathway Related Genes. We isolated from pepper putative *AXR1*, which relates to auxin signal pathway and whose mutant expresses high branching character. Two primers (forward: CCN GAY CAY TTY YTN GAY GAY, Reverse: RAA RTC NGC YTC NGC YTT NGC) that were used for amplification of *AXR1* had been designed from common sequence of *A. thaliana*, *Solanum demissum*, and *Oryza sativa*. cDNAs, which were synthesized from immature fruit, RNA of Sp, G, and Y were used as template for PCR under the following condition: initial denature at 94 °C for 5 min; setting of 35 cycles: denaturation for 30 sec at 94 °C, annealing for 30 sec at 55 °C, and extension for 1 min at 72 °C; final extension for 10 min at 72 °C. The amplified bands whose size was around 550 bp were introduced into vector and determined sequence by TA cloning and ABI prism 377 sequencer.

To isolate pepper putative *PIN1* that relate to auxin transfer, another two primers (forward: GAY YTN CAY ATG TTY GTN TGG, reverse: AAI GGN ACD ATN CCY TGN GG) were designed from common sequence of *A. thaliana*, *Momordia charantia*, and *O. sativa*. cDNAs that were synthesized from leaf RNA of Sp were used as template for PCR condition: initial denature at 94 °C for 5 min; setting of 35 cycles: denaturation for 30 sec at 94 °C, annealing for 30 sec at 50 °C, and extension for 45 sec at 72 °C; final extension for 10 min at 72 °C. Sequencing was performed according to the procedure mentioned above. More stable primers (forward: TTC AGT TGA TGA TGT CAT GTC, reverse: TTA TCC TTG TTA AGG TGG CAG) were constructed from determined sequence to amplify *PIN1* of G and Y. *PIN1* of G and Y was also determined.

Table1
The final number of nodes and branches of 'Sp', 'G' and 'Y' in 2004 and 2005

Materials	No. of nodes 2004	2005
Sp	11.76 ± 2.77 (17)	18.5 ± 1.2 (10)
G	17.71 ± 2.23 (14)	24.6 ± 1.83 (10)
Y	16.08 ± 1.26 (13)	21.0 ± 0.85 (5)
Sp × G (F_1)	14.5 ± 1.20 (8)	
Y × G (F_1)	15.21 ± 2.54 (24)	22.3 ± 0.99 (10)
Sp × Y (F_1)	13.2 ± 1.42 (15)	20.8 ± 1.78 (5)

Materials	No. of branches 2004	2005
Sp	3.56 ± 1.89 (18)	10.3 ± 0.62 (10)
G	11.67 ± 2.10 (12)	18.6 ± 1.12 (10)
Y	7.54 ± 2.07 (13)	11.4 ± 1.43 (5)
Sp × G (F_1)	2.38 ± 2.13 (8)	
Y × G (F_1)	7.17 ± 2.46 (24)	14.4 ± 0.79 (10)
Sp × Y (F_1)	2.73 ± 2.09 (15)	10.6 ± 0.92 (5)

Materials	Branching rate (No. of branches/No of nodes) 2004	2005
Sp	0.30	0.57 ± 0.04 (10)
G	0.66	0.77 ± 0.04 (10)
Y	0.47	0.55 ± 0.08 (5)
Sp × G (F_1)	0.16	
Y × G (F_1)	0.47	0.66 ± 0.05 (10)
Sp × Y (F_1)	0.21	0.53 ± 0.07 (5)

A: The number of nodes
B: The number of branches
C: The number of branches/nodes
*, **, *** and n.s.; respectively significant difference at 5%, 1%, 0.1% level and no-significant difference in T-test.

Table 1. Change of branch numbers by NAA application in decapitation test.

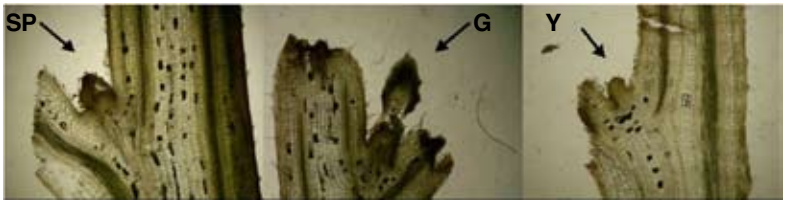

Figure 4. Microscopic observation of axillary buds. Fourth node was observed in each line.

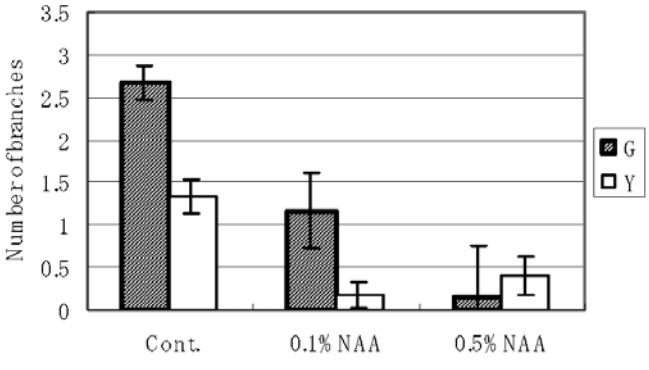

Figure 5. Change of branch numbers by NAA application in decapitation test.

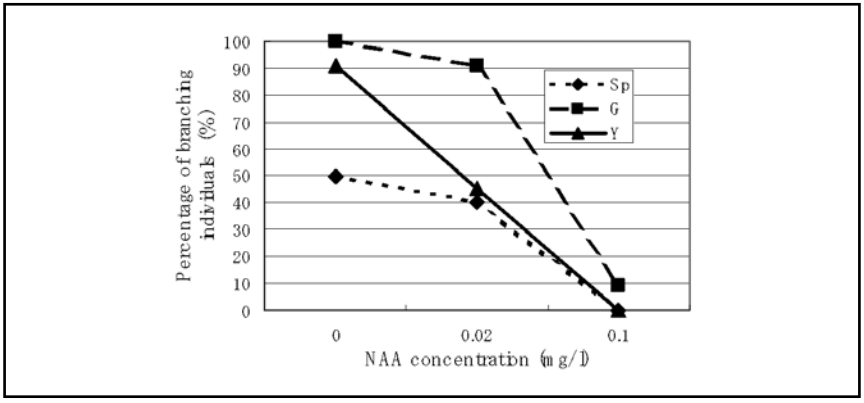

Figure 6. Change of branch formation rates by concentration of applied NAA solution in auxin sensitivity test using tissue culture. Evaluation was performed 1 week after application.

RESULTS

Number of Branches and Nodes in Each Line. Although the strengths of plant growth were different in 2004 from 2005, trends of number of branches and nodes were same in both years (Table 1 A and B). The largest number of branches and nodes occurred in G, Y was next, and Sp had the least. The F_1 progenies have similar phenotype with a pair of their parent that has less number of branches and nodes except the combination of Sp × Y in 2005.

G also had the highest average branching rate number (number of branches divided by number of nodes), Y was next, and Sp had the least number (Table1 C). From this result, high branching character in G was attributed to not only increasing nodes but also branch formation rate at the nodes was increased in G line.

Microscopic Observations of Axillary Buds. Developed axillary buds were observed among Sp, G, and Y (Fig. 4). Even further expanded leaf was seen but only in G. From this result, there was no difference in strength of axillary bud formation among Sp, G, and Y. Therefore the dormancy-breaking level or timing might be different among the lines.

Auxin Sensitivity Test.

Decapitation Test. In this control application that is performed by applying vaseline paste without auxin onto cut surface, G had 2.67 branches and Y had 1.33 branches (Fig. 5). However comparing application of 0.1% NAA and control, Y had $^1/_{10}$ (X = 0.17) branches and G had $^1/_2$ (X = 1.16) branches in 0.1% NAA application. From these results, we could estimate possibility of decreasing auxin sensitivity in G.

Culture Reaction Test. When a medium containing 0.5 $mg \cdot L^{-1}$ NAA was used as an apical medium, nodes formed calli on the cut surface and transformed their shape. In the control application (no NAA), axillary branches appeared in almost all cultured nodes of G and Y (Fig. 6). However in the application of 0.02 $mg \cdot L^{-1}$ NAA, 45% of nodes of Y formed axillary branches, 90.9% of nodes of G were formed. Consequently, we could confirm the decreasing of auxin sensitivity in G.

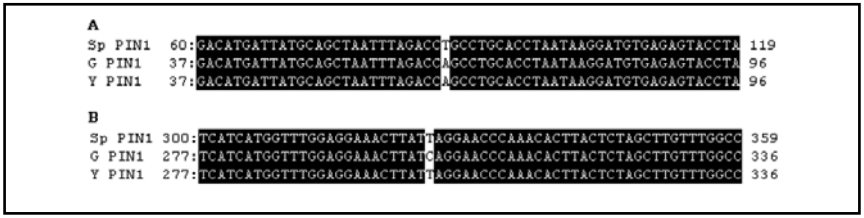

Figure 7. Partial sequence of *PIN1* derived from Sp, G, and Y.

Auxin Signal Pathway-Related Gene Isolation. In isolation of *AXR1*, separated bands around 550 bp in Sp, G, and Y were cloned and sequenced. Sequence of this gene has about 74% identity to *AXR1* of *A. thaliana*. From the determined sequence, gene specific primers were designed, and the stable band of *AXR1* from pepper was obtained. Detail of difference among Sp, G, and Y are being investigated.

In isolation of *PIN1*, separated bands around 650 bp in Sp and around 600 bp were cloned and sequenced. The 650 bp of Sp has 74% identity to auxin transport protein (*PIN1*) of *Populus tremula*. Moreover Sp-specific sequence (Fig. 7A) and G-specific (Fig. 7B) sequence were identified in their sequences.

DISCUSSION

In plant morphology, mutants of axillary branch formation are divided into three groups (Ward and Leyser, 2004). First mutant group has the changes in axillary branch formation, second has the changes in degree of breaking dormancy of axillary buds, and third has both. From the results of microscopic observation of axillary buds, Sp and Y have the same strength of axillary bud formation as G that has a high-branching character. Therefore, G is classified into second group; namely, high branching character of G is due to the difference of breaking dormancy of axillary buds.

It is generally known that dormancy of axillary bud was broken when the shoot apex is excised. Auxin that is constantly supplied to the shoot apex suppresses axillary bud outgrowth. When auxin is removed by excision of the shoot apex, suppression of outgrowth is stopped and dormancy breaking occurs. Taking this fact and G-specific decreased auxin sensitivity into consideration, it is thought that decreased auxin sensitivity may cause the high-branching character in G.

From this result, *AXR1* and *PIN1* genes that relate to auxin signal pathway was isolated by degenerated PCR. The sequence of *AXR1* has not been determined yet, however G specific sequence was determined in *PIN1* (Fig. 7). It would be a subject worth investigating whether these sequences cause the phenotypic difference.

In a previous study of auxin signal pathway, it was demonstrated that *AXR1* plays a significant role in the early stage and relates to almost all auxin signal transmission (Bennett, 2006). Therefore, not only sequence difference but also gene expression level of *AXR1* might cause the different phenotypic pattern. In addition, gene expression level of *PIN1* is also controlled by *MAX* series of genes whose mutants in *A. thaliana* express high-branching character. For that reason, expression

pattern of *PIN1* might also affect plant morphology. Therefore, it is necessary that the expression pattern of these genes in various tissues should be investigated by northern hybridization or real-time PCR.

Max1 mutant of *A. thaliana* that has a high-branching character also has rounder leaves in rosette phyllotaxis as a pleiotropic expression (Lazar and Goodman, 2006). Interestingly, G has also rounder leaves comparing with Sp and Y (Yagishita, 1979). The distribution of endogenous cytokinin in pepper leaf may affect partial expansion of leaf area (Ulvskov et al., 1992). It is well known that cytokinin and auxin have an antagonistic effect. Moreover, it is reported by Sugitani (1996) that cotyledons of G have different culture reaction. From these situations, high-branching character and changing in the ratio of width against length of leaves in G might be due to the different auxin sensitivity. At the present, we are investigating the leaf shape by Fourier-discriptor to analyze from the standpoint of genetic science (Suzuki, 2006).

This hormonal control research on graft-induced changes will be one key for the dynamic morphological change of the mechanism.

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A Novel Technique for Mass Propagation and Production of Miniature Pot Plants of Mountain Laurel (*Kalmia latifolia*)©

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A novel technique for mass propagation and production of miniature pot plants of mountain laurel (*Kalmia latifolia*) was developed using a tissue culture technique and a plant growth retardant. Juvenile shoot apices that were excised from mother plants in a glasshouse were surface sterilized and used for tissue culture. Woody Plant Medium supplemented with 1 $mg \cdot L^{-1}$ of N^6-(2-isopentenyl)-adenine was adequate for mass propagation of transferable shoots. Shoots taken from flasks were immersed in 100 $mg \cdot L^{-1}$ indolebutyric acid for 3 h to promote rooting and then transplanted to a potting mixture of peat moss, vermiculite, and perlite (8 : 1 : 1, by volume) in a 128-cell tray for acclimatization. Miniature pot plants with a number of flower buds were successfully produced by spraying the transplanted seedlings with 20 $mg \cdot L^{-1}$ growth retardant (Paclobutrazol), followed by another spray at 200 $mg \cdot L^{-1}$ 20 days later (Fig. 1). Excessive fertilization suppressed formation of flower buds and enhanced emergence of dwarf leaves. The suppression of plant growth by the Paclobutrazol treatment was recovered by an application of giberrellic acid, indicating that the miniaturization of plants was due to inhibition of gibberellin biosynthesis in the plants.

Figure 1. Producted plants by ordinary method (left) and novel method (right).

Tetraploid Induction by Colchicine in *Rosa bracteata*©

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Rosa bracteata is the only species in the genus *Rosa* that lives in subtropical areas — Okinawa in Japan to Vietnam — and has heat tolerance. Modern roses for cut and potted flower production do not have heat tolerance, with flowering and vigor declining during the summer season, because modern roses were bred from wild species living in temperature zones. In this study, we tried breeding modern roses with heat tolerance by crossing to *R. bracteata*e. As the chromosome number of modern roses is 2n = 4x = 28 and *R. bracteata*'s is 2n = 4x = 14, the F1 by crossing between those will have chromosome number of 2n = 3x = 21 and will not have fertility. So we attempted to induce a tetraploid form of *R. bracteata* with colchicine.

Studies on Dwarfing Rootstocks of Japanese Persimmon©

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Japanese persimmon tends to grow to a large tree. Hence the necessity of propagation of dwarfing rootstocks has been urged for 50 years (Ito, 1988), although nursery stocks grafted on the dwarfing rootstocks are not available yet. It has been thought that Japanese persimmon is one of the difficult-to-root fruit species, and propagation by cuttings has so far proved to be very difficult (Tao and Sugiura, 1992). A few reports on cutting propagation of Japanese persimmon proved that an etiolation treatment on mother plants and auxin and vitamin treatments on cutting bases were effective in rooting the cuttings collected from seedlings and cultivars (Machida and Fujii, 1969; Tukamoto et al., 1959). However, these techniques have not been applied to commercial production mainly because the production of mother plants and cuttings are cumbersome and complicated.

Many researchers have investigated the field performance of double grafted trees in which potentially dwarfing interstocks were grafted on seedlings. After long-term investigation, some strains and cultivars used as interstocks produced dwarfed trees (Asakura et al., 2002; Ito, 1988; Koshita et al., 2004; Manago et al., 2000; Morinaga et al., 2000; Nezu et al., 1999). Although a great number of apple trees in Japan are grafted on dwarfing interstocks, the roots of vigorous rootstocks make trees a larger size some years after field establishment (Kikuchi and Ikeda, 2001). Japanese persimmon trees on dwarfing interstocks are becoming larger than expected, because their roots are still seedlings.

Studies on in vitro propagation of Japanese persimmon began 20 years ago. Many commercial cultivars were micropropagated and produced as own-rooted nursery stocks (Copper and Cohen, 1984; Fukui et al., 1989, 1992; Fumuro et al., 1988; Murayama et al., 1989; Sarathchandra and Burch, 1992; Sugiura et al., 1986; Tao and Sugiura, 1992; Tetsumura et al., 1992; Tetsumura, 1997), while explants were harvested from shoots (suckers) sprouting from rootstocks' roots of dwarfed trees and micropropagated successfully (Ito-Ogawa et al., 2001; Kagami et al., 1995). Kimura et al. (1985) assumed that such a rootstock might have a genotypic dwarfing ability. In fact, some of the trees grafted on these micropropagated rootstocks showed dwarfism (Kamada et al., 2004; Wada et al., 2004). In the near feature, other cultivars grafted on the potentially dwarfing rootstocks will be investigated for their field performances under various conditions. However, the expensive facilities required for micropropagation and the multiplication rate of micropropagation of Japanese persimmon is high partly because of the difficulty in acclimatization of micropropagules (Tao and Sugiura, 1992). This fact will possibly present an obstacle for success of commercial micropropagation of dwarfing rootstocks.

The phenomenon of cuttings from the micropropagated trees rooting better than those from grafted trees has been reported for many woody plants (Hogue and Neilsen, 1991; Howard, 1987; Howard et al., 1989; Jones and Webster, 1989; Marks, 1991; Plietzsch and Jesch, 1998; Tetsumura et al., 2001). Micropropagated stock plants of Japanese persimmon also produced the hardwood and softwood cut-

Figure 1. A well-rooted hardwood cutting derived from a micropropagated Japanese persimmon tree.

Figure 2. A well-rooted leaf-bud cutting derived from a micropropagated Japanese persimmon tree.

tings with high rooting ability (Tetsumura et al., 2002) (Figs. 1 and 2), which will promote commercial production of the dwarfing rootstocks. The apple trees grafted on micropropagated dwarfing rootstocks often showed undesirable characteristics, such as more vigorous shoot growth, delayed cropping, and increased sucker production (Jones and Hadlow, 1989). However, apple trees on dwarfing rootstocks derived from cuttings, which were collected from micropropagated plants, were similar to trees on rootstocks from conventional propagation, not to trees directly from micropropagation (Jones and Webster, 1993). Dwarfing rootstocks propagated by cuttings will exhibit their dwarfing ability in the field, since trees propagated by cuttings of Japanese persimmon grew less vigorously than micropropagated trees (Tetsumura et al., 2003). In the meantime, cuttings taken from suckers sprouting from rootstocks' roots of a dwarfed Japanese persimmon tree had a high rooting ability (Tetsumura et al., 2000) (Fig. 3), which will shorten a term for production of dwarfing rootstocks because of no need of micropropagation. Although it takes a very long period of time to research on rootstocks for fruit trees, we have to pursue further investigations on dwarfing rootstocks of Japanese persimmon.

Figure 3. A source of cuttings of a potentially dwarfing rootstock for Japanese persimmon. A dwarfed tree cut off just above the ground level in spring. Many root suckers sprouted and elongated in early summer. Their rooting ability was high.

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Potential of Neem Extracts for Insecticide©

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INTRODUCTION

Synthetic pesticides often cause environmental contamination and can be a great risk to human health. As a consequence, there has been an intense search for safer pesticides. Neem (*Azadirachta indica* A. Juss, syn. *Melia azadirachta* L., *Antelaea azadirachta* (L.) Adelb.) is a tree in the mahogany family *Meliaceae*. It is the only species in the genus *Azadirachta*, and is native to India and Burma. It became naturally distributed throughout much of the Indian subcontinent, particularly in drier areas. The medicinal properties of the neem tree have been well known in the Indian subcontinent for thousands of years. The bark, leaves, flowers, seeds, and fruit of neem plants are used to treat a number of diseases, and the tree had a cherished place in all ancient Indian treatises on medicine (Musabyimana and Saxena, 1999). Neem oil is pressed from seeds of the neem tree and has powerful pest controlling activities and medicinal properties (Singh and Singh, 1998; Pavela et al., 2004). Of primary interest to research scientists is its activity as an insecticide. Major component of neem seed oil is azadirachtin, which is a chemical compound belonging to the limonoids. Azadirachtin has insect growth regulator characteristics and interferes with the molting process during growth. Therefore, it causes death only to immature stages (larvae and nymphs). However, it is known to have repellency to some adult insects. Pesticides made from the neem oil are much safer than synthetic pesticides. Use of neem products for plant protection will reduce the demand for chemical pesticides and thereby reduce the environmental load of these synthetic pesticides. In U.S.A., E.C., and China, the neem oil has been officially authorized as organic material.

However, in Japan the neem oil is not registered as an agricultural chemical, and it is not possible to use it for the purpose of controlling insect pests currently. Recently, neem and azadirachtin have gained momentum as specific agricultural chemicals recognitized as "safe" chemicals for human's health (The Ministry of Health, Labour and Welfare along with one Food Sanitation Law revision in May, 2003). This would support the safety of the element of the neem oil and neem in agricultural sector in the future. The objective of this research was to evaluate neem as a pest control material in plant cultivation.

MATERIALS AND METHODS

Two formulations were tested: "Neem Extract 1% EC AZA" (azadirachtin 10,000 ppm; Fortune Bio Tech, India) and "Neem oil Natural" (natural extracted material, ca 2000 ppm azadirachtin; Fortune Bio Tech, India). Dilutions of both materials (the range of 3 to 50 ppm) were applied to test plants using a handy spray. Water was used as a control. All tested plants in a greenhouse were damaged by various

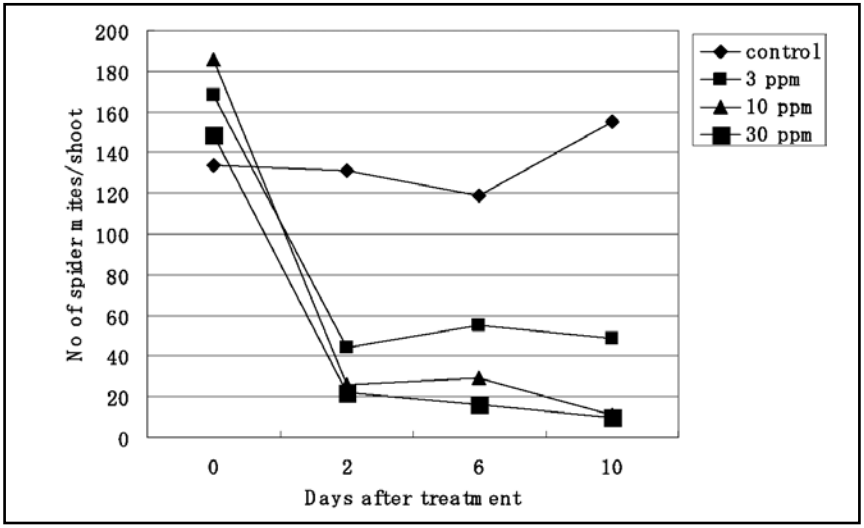

Figure 1. Effect of concentrations of the neem extract 1% EC AZA on number of two-spotted spider mite (*Tetranychus urticae*) on shoot of *Chrysanthemum* × *grandiflorum*.

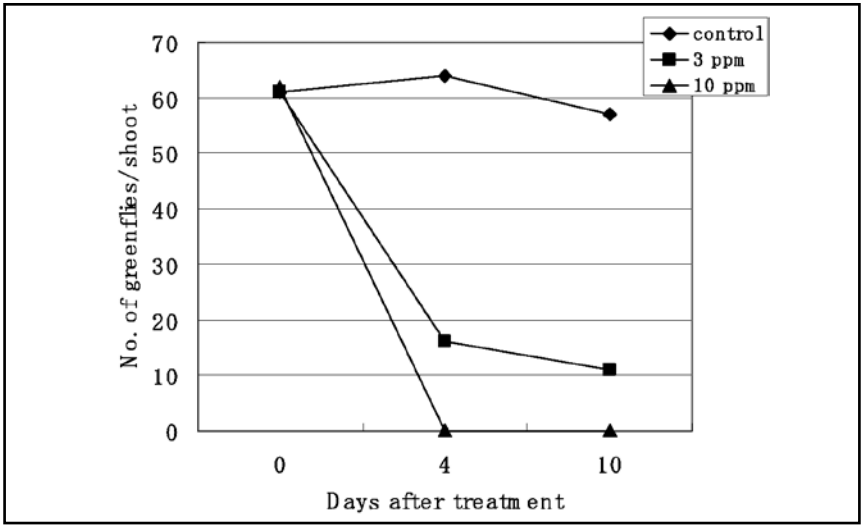

Figure 2. Effect of concentrations of the neem extract 1% EC AZA on number of greenflies (*Myzus persicae*) on shoots of *Kalanchoe blossfeldiana*.

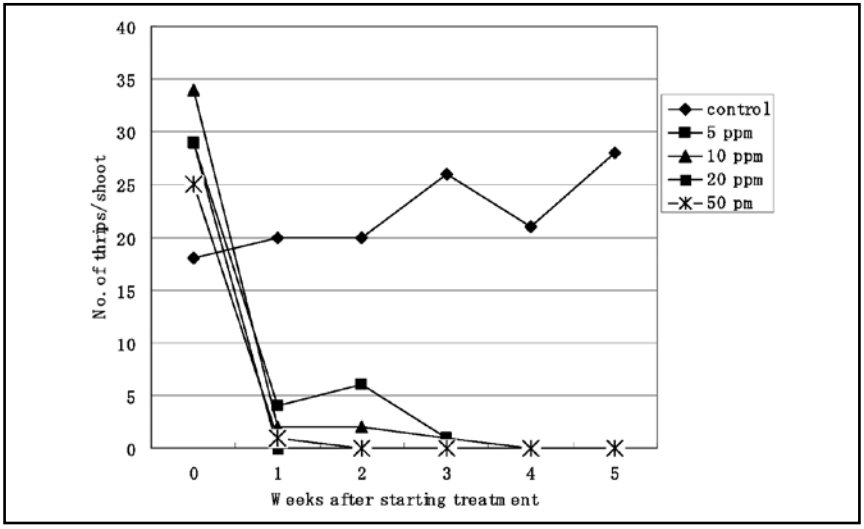

Figure 3. Effect of concentrations of the neem extract 1% EC AZA on number of western flower thrips (*Frankliniella occidentalis*) on shoot of *Petunia* × *hybrida* 'Fuller Red'. Treatment dilutions were applied every week.

harmful insects: *Chrysanthemum grandiflorum* (syn. *Dendranthema* × *grandiflorum*) by two-spotted spider mite (*Tetranychus urticae* Koch), *Kalanchoe blossfeldiana* cv. by greenflies (*Myzus persicae* Sulzer), and *Petunia* × *hybrida* 'Fuller Red' by western flower thrips (*Frankliniella occidentalis* Pergande). Treatment dilutions were thoroughly sprayed on 12- to 20-pot plantlets of each treatment in each test. For *P.* × *hybrida* 'Fuller Red', treatment dilutions were applied every week. After the treatment, shoots were collected from each plant and the effects of concentration of the treatment dilutions on the number of insects were investigated.

RESULTS AND DISCUSSIONS

The damages by various harmful insects has decreased by spraying neem extracts compared with the water control. There are no differences observed on the effect of both Neem Extract 1% EC AZA and Neem oil Natural (Figs. 1 to 3). The treatment concentration influenced the control. However, under higher treatment concentrations plant growth of *P.* × *hybrida* 'Fuller Red' was exhibited and those flowers were damaged by neem (Figs. 4 and 5). As a result of the study, neem materials were able to achieve a constant effect of control if properly used. Therefore, the possibility of contributing to a new pest control system that considers the environment was shown by using neem materials as parts of a rotation in the pest control program.

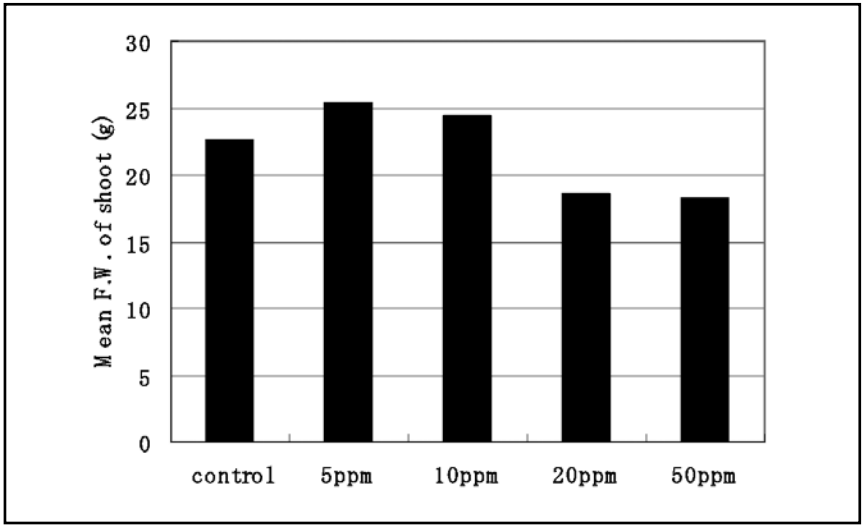

Figure 4. Effect of concentrations of the neem extract 1% EC AZA on fresh weight (F.W.) of shoot of *Petunia* × *hybrida* 'Fuller Red' after 6 weeks. Treatment dilutions were applied every week.

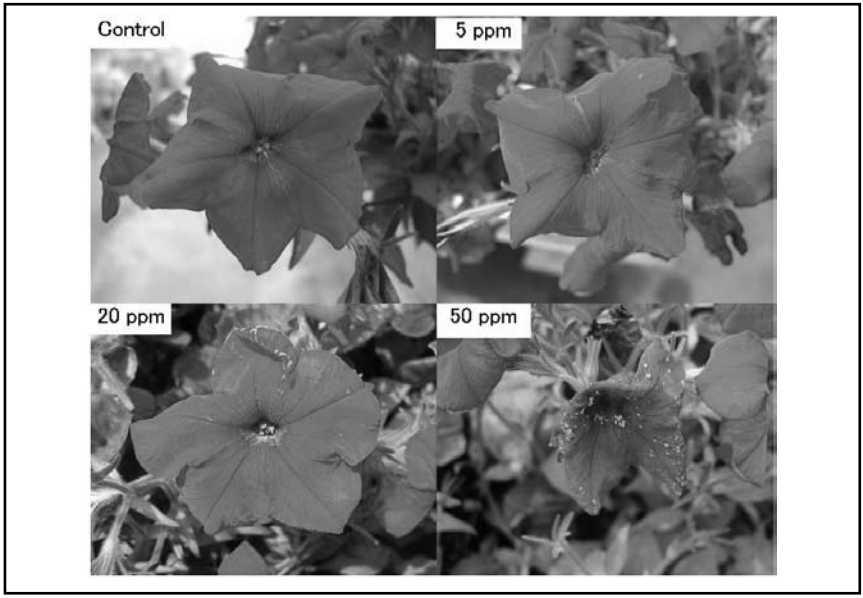

Figure 5. Effect of concentrations of the neem extract 1% EC AZA on flowers of *Petunia* × *hybrida* 'Fuller Red' after 6 weeks. Treatment dilutions were applied every week.

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Summary of Development, Introduction, and Marketing Strategy to Share Lotus in the Southeast United States©

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Lotus (*Nelumbo nucifera* Gaertn.) is a well-known plant based on its edible, ornamental, and medicinal uses. Lotus is an impressive flowering rhizomatous, perennial, aquatic herb, which has a long history in the diverse cultures of the Orient (Follett and Douglas, 2003). The plant is sacred in the Hindu and Buddhist religions. Sacred lotus has been cultivated in Asia for thousands of years and has been a prestigious crop in China for nearly 5,000 years (Shen et al., 2002). Lotus is known in the United States, and there is a native yellow-flowered species (*N. lutea* Willd.). However it is used sparsely in the landscape and rarely eaten. A developing and open world economy has led to increasing exchanges and meshing of cultures, ideas, and horticultural treasures. In 2000, two professors and two graduate students from Auburn University visited Wuhan Institute of Botany in Wuhan, China, in the Hubei province. Their hosts at the Institute shared the beauty, diversity, and development advances of lotus. Professors from Auburn University returned to Auburn with the enthusiasm and the cooperative relationship with China to develop and share the plant that is used and enjoyed by billions of people throughout the world with the gardeners and nursery producers of Alabama and the Southeast United States. This paper offers a summary of the on-going development and promotion of lotus and the exploration of opportunities for farmers in an economically depressed region of Alabama called the "Black Belt." The Black Belt is a crescent-shaped region extending from Texas through Alabama to Virginia and is characterized by the dark color of the soil that is also synonymous with large areas of economic poverty. It is also a region that has developed a viable catfish and tilapia industry. This industry has the potential to meet the cultural requirements of lotus as a companion crop.

The plan to develop this new economic venture was to establish a parallel program of research and marketing similar to other products in our economy. Research and marketing work hand-in-hand, so that when growers have the knowledge and infrastructure to produce and ship lotus, buyers will be knowledgeable and eager to buy the plants. Research involves cultivar evaluation and adapting production programs to meet the requirements of a U.S.A. workforce and economy. Economic analysis of the production program was planned to provide realistic information for farmers and bankers that may be financing the venture. Research also looks at incorporating lotus production into an already strong aquatic fisheries production industry to enhance utilization efficiency of production space and increase profits.

Marketing involves expanding the scope of the program, which currently includes Mississippi and Georgia as well as Alabama. The land-grant universities in these states have the respective Cooperative Extension systems, including the Master Gardener programs, to disseminate educational information as it becomes avail-

able. Cultivar evaluations are in Cullman and Auburn, Alabama, and Savannah, Georgia. Plantings are planned for Mississippi in 2007. Field days at research stations and displays at Botanical Gardens in Alabama are part of the promotional activities. A web site has been established to provide regular updates on our research activities to the interested gardeners and producers. Surveys at garden centers and botanical gardens will be conducted this year to learn consumer preferences for size, color, and acceptance of lotus for the garden. Target audiences will be random home gardeners and Master Gardeners within the various cooperating state programs. There is also an edible program being developed by vegetable specialists in the other cooperating states including cultivar evaluation and culinary evaluation for the American palette.

Some initial results from early research programs include fertility requirements, soil depth, storage requirements, and effects of disbudding on propagule development. One year's data has been collected on cultivar evaluation including desirable characteristics of color, size, flower number, height of flower above leaves, number of leaves, and overall ornamental ratings.

A preliminary study was conducted to investigate the effects of fertilization and soil level on performance of container lotus. Three ornamental cultivars were selected for the two studies. 'Embolene' (medium sized, with numerous leaves and flowers) and "98 Seed" (large unnamed seedling with numerous leaves and few but large flowers) were used in examining the effect of container soil level on the growth of lotus. "No1," another unnamed seedling (medium sized, with few emerging leaves and flowers) was used in testing the effect of two fertilization rates. Lotus rhizomes were divided and planted in 28.4-L (7.5-gal) black plastic containers [38 × 36 cm (15 × 14.2 inches)]with no holes on 17 May 2004, when new young leaves (coin leaves) had emerged in the original stock pot. For "No1," each pot was filled with 1/2 level ([1/2 L, 18 cm (7.1 inches)] of sandy loam soil. For the other two cultivars, containers were separated into two groups, one group was filled to 1/2 container soil level while the second group was filled to 3/4 container soil level [3/4 L, 27 cm (10.6 inches)] with a sandy loam soil.

After planting, all pots were filled with water. Fertilizer was applied once every 20 days from 9 June 2004 when the lotus had at least several coin leaves and possibly one or two emerging leaves. Fertilizer treatments ended on 21 July 2004. Water solution samples were taken twice (1 h before fertilization and 24 h after fertilization) in the afternoon in the same pots to better monitor the nutrient status. When taking samples, pots were irrigated to the full level of water by hand carefully to ensure the same water level. On 23 Aug. 2004, young, fully expanded leaves were sampled from each cultivar for nutrient analysis. Fertilizer applied was water soluble 20-10-20 (Pro•Sol Inc, 1792 Jodie Parker Rd., Ozark Alabama 36360, U.S.A.). One and two teaspoons (4 g and 8 g, respectively) of fertilizer were added to each of 10 pots of lotus "No1." Cultivars in the soil level study received one teaspoon (4 g) of fertilizer at the same dates.

Data collected included number of emerging leaves, flowers, propagules (normally containing 2–3 internodes), and number of expanded internodes. Fresh root (combining rhizomes and roots) weight was also collected.

A summary of practical results of this initial evaluation was that the average initial pH value of 7.3 of all water samples taken from the three cultivars on 9 June vacillated depending on the cultivar, soil level, and concentration of fertilizer applied. Unlike pH, electrical conductivity (EC) in water solution exhibited regular expected changes for all cultivars during fertilization: (1) EC increased after fertilization and then went down with the absorption of fertilizer; (2) EC increased with the concentration of fertilizer within cultivars.

Two teaspoons of fertilizer on "No1" lotus increased root fresh weight, number of propagules, and expanded internodes, which are important parameters in commercial production compared to the number of emerging leaves and other parameters of lotus receiving 1 tsp of fertilizer. Lotus plants respond favorably to increased fertilizer rates. However, the response level to fertilizer depends on the cultivar, container size, and possibly the soil level. Generally, 2 tsp of fertilizer was excessive relative to fertilizer efficiency, because the utilization rates of N, P, and K were obviously lower than those of 1 tsp treatment.

In the soil level study, treatments of 1/2 L and 3/4 L for 'Embolene' and "98 Seed" had no significant effect on growth except for the flower number of the latter. In 3/4 L for 'Embolene', the fresh weight of roots, the number of propagules, and expanded internodes only slightly increased, but the number of emerging leaves and flowers slightly decreased in contrast to that of 1/2 L. For "98 Seed," in the group of 3/4 L, the number of flowers decreased in comparison with the group 1/2 L. All plants in 1/2 L containers had 1–3 flowers but only two of 6 pots in 3/4 L had 1–2 flowers. Data suggested increasing soil level in containers decreased flower formation and ornamental value of "98 Seed." Fresh weight of roots in 3/4 L also decreased. A slight increase was found in the number of propagules, expanded internodes and emerging leaves.

Edible lotus tubers have vitality for about 20 days under room temperature conditions. In a study evaluating treatments to extend the potential storage/shelf-life of lotus rhizomes, ornamental lotus, *N. nucifera* 'Embolene', was used to evaluate effects of gum acacia (natural bio-polymer), peat moss, and hydrogel (super-absorbent synthetic polymer) on cooler-stored lotus propagules. Results indicated there was no significant difference in retaining water and prolonging shelf-life among all treatments during 45 days of storage. After harvest, there were large differences in total sugar among treatment samples, but reducing sugar maintained a relatively stable level. No significant effect of treatments was found on carbohydrate change. Low temperature is possibly the most critical factor to influence the viability of lotus tubers or rhizomes during storage.

For the lotus cultivars tested, discarding or disbudding flowers increased biomass and the production of propagules. In production, where flowers are not necessarily needed, this cultural practice could increase profits, depending on the cost analysis for labor to execute the disbudding practice.

Some of this data represents only 1 year's results ,and the studies are currently being replicated. This project is an on-going effort to develop a production and marketing strategy to promote the value of lotus as an ornamental and food crop. People

throughout the world appreciate this plant. We would like to share that excitement with people in the southeast and at the same time offer economic opportunities to farmers in depressed areas of Alabama's Black Belt Region. You can follow our efforts on our web page at <www.ag.auburn.edu/landscape>. Look for "Lotus" under the heading of "Research."

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I.P.P.S. New Zealand and Qualification of I.P.P.S. Japan©

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We, Katsuaki Suzuki (MS student) and Yutaka Hirata, attended the 27th Annual Meeting of I.P.P.S New Zealand at Dunedin in the South Island from 27th to 30th April 2006. We arrived in Auckland April 24th and traveled to Dunedin aided by Mr. Peter Waugh via Hamilton. On the way to Dunedin, we visited many beautiful cities and towns including Hamilton, Oxford, and Wellington in the North Island and then traveled to the South Island visiting Picton, Nelson, Greymouth, Christchurch, and Dunedin (a most Scottish town). We returned to Wellington and Hamilton, visiting Maori cultural regions in the north and finally returned to Auckland. Low population and high sheep and cattle numbers with large areas of grape growing and pine forests, were very impressive even for us. Gardening and horticultural activity using organic technology and enthusiasm are fairly high. The strong basis of IPPS New Zealand (I.P.P.S. N.Z.) has come from their needs, life style, and social status.

The Conference program was as follows:

April 27 (Thursday): Registration in the afternoon, welcome assembly, visiting the city—especially Speight's Brewery—and then the Plant Auction back at the Hotel.

April 28 (Friday): General opening meeting with breakfast in museum, opening remarks by Mayor Peter Chin. Visiting botanical garden and memorial planting. In the afternoon visiting Blueskin Nursery. General Meeting of I.P.P.S. N.Z. and new committee selection. President Grant Hayman will change to new International Director. In the evening funny and exciting "Icon Party."

April 29 (Saturday): Presentations, visiting Southern Treasures, Marine Research Institute for sea vegetables, and Larnach Castle. Official evening and awards.

April 30 (Sunday): In the morning presentations including Hirata's presentation. Depart for Wellington and Hamilton.

During the meeting, exciting programs were devised with nice parties and excursions.

Based on the visiting and meeting, several important suggestions could be obtained.

- Main activities are organized by members and supported by companies and growers through sponsorship.
- Financial basis is strong.
- Member size is twice and activity is very high with information exchange. Gardening activity and demands are bigger than Japan, showing importance of social status.
- Unique events and activities have been organized such as "Icon Party" and "Plant Auction."

Hormonal Morphogenesis of Mulberry Tree Mutant©

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Mulberry tree mutant 'Garyu' exhibited bending on its stem similar to dwarf mutant of trifoliate orange tree 'Hiryu'. Hormonal treatment by GA_3, (S)-(+)-ABA, and their mixture (GABA) showed that normal stem mulberry types, 'Ichibei' and 'Ryoumenguwa', responded to these hormones, whereas bending-stem mutant mulberry, 'Garyu', and hybrid mulberry, 'Shin-ichinose', did not respond to them. Through genetic analysis, we show that mulberry had hormonal related genes *GIA* and *BRI1* homolog genes.

INTRODUCTION

Mulberry trees (*Morus* sp.), species belonging to Moraceae family, have many uses. Sanchez (2002) noted that the uses of mulberry were for sericulture, fruit, wood, landscaping, and forage. However most of the mulberry production in Japan is to produce foliage for sericulture (rearing of silkworms for the production of raw silk).

Mulberry farm management is mostly designed to have high productivity of foliage and highly nutritive leaves for the silkworm. Tree pruning is one of the agronomic treatments frequently used to control the height of the mulberry tree so it will be easier for farmers to harvest the foliage. Hormonal control of tree developmental has been used for improvement in several plant species. Trifoliate orange tree is one example of a plant species that has been successfully used as dwarf-controllable stocks related to hormonal control in citrus tree breeding (Lliso et al., 2003).

Mulberry has many genetic variations in Japan (Machii et al., 2001). we studied the hormonal control of morphogenesis in the mulberry mutant 'Garyu', which has morphological growth similar to the trifoliate orange tree mutant 'Hiryu'.

MATERIALS AND METHODS

Four mulberry tree genotypes, 'Garyu', 'Ichibei', 'Ryoumenguwa', and 'Shin-ichinose', were used in our study. We first compared the distinctive morphological characteristics of 'Garyu' with the wild type 'Ichibei'. Next we carried out gibberellic acid and abscisic acid hormonal treatments and observed the effects of these treatments on their morphological characteristics. We also performed genetic analysis on mulberry 'Garyu' and 'Kokuso 16' to determine the hormonal-related genes in mulberry. Steps in genetic analysis were PCR, cloning, and sequencing.

RESULTS

Morphological Observation. Observation on 'Garyu' showed that it exhibited stem bending similar to that of the trifoliate orange tree mutant 'Hiryu' (Figs. 1A and B). Distinctive stem characters on mulberry were measured in the mid-summer. Distinctive shoot characters observed were: length, internode diameter, thickest internode diameter, the thinnest internode diameter, internode number, internode distance, the longest internode, and the shortest internode. Morphological

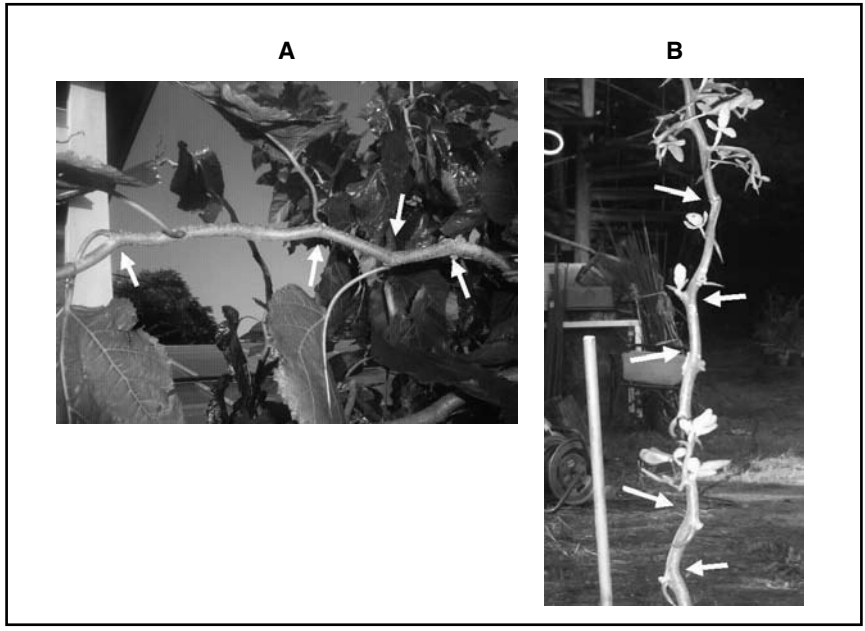

Figure 1. Stem morphology of mulberry 'Garyu' in field-grown (a) and trifoliate orange tree 'Hiryu' (b). Arrows showed some of the nodes position that exhibit bending stem characters.

characteristics that were found to be significantly difference between 'Garyu' and 'Ichibei' were only internode distance and the longest internode of the branch (Table 1). Internode distance of 'Garyu' was shorter than the wild type 'Ichibei'. These internodal distance measurement results are in agreement with the list of mulberry genetic resources that show mulberry 'Garyu' had a relatively short internode distance among 260 mulberry genotypes (Machii et al., 2001). The average of the longest internode distance was also significantly shorter in 'Garyu' than 'Ichibei' (Table 1).

Hormone Treatment Experiment. Treatment with GA_3 and (S)-(+)-ABA did not significantly affect the observed characters in the mutant 'Garyu'. Similarly, in the mulberry hybrid 'Shin-ichinose' the observed characters were not significantly affected by treatment with GA_3 and (S)-(+)-ABA. Responsive effects were found in wild type mulberry 'Ichibei' and the leaf developmental mutant 'Ryoumenguwa' (Table 2).

Mulberry wild type 'Ichibei' was grown dominantly to the vegetative phase (Fig. 2A); on the other hand, mulberry 'Garyu' was grown dominantly to generative phase (Fig. 2B).

Genetical Analysis. Two bands indicating gene fragments were found in agarose gel electrophoresis result of mulberries PCR product using *GAI*-gene-generated primers and in case of PCR result using *BRI1*-gene-generated primers on mulberries, there were three bands indicating gene fragments appeared (data not shown). We cloned a band of each PCR product and sequenced them. We found that from

Table 1. Variables that were measured at shoot in mulberry mutant 'Garyu' and wild-type 'Ichibei' in mid-summer.

Variables	N	Measurement 'Garyu'	Measurement 'Ichibei'	unit	t value
Shoot length	6	139.67 ± 43.72	178.33 ± 31.42	cm	-1.7594
Internodes diameter	6	8.80 ± 0.49	9.22 ± 1.50	mm	-0.6555
Thickest internodes	6	15.61 ± 1.92	15.70 ± 3.78	mm	-0.0529
Thinnest internodes	6	2.44 ± 0.57	3.19 ± 0.79	mm	-1.8870
Internodes number	6	38.8 ± 11.7	33.0 ± 7.4		(0.8221)
Internodal distance	6	3.74 ± 0.45	5.46 ± 0.46	cm	-6.4959*
Longest internodes	6	6.57 ± 0.52	9.60 ± 1.35	cm	-5.1387*
Shortest internodes	6	1.08 ± 0.44	1.82 ± 0.69	cm	-2.1858

Asterisk mark (*) on t value column indicates that there is a significance difference in 95% confidence interval among variable measurement in mulberry mutant 'Garyu' and wild-type 'Ichibei'. Minus value on t value column indicate that variable measurement of mulberry mutant 'Garyu' is lower than wild-type 'Ichibei'. Number in parentheses on t value column indicated that the t value was calculated by using logarithmic transformed data. n = number of samples that were measured for each genotype.

Table 2. Effect of hormones treatment to mulberry (4 days after treatment).

Mulberry genotype	Number of Flower		Number of Leaf		Remark.
'Garyu'	2.35	ns	0.33	ns	No effect
'Ichibei'	6.45	*	0.59	ns	Effect
'Ryoumenguwa'	3.79	*	2.61	ns	Effect
'Shin-ichinose'	0.83	ns	1.88	ns	No effect

* Significant; ns, not significant

mulberry 'Kokuso16' the first PCR product had homology to members of DELLA protein (Table 3) and from 'Garyu' the second PCR product had homology to conserved region of *BRI1* gene, LRR (leucine-rich repeat) (Table 4).

DISCUSSION

'Garyu' has a bending stem character. The bending character was similar to trifoliate orange tree 'Hiryu'. Experiment with GA_3 and (S)-(+)-ABA treatments on 'Garyu' showed that it was not affected by the application of either hormone. 'Garyu' did not respond to GA_3, (S)-(+)-ABA or the mixture GA_3 and (S)-(+)-ABA in both vegetative and generative phase.

Phytohormone GA_3 and growth inhibitor (S)-(+)-ABA have roles in development of morphological stem characters. The GA can enhance internodal cell elongation that further will promote stem elongation and plant height in rice (Kende et al., 1998). The ABA can reduce cell elongation and further reduce de-etiolation in

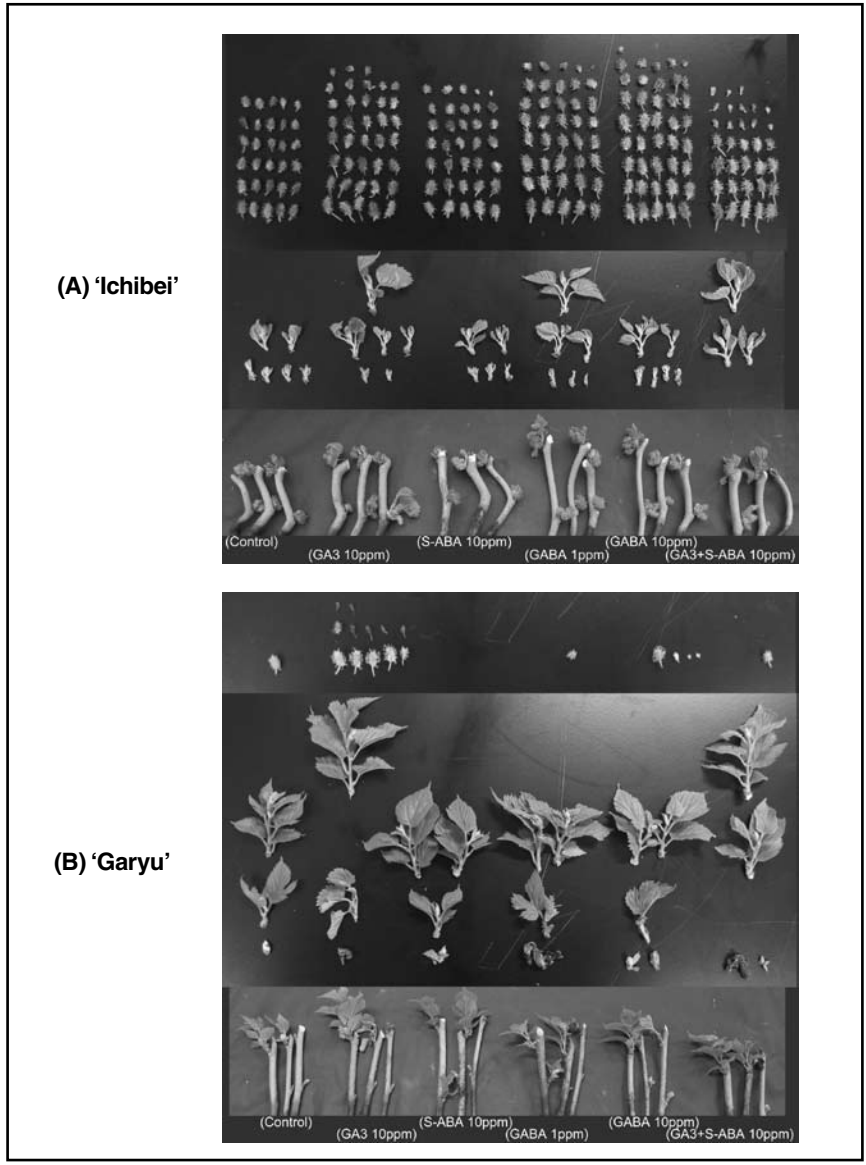

Figure 2. Morphological growth conditions of mulberry wild type 'Ichibei' (a) and bending stem mutant 'Garyu' (b). Label f indicates generative phase (flowers) and label l indicates vegetative phase (leaves at shoots). Each photo of mulberry hormones treatment responses were arranged as follow: Control, GA_3 10 ppm, S-(+)-ABA 10 ppm, GABA 1 ppm, GABA 10 ppm and mixture GA_3+S-(+)-ABA 10 ppm.

Table 3. Homology of *GAI* gene fragment clone sequence of mulberry 'Kokuso 16' with other plants.

Plants	Homology (%)	Description	Gene bank accession	Sequences hit number
Brassica rapa	87	DELLA protein (RGA2) gene	AY928550.1	178/207
Arabidopsis thaliana	86	RGA1 (repressor of GA1-3 1); transcription factor (RGA1) mRNA	NM_126218.2	105/122
Vitis vinifera	82	GAI-like protein 1 (GAI1) gene	AF378125.1	136/164
Cucurbita maxima	83	Gibberellic acid insensitive phloem (GAIP) mRNA	AY326306.1	178/214

Table 4. Homology of *BRI1* gene fragment clone sequence of mulberry 'Garyu' with other plants

Plants	Homology (%)	Description	Gene bank accession	Sequences hit number
Mangifera indica	85	Putative leucine-rich repeat protein gene	AY776277.1	265/308
Capsella rubella	86	ORF1, ORF2, ORF3, ORF4, ORF5 and ORF6	AJ303349.1	314/379
Arabidopsis thaliana	82	BRL1 (BRI 1 LIKE); kinase BRL1 mRNA	NM_104437.1	355/453
Daucus carota	81	LRR-S/T-RLK mRNA for putative leucine-rich repeat-type serine/threonine receptor-like kinase	AB178084.2	312/386

tomato (Fellner et al., 2000). Although they have contrary functions, the mixed application of GA and ABA has been shown to promote the generative phase in long-day plants (Kamuro et al., 2001).

In dwarf rootstock of orange tree as offspring of dwarf trifoliate orange tree, GA_3 takes a role in regulation of vegetative and generative phase. Competition among generative and vegetative phases as a result of GA regulation developed dwarf-type plants (Lliso et al., 2003). In the case of 'Garyu' in our experiment, the developmental phase during GA_3 and (S)-(+)-ABA application whole seedlings were dominantly developed into the generative phase and completed the vegetative phase. This case resulted in ineffective response of GA_3 and (S)-(+)-ABA application.

Muangprom et al. (2005) showed that gibberellic acid promoted stem growth by causing degradation of DELLA proteins via the ubiquitin-proteasome pathway. The most widely utilized dwarfing alleles in wheat (*Triticum aestivum*; e.g., *Rht-B1b* and *Rht-D1b*) encoded gibberellin-resistant forms of a DELLA protein that function as dominant and constitutively active repressors of stem growth. The other members of DELLA proteins were *RGA1* of *Arabidopsis thaliana*, *GAI* of *Vitis vinifera*, and *GAIP* of *Cucurbita maxima*, *GRAS* of *Musa* × *paradisiaca*, dwarf 8 of *Zea mays*, *SLN1* of *Hordeum vulgare*, and *rht-D1a*.

We found the homolog of *GAI* gene fragment in mulberry 'Kokuso 16' and also conserved region of *BRI1* gene fragment, which was leucine-rich repeat (LRR) in mulberry 'Garyu' in our genetical analysis. Zhou et al. (2004) mentioned that *BRI1*-like receptor kinase (*BRL1*) was identified as an extragenic suppressor of a weak *bri1* allele, *bri1-5*, in an activation-tagging genetic screen for novel brassinosteroid (BR) signal transduction regulators. The *BRL1* encodes a LRR receptor-like protein kinase (LRR-RLK). They showed that in *A. thaliana* sequence alignment revealed that *BRL1* is closely related to *BRI1*, which is involved in BR perception.

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Development of a Pest Warning System to Reduce Chemical Use in Hardy Nursery Stock Production and by Professional Gardeners©

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INTRODUCTION

In Belgium a pest early warning system was introduced in 1996 by the extension service of the Belgian Ministry of Agriculture.

Its creation was prompted by the withdrawal from the market of several broad-spectrum pesticides and the growing environmental consciousness of both growers and their customers. The warning system meant that existing routine calendar-based treatments could be replaced by a more integrated pest management approach with selective pesticides and more attention paid to use of natural enemies. The aim of the system is reduced and more effective use of pesticides by limiting treatment to the moment in the lifecycle of a pest when it is most vulnerable. The number of treatments and thus the cost therefore decrease. The system is available to nurseries, garden contractors, and local authority parks and open spaces managers.

The service initially provided warning messages regarding five pest species. In 1997 operation of the warning system was transferred to the Research Centre for Ornamental Plants. At that time it was part of a 5-year project receiving financial support from the European Union, and the warning messages were free to growers. In 2001 the funding was finished and the system had to begin to charge a membership fee to cover its costs. This did not prevent uptake, and the system has developed further so that in 2006 it provides warnings about the activity of 50 pest species including insects, mites, and some fungal diseases.

THE BASIS OF THE WARNING SYSTEM

There are three major elements to the warning system. These are detailed below:

Observation. There are observation points in the four important nursery areas in the Flanders region of Belgium. Observation points include nurseries, gardens, and parks. Pest advisers using hand lenses carry out observations in the field, and plant samples are also collected for laboratory examination and diagnosis using microscopes and Berlese funnels. Samples placed in the Berlese funnel are exposed to heat and light, which makes any pests hidden within a sample escape. While migrating they fall into a small jar of preserving liquid (alcohol) and can then be removed and identified.

Warning. Warning messages are sent when we detect pests that are hatching or that are at another stage in the lifecycle when control measures are most effective. The messages contain information about the life cycle of the pest, a description of symptoms, and advice on treatment (including products and the dose that may be required). They are illustrated with pictures of symptoms to make recognition easier. Each message contains advice to check the plants for symptoms first. The message

is intended as an alert to encourage growers to go out and check their crops, not an instruction to apply treatments regardless of the presence or absence of the pest.

Education. To manage pests, growers must learn how to recognise them and understand something about their way of life. Therefore, an important element in the pest-warning programme is the provision of courses and practical sessions for users. Each year members of the scheme are sent a number of illustrated index cards containing information about pests and diseases and about the natural enemies that control them. The cards contain comprehensive information about the lifecycle of the species, each stage being described and illustrated with pictures. Diagrams of the lifecycle clearly show the stage when control measures are most effective.

Growers should also be aware that not everything they see crawling on their plants is harmful. Many organisms are very useful, so the warning scheme also promotes the creation of habitats for beneficial organisms, such as wild flower areas to harbour hoverflies and lacewings.

SOME PARASITES INCLUDED IN THE SYSTEM

Scale. Scales demonstrate the importance of observations and warnings. The best moment to control these pests is when the eggs hatch and the young larvae come out from under the mother's protective shield. During a short period these "crawlers" are mobile and shieldless, which makes them vulnerable to pesticides. The scales can't be reached for the rest of the year, except for a very short period in spring when they migrate to lay eggs. Some species of scales lay eggs outside the shield in white egg sacs. Scales are most obvious in spring, which is when people start to panic and want to spray, but at this stage treatments are useless.

Gall Mites. Because of their way of life, gall mites are one of the most difficult pests to control. Many species have a very complicated lifecycle. In general the migration period is the best time for control measures. The rest of the year they are protected by the galls of plant tissue. In the case of *Aceria unguiculata*, which occurs on boxwood, the plant does not produce closed galls, but the mites do cause heavy stunting of the upper shoots. As a result they are difficult to reach in the deformated leaves. They migrate to new shoots on warm sunny days. A warning message is sent in spring when the overwintering females migrate towards the upper shoots.

Spider Mites. It is important to control these pests as soon as possible in the season, while winter eggs are hatching. Delay of treatment can lead to permanent visual damage in the case of boxwood spidermite (*Eurytetranychus buxi*) or needle loss and even death in the case of conifer spinning mite (*Oligonychus ununguis*).

Plant Lice. Treatment when winter eggs are hatching is necessary to prevent large-scale infestations.

Vine Weevil (*Otiorhynchus sulcatus*). This can be controlled biologically by using nematodes in late summer to early autumn or spring. Field trials showed a good result for the spring application. Chemical treatment must be carried out when the adults hatch from the pupa in early summer.

SCHEME MEMBERSHIP

Our membership includes a number of services. Each member receives a folder to put the warning-messages and illustrated index cards in. We also send messages regarding recent developments in crop protection, correct and efficient use of products, and so on. Members can also phone us for advice. Samples can be sent for identification and advice given on treatment. There is also information available on our website with a part which is exclusive for members.

Breeding Strategies for Woody Ornamentals: Selection Towards Disease Resistance with Particular Reference to Powdery Mildew©

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In breeding programmes, including those for woody ornamentals, polyploidization and interspecific hybridisation offer potential to introduce new genetic variation. Some examples in *Buddleja* and *Hibiscus* breeding programs are presented. In roses, as in many other species, disease resistance breeding is currently one of the major challenges. To be able to select genotypes with enhanced disease resistance, appropriate bioassays are needed. Inoculation protocols to test powdery mildew resistance of both parent plants and large populations of progenies have been developed. By these methods an early selection towards powdery mildew resistance is possible in a cost-effective way.

INTRODUCTION

Currently, in woody ornamentals, most new introductions are the result of "lucky finds" in seedling populations or from spontaneously occurring mutations. Since most plants are vegetatively propagated, these mutations might result in a stable, new cultivar. Only in a few genera (such as *Rosa*, *Rhododendron*, *Clematis,* and *Hydrangea*) are progenies raised from controlled pollinations and a planned breeding and selection scheme followed. For most species, the market share is too low to justify costly breeding programs.

Objectives for new introductions vary with the genus and during time. Novelty itself (flower, growth habit, leaf colour, and fruit set for example) is today still the most important character to interest both the grower and the consumer. Besides morphological characteristics, physiological ones such as winter hardiness, growth vigour, flowering period, and multiplication rate may also be selection criteria. More recently, driven by a market desire to reduce the use of chemical fungicides, disease resistance has become a major criterion for many genera.

In breeding programmes for woody ornamentals, polyploidy induction and interspecific hybridisation can be used to introduce new genetic variation. At the Institute for Agricultural and Fisheries Research (ILVO, Belgium) research on interspecific breeding, ploidy breeding, and the development of appropriate disease-resistant selection protocols are performed. This research is done in close collaboration with BEST-select a cooperative association of 22 Flemish nursery companies <www.bestselect.be>.

PLOIDY BREEDING

Most organisms contain two copies of their chromosome sets (2n) in their cells, and single copies (1n) in their gametes or sex cells (pollen or egg in the case of plants). Polyploidy is the condition in which cells or organisms contain more than two copies

of their chromosome sets. Where an organism is normally diploid (2n), some spontaneous aberrations may occur that are usually caused by a hampered cell division. Polyploid types are termed corresponding to the number of chromosome sets in the nucleus: triploid (3n), tetraploid (4n), pentaploid (5n), and so on.

Polyploidy can be induced during cell division by chemicals such as colchicine, oryzalin, or trifluralin. Polyploid plants in general are more robust than diploids, often with larger flowers, bigger leaves, and more vigorous growth. Many ornamental plants show a higher level of ploidy either because they have been selected after spontaneous doubling or because polyploidy has been induced by breeders. Examples are roses (often tetraploid) (Leus, 2005) and chrysanthemums (often hexaploid, 6n) (Endo et al., 2004).

The induction of polyploidy is also a common technique in interspecific crosses to overcome the sterility in F1 progenies or to generate genotypes with equal ploidy level.

Use of Ploidy Breeding in *Hibiscus*. In *Hibiscus syriacus* most cultivars are tetraploid with 80 chromosomes per cell (Skovsted, 1941). However some hexaploid cultivars have been developed, including 'Diana'; 'Hélène'; 'Flogi', Pink Giant™ rose of Sharon; and 'Melrose'. Compared to most of the tetraploid cultivars, these hexaploids have bigger flowers, grow very vigourously, and produce few seeds. Because of this reduced seed production, flowering is never inhibited during the season and there is no spread of unwanted seedlings in the garden. The goal of our work was to generate a hexaploid *H. syriacus* cultivar with a deep blue flower colour and vigorous growth. Seedlings from *H. syriacus* 'Oiseau Bleu' were first chromosome doubled with colchicine. Then seedling populations were generated from crosses between the chromosome-doubled *H. syriacus* 'Oiseau Bleu' seedlings (octaploid) and other cultivars (tetraploid). Determination of the ploidy level showed that all seedlings from the interploidy cross were hexaploid, indicating that the F1 seedlings were true hybrids.

After two subsequent selection cycles, one blue-flowering seedling was finally selected. Morphological characteristics of this selection were compared to existing commercial cultivars. Growth vigour of the hexaploid selection was significantly better than the existing commercial tetraploid cultivars 'Oiseau Bleu' and 'Marina'. For example, the selection had put on 59 cm of shoot growth in 1 year, while 'Oiseau Bleu' and 'Marina' grew 25.8 cm and 50.7 cm, respectively. The leaf morphology of the hexaploid clones was similar to the tetraploid cultivars. Flower shape and flower colour were similar to 'Oiseau Bleu'. No fruit formation was observed on the hexaploid selection. As a consequence, flowering was not inhibited during the season and flowering period was significantly extended compared to the commercial cultivars. The new selection is being propagated, and market introduction is planned for 2008.

INTERSPECIFIC HYBRIDISATION

Interspecific hybridisation offers the potential to introduce new genetic variation such as different growth habits, new colours, and improved cold hardiness and disease resistance. But interspecific hybridisation becomes more difficult the less closely related the parents are. Frequently multiple barriers are observed. Growth and development of "alien" pollen tubes can be impeded in the female style (prezygotic incongruity). After fertilization, embryo development can be arrested by malformation of nurse tissue, mostly endosperm (postzygotic incongruity). Heavy chlo-

rosis occurring after interspecific hybridisation may cause inviability of the hybrid seedlings. Finally lack of growth vigour and hybrid sterility may hamper further use of the hybrids.

In vitro protocols and polyploidization strategies can play an important part in overcoming these barriers in interspecific crosses (Hogenboom, 1973; Eeckhaut et al., 2006). Some examples in *Hibiscus* and *Buddleja* breeding programs are described here, with the aims of more vigorous plants (in *Hibiscus*) and altered flower colour (*Buddleja*).

Hibiscus. Crosses between winter-hardy *Hibiscus* species were only successful when *H. syriacus* was used as the seed parent (Table 1). Both in vitro and in vivo sowing resulted in plantlets for *H. syriacus* × *H. paramutabilis* crosses. However, for the cross *H. syriacus* × *H. sinosyriacus* in vitro embryo rescue yielded more seedlings. Unfortunately, a lot of these in vitro seedlings were lost during acclimatisation due to total and variegated albinism and growth aberrations. The F1 progeny from *H. syriacus* × *H. paramutabilis* grew very vigorously, and leaf morphology was always intermediate compared to the parent plants. The hybrid seedlings had bigger flowers compared to both parent species, and flower colour was intermediate. Although the F1 plants from *H. syriacus* × *H. paramutabilis* crosses had low pollen fertility, some F2 hybrids were generated.

Table 1. Overview of interspecific *Hibiscus* crosses and obtained hybrids.

Parentage				
♀	♂	Fruits	F_1-hybrids	F_2
H. syriacus	*H. paramutabilis*	x	x	x
H. paramutabilis	*H. syriacus*	0	-	-
H. syriacus	*H. sinosyriacus*	x	x	-
H. sinosyriacus	*H. syriacus*	0	-	-

Buddleja. In *Buddleja*, the efficiency of interspecific crosses depends on the species combination (Table 2). Failure of some cross combinations, such as *B. davidii* × *B. globosa,* could be explained by difference in ploidy level. Polyploidization of one parent species might help to overcome this barrier. Crossing compatibility with *B. lindleyana* was unilateral and only successful when it was used as pollen donor. The progenies from *B. davidii* × *B. lindleyana* were all triploid, indicating their hybrid nature. The plantlets had intermediate morphological characteristics and had reduced fertility. In *Buddleja* this sterility can be an advantage for commercial cultivars since it prohibits the uncontrolled spread of seedlings in cultivation. In spite of the low fertility of *B.* × *weyeriana* 'Sungold', which is a selection from a *B. globosa* × *B. davidii*, F1 and F2 hybrids could be obtained from crosses with *B. davidii* in both directions using embryo rescue.

DISEASE RESISTANCE BREEDING

In roses, disease resistance is generally low, because in the past aesthetic properties and productivity were the main breeding goals. The major fungal pathogen of roses grown in greenhouses and also an important disease on field-grown roses is powdery mildew (*Podosphaera pannosa*). To be able to select genotypes with enhanced disease resistance, four steps are necessary: understand the pathogen, understand pathogen-host interactions, screen parent plants, and establish resistance-screening protocols to test progenies.

Pathotypes. Knowledge about the population structure of a pathogen can aid resistance-breeding strategies. Results on the occurrence of different pathotypes are important for a better understanding of resistance in plant genotypes, as well as to interpret disease resistance screening. Variation in pathotypes might also explain observations of different resistance levels of the same cultivar at different locations or in subsequent years. A number of different pathotypes have been isolated from roses (Linde and Debener, 2003; Leus et al., 2006). The most virulent of these are the most interesting for plant resistance screening in a breeding program.

Pathogen–Host Interactions. Two rose species (*R. wichurana* and *R. laevigata*) and two cultivars ('Excelsa' and 'Gomery') were selected to examine microscopically the interaction between fungal development and plant resistance mechanisms. On the different rose genotypes tested, different resistance mechanisms towards powdery mildew development were found. These mechanisms influence both mycelium formation and sporulation. Resistance reactions depended on the proportion between normal and abnormal haustoria, papillae formation, physiological

Table 2. Overview of interspecific *Buddleja* crosses and obtained hybrids.

Parentage						
♀	♂	Fruits	Isolated ovules	Germinating ovules	F_1-hybrids	F_2
B. davidii	*B. globosa*	0				
B. davidii	*B.* ×*weyeriana*	x	x	x	x	x
B. davidii	*B. lindleyana*	x	x	x	x	-
B. lindleyana	*B. davidii*	0				
B. lindleyana	*B.* ×*weyeriana*	0				
B. lindleyana	*B. alternifolia*	0				
B. alternifolia	*B. lindleyana*	x	x	-		
B. ×*weyeriana*	*B. davidii*	x	x	x	x	x

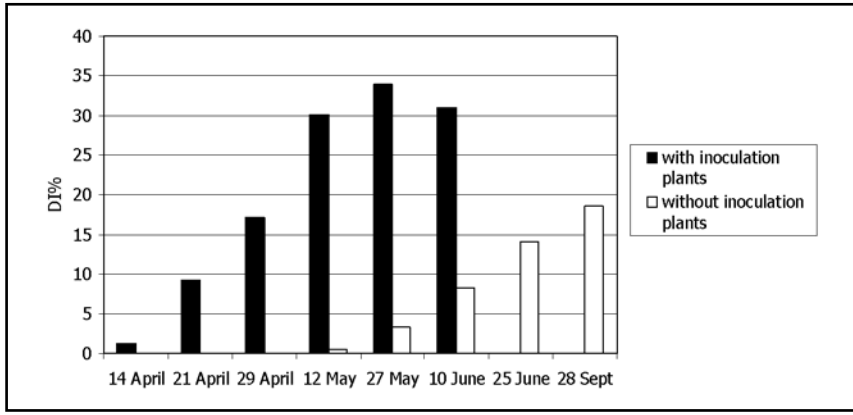

Figure 1. Disease index (DI%) for seedlings scored on different dates in 2004 in two different greenhouses, with and without inoculation plants. In the greenhouse with inoculation plants the disease is present earlier in the season and reaches also higher levels compared to the control without inoculation plants.

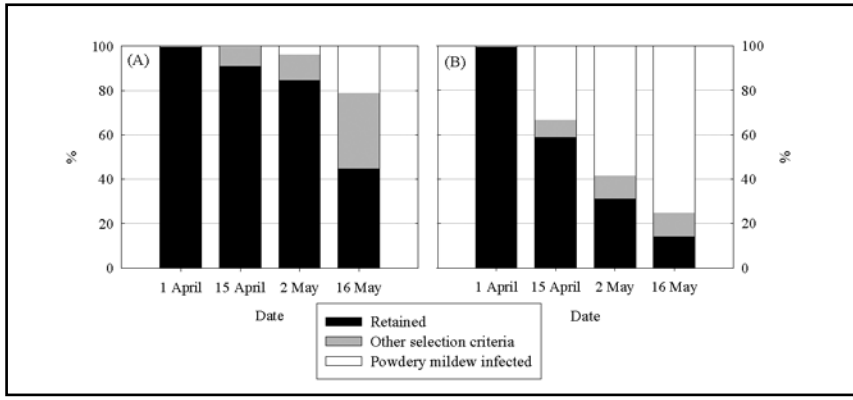

Figure 2. Selection pressure in a commercial rose breeding programme in 2002. Rose seedling populations were grown in either a greenhouse without (A) or with (B) powdery mildew inoculation. Negative selection was done on different dates

responses, and formation of antifungal phenolic compounds (phytoalexins). Two different forms of physiological responses could be observed, with and without cell collapse. The most important resistance mechanism was, however, the inhibition of normal haustoria formation.

Screening of Parent Plants. To test disease resistance in individual rose genotypes an inoculation tower can be used (Leus et al., 2003). The use of this tower allows infections with characterized powdery mildew isolates under standardized test conditions on detached rose leaves. Factors that need to be controlled are the conidia density dispersed and the age of the leaves used in the test. This method is more suitable for use with characterized monoconidial isolates to test resistance in candidate parent plants or on small numbers of promising cultivars. The method is

not suited for large populations. Since, disease-resistance sources are very rare in the today's gene pool of cultivated roses, this screening method is also valuable for the detection of resistant genotypes in wild rose species (Leus, 2005).

Resistance Screening of Progenies. In a practical breeding programme it is important to have an easy, cheap, and fast screening method to test disease resistance on large seedling populations. The earlier in the selection process resistance is screened, the more resistant genotypes can be selected for further evaluation in a cost-effective way. In the rose breeding program at ILVO inoculation plants were used to evaluate powdery mildew resistance on seedling populations in the greenhouse. In this method artificial inoculation was performed by placing very susceptible genotypes (*R.* 'Pfänder's Canina') at regular spacings among rose seedling populations. These susceptible plants were then artificially inoculated by dusting a conidial mixture of powdery mildew very early in the growing season. It was shown that inoculation plants introduced the pathogen homogenously with a higher infection pressure and earlier in the season when compared to natural infection (Fig. 1) (Leus et al., 2003). By this method an early selection towards powdery mildew resistance is possible as is also shown in Figure 2. When comparing this artificial infection screening with field resistance positive correlations were found.

CONCLUSIONS

The results presented here demonstrate that in woody ornamentals new cultivars with improved characteristics can be developed by using a range of techniques. In most cases an integrated approach is necessary to obtain results. Close collaboration between research and industry helps ensure that new introductions will be commercially successful.

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Propagating Dahlias for Royal Horticultural Society Trials©

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INTRODUCTION

The dahlia is a member of the Asteraceae and comprises 30 species of perennial herbs and sub-shrubs. It is found growing in the wild from the mountains of Mexico to Columbia. The genus was introduced into European cultivation in 1789 at the Royal Botanic Gardens in Madrid, from where it was distributed across Europe, reaching the U.K. (Royal Botanic Gardens, Kew) in 1798.

Dahlia coccinea and *D. pinnata* are the origin of the vast majority of garden hybrids. Dahlias hybridise readily and today there are more than 50,000 registered cultivars.

Each year the dahlia trial at RHS Garden, Wisley, produces an unrivalled display from late summer until the November frosts. Wisley's propagators produce three 13-cm pots each of 120 to 150 entries trialled each year. The trial includes a selection of the best new cultivars and a selection of old standards with which the new ones can be compared.

DEVELOPMENT OF PROPAGATION TECHNIQUES

Propagation methods for the trial have evolved over the past 20 years. Apart from the few occasions when the trials committee requires seed-raised stock, the entries that are assessed for the RHS Award of Garden Merit are raised vegetatively.

For many years the trial was propagated using cuttings from shoots produced by field tubers. This enabled the committees to identify the particular plant that would be lifted from the trials field, for use as stock for the following year. Because the dahlia continually throws up sports, changes its appearance slightly, or succumbs to virus, it was felt that selecting field-grown tubers for propagation material produced plants that the committee could most confidently say were true to type.

Field Tubers as Stock Plants. Once the first frosts of late autumn have blackened the tops of the still-flowering dahlia, the vegetative growth is cut back to within 15 cm of ground level. The tubers are lifted and stored frost-free before cleaning. A field-grown tuber stores food to ensure its survival over winter, but also contains large volumes of water, which, if left, rots the tuber.

Most of the soil around the tuber is washed off. Any damaged tubers and fine roots are removed with secateurs and then dried out prior to placing in soilless substrate in trays or boxes.

Large tubers may need further draining and this can be achieved by sawing off the remaining vegetative growth down to the neck of the tuber. This is where many resting vegetative buds have formed during the growing season. A power tool is used to drill through the centre of the tuber from the neck to the base. This allows excess water to drain through the hole. The tuber is left to dry for a further couple of days and then placed in soilless compost as above. The tuber is covered leaving the neck exposed and over-winter frost-free.

This time-consuming and costly process remained the main source of propagation material for the trial for many years. However, 10 years ago we began to use pot

tubers. These produce more reliable stock plants, which are less prone to rotting during the winter months and less time consuming to store and which produce many more, better quality, cuttings compared to the fleshy cuttings thrown up from a field tuber.

Pot Tubers as Stock Plants. Pot tubers, as the name suggests, are grown in containers. From a young cutting struck in spring the plant is managed in a container. This restricts the roots and tuber growth while encouraging vegetative growth. Good growth in autumn will ensure good quality tubers as the plant is laying down its food reserves. This leads to a tuber with more carbohydrate reserves compared with a fleshy, nitrogen-rich, field tuber. A field tuber can be 20 times bigger than one of the same cultivar grown in a 13-cm pot.

With this technique shoots begin to grow rapidly when the pot is moved in spring into a warm glasshouse (18 °C) and watered. Crops of thin nodal tip cuttings can harvested within a fortnight.

Pot tubers are easier to over-winter and usually produce excellent cutting material but still require a large labour input to produce a high quality product. Each year the RHS propagation team grew and then "planted out" between 600 and 1000 pot tubers in prepared beds in June. Seep irrigation was installed, but the beds had to be kept free of weeds, pests, and diseases. Once poor performers and those not true to type were removed, the plants were constantly deadheaded to ensure that maximum energy went into the tuber. In autumn, after the first frosts, the plants were cut back and the pots lifted and cleaned before storing dry over winter on Danish trolleys in a frost-free environment. In spring the tubers were knocked out and repotted into fresh substrate before going into the warm greenhouse.

To help us reduce the labour input while maintaining quality of propagation material we have in the last 2 years begun to take cuttings from mother plants that we keep growing throughout the winter.

Propagating From Over-Wintered Mother Plants. To propagate mother plants we select the best stock from the trials field in the beginning of September and cut back a couple of the flowering stems. Within 2 weeks, fresh vegetative growth will have developed and at this point we take and strike our cuttings. We avoid hollow growths or shoots ending in flower buds. These are very common at this time of year as dahlia flower bud initiation takes place in short days. To reduce the risk of virus transfer, we sterilise knives and secateurs with Virkon between cultivars.

At the propagation bench we prepare 4- to 6-cm cuttings by removing one or two lower leaves, where possible cutting below a node while retaining the tip. Once again we sterilise blades between cultivars. Most dahlias root easily in spring but are slightly more reluctant in September. We apply a 5-sec quick dip of rooting hormone (Synergol at 1000 ppm) to the base of the cutting and insert into plug trays. We currently prefer the preformed 104 Jiffy glue plug.

Dahlias require high humidity to root so we place them on a mist bench and provide a minimum of 20 °C bottom heat. Most cultivars root within 3 weeks. If rooting is slow we have tried using Rhizopon tablets, which we then dissolve and apply as a spray over the foliage of the rooting cuttings. This appears to top up the rooting hormone levels at this time of year and has increased our success rates.

The rooted cuttings are then weaned and potted off into a 9-cm container, using a general purpose potting compost suitable for bedding and houseplant production.

The pots are placed on a heated bench (15 °C) and provided with an 18-h day (high-pressure sodium lamps). Without the lamps at this time of year, any growth would be poor and probably run to flower bud. With the additional lighting the young mother plants continue growing throughout the winter and require cutting back on two or three occasions. From mid-March we turn off the lights.

Plants for the trial are propagated from cuttings taken from these over-wintered mother plants towards the end of March. These are struck and rooted as described above. The rooted cuttings are potted off into 13-cm containers, grown on under glass, and hardened off outside in mid-May ahead of planting in the trials field in June.

The young plants grow rapidly in spring and require the addition of a cane and a single Max Tapener tie. Dahlias are prone to attack from aphid and spider mite, both of which can be treated with biological controls such as *Aphidius colemanii* for aphid and *Phytosieulus persimilis* for spider mite. We also apply a regular spray of SB Plant Invigorator, which has reduced the need to use both biological agents and conventional pesticides.

Acknowledgement. I would like to recognise the assistance of Ron Thomas in putting this paper together, until recently a member of the RHS Dahlia Committee responsible for assessing the trial.

Alpine Habitats and Cultivation in North-West Yunnan©

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In 2005, the author spent 3 weeks (August to September) studying alpine plants in the Lijiang and Zhongdian areas of Yunnan, China, both in the wild and in a local nursery. This helped in the understanding of how these plants grow in relation to soil, climate, aspect, and associated flora. The author also gained an insight into Chinese horticulture and was able to share experiences of alpine plant cultivation with Chinese students and nurserymen.

INTRODUCTION

As propagator for Kevock Garden Plants (Kevock), a nursery that specialises in unusual alpines, I have been responsible for the cultivation of a wide range of Chinese origin plants since July 2003. In August 2005, an opportunity arose for me to participate in a joint expedition to northwest Yunnan with the University of Edinburgh and the Kunming Institute of Botany. Although the main aim of their expedition was to study *Rhododendron* growing on limestone and its fungal associations, this would take them into the alpine zone where I could study the growing conditions of the plants I cultivate.

In particular, I wanted to focus on ten key genera: *Arisaema, Codonopsis, Cyananthus, Daphne, Gentiana, Meconopsis, Pedicularis, Primula, Rhododendron,* and *Saxifraga.* I also sought to gain an understanding of how a local nursery, Yunnan Gesang Flower Company Limited (Gesang), grows its alpines.

Yunnan is a huge and geographically diverse province ranging from the eastern fringes of the Tibetan Plateau to semi-tropical rainforests on the Vietnamese border. The northwest corner is dominated by the massive Hengduan Mountain Range, which is dissected north-south by the upper reaches of three mighty rivers: the Salween, the Mekong, and the Yangtze.

The range contains a huge variety of plant habitats between the river at or face on 1,500 m above sea level and the snow-capped peaks above 5,000 m. The prevailing wind brings warm wet monsoons from India, creating lush temperate vegetation on western slopes and progressively drier, Mediterranean landscapes to the east.

LIJIANG AREA

We explored the Yu Long Shan, a predominately limestone mountain separated from the rest of the range by the Lijiang Plain and bends in the Yangtze River. Our daily explorations clearly demonstrated how the vegetation changed: from damp meadows of *Primula, Gentiana*, and *Pedicularis* to forests of *Rhododendron* — the species mix reflecting the levels of moisture, altitude, aspect, and soil. The Gang Ho Ba glacial moraine was particularly exciting because species of *Rhododendron, Primula, Gentiana,* and *Daphne* were growing in virtually pure limestone.

We also saw people harvesting wild plants as traditional medicine, and inevitably the more valuable species are becoming rarer. The Royal Botanic Garden

[1]Recipient of the GB&I Region's Mary Helliar Travel Scholarship for 2005

Edinburgh is encouraging some of the local people to cultivate medicinal plants in addition to their traditional crops in return for their support for the Nature Reserve and a new Botanic Garden on Yu Long Shan.

ZHONGDIAN AREA

Although we failed to reach the upper screes of Shika Shan, we did see alpine meadows and a wide range of woodland plants. We also gained an insight into what the early plant explorers endured as we tried to fight a way through dense *Rhododendron* forest.

At Hong Shan and Bai Ma Shan we were able to drive up to the alpine zone, finding gems such as *Primula bella* or carpets of *Gentiana hexaphylla* within a metre of the roadside. It was amazing to see the different mechanisms used by plants to survive on the exposed scree and rocky outcrops: deep tap roots or tubers, the frost protecting hairs, and the vivid blue and pink flowers to attract pollinators.

At Tianchi Lake, at 3,800 m, the habitat was more acidic *Rhododendron* woodland and damp meadows of *Gentiana sino-ornata*. Although winters can be severe here, the upper canopies of the woodland and forests protect the under-storey vegetation, which includes members of genera such as *Arisaema*, which in the U.K. may not be fully hardy.

At Napa Hai we found *Rhododendron* growing on the edge of a limestone quarry.

YUNNAN GESANG FLOWER COMPANY

After the official expedition I stayed on to visit Gesang, particularly the areas of alpine and lily production. I discussed propagation and cultivation techniques with the nursery manager.

The nursery sourced most of its alpines from the wild as seed or as a few plants that were then grown in the alpine research unit where growth could be monitored and stock accumulated. I saw cultivated *Meconopsis* seed being dried and cleaned in large round wicker trays. All seed was sown in small plastic crates and seedlings were generally left for a year before planting out in beds, some of which were covered by shade netting. Cuttings were simply placed in pots of sand and peat moss, since there were no mist units or systems for supplying bottom heat. There have been trials at Gesang with micropropagated *Cypripedium,* but these appeared to be in "shock" following transfer to a peat-based medium.

The lily production area was more sophisticated, reflecting the considerable assistance that Gesang has received from a Dutch bulb specialist company. Facilities included 30 sealed polytunnels, bulb grading and counting machines, cold storage areas, and a micropropagation unit. The breeding programme is based on crossing imported oriental lilies with local native species. The company also has a range of satellite farms for the production of early forcing tulips and other lilies to maximise the flowering period.

Gesang is able to produce large quantities of high quality cut flowers for the markets in Kunming, Shanghai, and Beijing. Production of alpines is, by comparison, a low priority, presumably because there is not yet a significant market for them within China.

CONCLUSION

Horticulture in China is inevitably benefiting from the dynamic economy. Gesang's success shows that disposable income is already being spent on cut flowers. The pace of urban development, which includes the provision of parks, street planting, and a proliferation of private gardens, must be stimulating horticulture more generally. The commercial cultivation of alpines in China may be in its infancy, but it could help to save the wild plants as well as generate planting material for new alpine gardens.

Other companies are likely to follow the Gesang approach and bring in foreign advisors and technology, which can then be adapted to local circumstances. However, according to the students on the expedition, horticulture is still seen as part of agriculture and there is little by way of training for amenity horticulture. I left wondering where the new gardeners and landscapers are going to come from and sorry that I did not have more time to discover and explore other nurseries.

I learned a lot about planning and participating in an expedition to look at plants in the wild. It is vital to have a good guide with reliable local knowledge of the plants, their whereabouts and accessibility.

Overall, I believe I had a very successful trip to China and left with a better understanding of how alpines grow in relation to soil, climate, aspect, and associated flora. Nurseries will only be able to provide appropriate growing conditions for alpines if the provenance is understood. However, there will still need to be a degree of trial and error, as we will never be able to create a complete match, especially on a commercial scale. In any case, if the plant is too tricky to grow, the customer may not be interested.

But, I only saw the tip of the iceberg — not only is there still much to be learned from the known areas of interest, such as the Yu Long Shan, but there are so many alpine areas of China that have yet to be explored by horticulturalists and conservationists.

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A full report of Jane Armstrong's findings is available to sponsors of the Mary Helliar Travel Scholarship.

Suitability of Processed Whole Pine Tree as a Substrate Component for Production of Greenhouse Crops©

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INTRODUCTION

Peat moss is the primary component of growth substrates in the production of greenhouse-grown herbaceous annual crops. Rising transportation costs of peat moss from Canada or Europe is affecting the profitability of many greenhouse operators (personal growth communication). Alternative substrate components have been evaluated in the U.S.A. for use in greenhouse production. Some substrates have been evaluated as additions to reduce the quantities of peat moss in a given substrate and others as replacements for peat moss. A cost-effective sustainable alternative substrate is processed whole pine trees. Gruda and Schnitzler (2004) demonstrated the suitability of wood fiber substrates as an alternative for peat-based substrates in cultivation of greenhouse tomato plants. Wright and Browder (2005) showed that whole chipped pine logs ("clean chips") could be used successfully for nursery crop production with attention to nutrition and irrigation. Substrates composed of whole pine trees have previously been used successfully to produce container-grown vinca (*Catharanthus roseus*) (Fain and Gilliam, 2006). The objective of the research presented here was to evaluate processed whole pine trees as an alternative growth substrate for greenhouse crops.

MATERIALS AND METHODS

Studies were conducted at the Southern Horticultural Laboratory (SHL) in Poplarville, Mississippi. Loblolly pine (*Pinus taeda* L.) at 15 to 20 cm diameter was harvested at ground level from a 12-year-old pine plantation in south Alabama. Entire trees, including needles, were fed through a horizontal grinder. Resulting chips were then further processed using a swinging hammer mill to pass a 6-mm screen, with the resulting material used alone or in combination with Canadian sphagnum peat moss and compared to a standard greenhouse substrate. Substrates (Table 1) were amended per cubic metre with 1.78 kg dolomitic lime, 0.59 kg gypsum, 0.44 kg micromax, 1.78 kg Harrell's 16N–2.6P–9.8K plus (3–4 month formulation), and 1.78 kg Harrell's 16N–2.6P–10.7K (2–3 month formulation). Supplemental quick release starter fertilizer (7N–1.3P–8.2K) was incorporated at 0, 1.19, 2.37, or 3.56 $kg \cdot m^{-3}$).

On 23 June 2006, 15-cm containers were filled with the trial substrates and four (288 cell) plugs of marigold (*Tagetes patula* 'Hero Spry') or impatiens (*Impatiens walleriana* 'Super Elfin Apricot') were planted into each container. Containers were placed on a greenhouse bench and hand watered as needed. Data collected included substrate electrical conductivity (EC) and pH at 0, 14, and 34 days after potting,

plant growth indices, and or plant shoot dry weight, leaf chlorophyll content, flower number, and root growth (0–5 scale where 0 = no roots present at substrate-container interface; 5 = roots present at all areas of the substrate-container interface) at 34 days after potting.

RESULTS

By 34 days after potting, pH had risen on all substrates. The mixes containing the highest amounts of peat moss remained the most acidic (Table 1). The EC was generally higher for substrates with high peat content and at potting and 14 days after potting increased linearly with increasing fertilizer rate for all substrates (Table 1). By 34 days, all ECs were similar except in the peatlite mix at the 3.56 $kg \cdot m^{-3}$ starter fertilizer rate where it was more than twice that of any other treatment at 4.1 $mS \cdot cm^{-1}$.

There were no differences in the number of flowers present at 34 days for any treatment for either species tested (Table 2 and 3). With the peat, perlite, and vermiculite (8 : 1 : 1, by volume) substrate, starter fertilizer rate had no effect on plant shoot dry weight for either species tested (Tables 2 and 3). Growth of impatiens in 100% whole pine tree substrate increased with increasing starter fertilizer rate while there was a quadratic response to fertilizer rate for plants grown in equal parts whole pine tree and peat.

Impatiens grown in the whole-pine-tree substrate that received the 3.56 $kg \cdot m^{-3}$ starter fertilizer rate were similar to other substrate-fertilizer combinations — except the equal parts whole pine tree and peat with 2.37 $kg \cdot m^{-3}$ starter fertilizer.

Marigold also showed a fertilizer rate response for plants grown in whole pine tree substrate alone and the equal parts whole pine tree and peat mix. However, unlike impatiens, there was a fertilizer rate response for plants grown in mixture of whole pine tree and peat (v/v) (WT20P) (Table 3).

CONCLUSION

The results of this experiment indicate that whole pine tree substrates, especially when provided with a starter fertilizer charge and/or combined with peat moss are a potential alternative to conventional greenhouse substrates.

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Table 1. Effects of starter fertilizer rate and substrate on pH and electrical conductivity.

Substrate	Fertilizer[z] (lbs/yd^3)	0 DAP[y]		14 DAP		34 DAP	
		pH	EC[x]	pH	EC	pH	EC
100% WPT[w]	0	5.8 a[v]	1.45 e	5.7 a	3.04 def	6.8 a	0.23 c
100% WPT	2	5.5 abc	2.15 cde	5.7 a	3.13 def	6.7 a	0.40 bc
100% WPT	4	5.5 abc	2.65 bcde	5.6 ab	4.96 bcdef	6.7 a	0.37 bc
100% WPT	6	5.7 ab	2.89 bcde	5.4 ab	6.12 abcd	6.7 a	0.43 bc
WPT and peat (4 : 1, v/v)	0	5.3 abcd	1.67 de	5.7 a	2.16 f	6.4 abcd	0.50 bc
WPT and peat (4 : 1, v/v)	2	5.3 abcd	3.03 bcd	5.5 ab	3.84 cdef	6.6 ab	0.50 bc
WPT and peat (4 : 1, v/v)	4	5.7 ab	2.46 bcde	5.3 ab	5.59 abcde	6.6 ab	0.43 bc
WPT and peat (4 : 1, v/v)	6	5.2 bcde	3.24 bc	5.1 ab	6.56 abc	6.4 abcd	0.73 bc
WPT and peat (1 : 1, v/v)	0	5.0 cdefg	1.65 de	4.9 ab	2.96 def	6.2 abcde	0.39 bc
WPT and peat (1 : 1, v/v)	2	4.9 defg	2.50 bcde	4.9 ab	4.38 cdef	6.0 cdef	0.79 bc
WPT and peat (1 : 1, v/v)	4	4.9 defg	3.05 bcd	5.0 ab	4.77 bcdef	5.8 def	1.31 bc
WPT and peat (1 : 1, v/v)	6	5.4 abc	3.19 bc	4.7 b	8.64 a	5.8 def	0.96 bc
Peat, perlite, and vermiculite (8:1:1, by vol.)	0	5.2 bcde	2.05 cde	4.9 ab	2.8 ef	5.5 f	1.00 bc
Peat, perlite, and vermiculite (8:1:1, by vol.)	2	4.8 efg	3.42 bc	4.7 b	2.89 def	5.6 f	1.50 bc
Peat, perlite, and vermiculite (8:1:1, by vol.)	4	4.7 fg	3.90 b	4.9 ab	5.84 abcde	5.5 f	1.90 b
Peat, perlite, and vermiculite (8:1:1, by vol.)	6	4.6 g	5.99 a	5.2 ab	7.83 ab	5.4 f	4.10 a

Table 1. Continued

		Fertilizer Rate Response					
100% WPT	0, 2, 4, 6	Q***[u]	L***	NS	L**Q**	NS	NS
WPT and peat (4 : 1, v/v)	0, 2, 4, 6	Q***	L***	L*	L***	NS	NS
WPT and peat (1 : 1, v/v)	0, 2, 4, 6	L**Q**	L***	NS	L***	L*	NS
Peat, perlite, and vermiculite (8:1:1, by vol.)	0, 2, 4, 6	L***	L***	NS	L***	NS	L***Q*

[z]Supplemental starter fertilizer (7N-1.3P-8.2K) incorporated at 0, 2, 4, or 6 lbs per cubic yard (0, 1.19, 2.37 or 3.56 kg·m^{-3}).

[y]Days after potting.

[x]Electrical conductivity (mS/cm) of substrate solution using the pour through method.

[w]WPT = Whole tree substrate made from 12-year-old *Pinus taeda* mechanically processed to pass a 1/4-inch screen.

[v]Means followed by same letter within columns do not differ significantly ($P < 0.05$, Tukey's Honest Significant Difference).

[u]Non-significant (NS), linear (L), or quadratic (Q) response at $P < 0.05$ (*), 0.01 (**), or 0.001 (***) based on single-degree-of-freedom orthogonal contrasts.

Table 2. Effects of whole tree substrate and starter fertilizer rate on *Impatiens walleriana* 'Super Elfin Apricot'.

Substrate	Fertilizer[z] (lbs/yd^3)	LG[y]	Flower (ct)	Growth Index[x] (cm)	Dry Weight[w] (g)
100% WPT[v]	0	45.2 bc[u]	11.0 a	25.7 d	3.3 e
100% WPT	2	43.3 c	10.4 a	26.1 d	3.4 de
100% WPT	4	46.5 abc	9.9 a	27.1 cd	3.8 cde
100% WPT	6	46.6 abc	12.3 a	29.0 bcd	4.4 bcde
WPT and peat (4 : 1, v/v)	0	43.6 c	13.1 a	29.5 bcd	4.6 bcde
WPT and peat (4 : 1, v/v)	2	45.8 bc	10.9 a	30.0 abcd	4.8 abcde
WPT and peat (4 : 1, v/v)	4	46.5 abc	12.3 a	29.5 bcd	4.8 abcde
WPT and peat (4 : 1, v/v)	6	46.9 abc	12.8 a	30.6 abcd	5.2 abc
WPT and peat (1 : 1, v/v)	0	47.6 abc	11.3 a	30.2 abcd	4.7 abcd
WPT and peat (1 : 1, v/v)	2	48.1 abc	15.0 a	32.8 abc	5.2 abcd
WPT and peat (1 : 1, v/v)	4	46.6 abc	15.3 a	35.6 a	6.4 a
WPT and peat (1 : 1, v/v)	6	48.4 abc	13.0 a	31.9 abc	5.2 abcd
Peat, perlite, and vermiculite (8:1:1, by vol.)	0	51.9 a	11.0 a	33.3 ab	5.8 ab
Peat, perlite, and vermiculite (8:1:1, by vol.)	2	50.1 ab	11.9 a	32.0 abc	5.4 abc
Peat, perlite, and vermiculite (8:1:1, by vol.)	4	50.9 ab	8.4 a	27.2 cd	4.1 bcde
Peat, perlite, and vermiculite (8:1:1, by vol.)	6	50.5 ab	12.1 a	30.9 abcd	5.1 abcde

Table 2. Continued

	Fertilizer Rate Response				
100% WPT	0, 2, 4, 6	Q*[t]	NS	L*	L*
WPT and peat (4 : 1, v/v)	0, 2, 4, 6	L*	NS	NS	NS
WPT and peat (1 : 1, v/v)	0, 2, 4, 6	NS	Q*	Q**	Q*
Peat, perlite, and vermiculite (8:1:1, by vol.)	0, 2, 4, 6	NS	NS	Q*	NS

[z]Supplemental starter fertilizer (7N-1.3P-8.2K) incorporated at 0, 2, 4, or 6 lbs per cubic yard (0, 1.19, 2.37, or 3.56 kg·m^{-3}).

[y]Leaf greenness (chlorophyll content) quantified using a SPAD-502 chlorophyll meter (average of 4 leaves per plant).

[x]Growth index = (height + width 1+ width 2) / 3.

[w]Plant shoot dry weight in grams.

[v]WPT = substrate made form 12-year-old *Pinus taeda* mechanically processed to pass a 1/4-inch screen.

[u]Means followed by same letter within columns do not differ significantly ($P < 0.05$, Tukey's Honest Significant Difference).

[t]Non-significant (NS), linear (L), or quadratic (Q) response at $P < 0.05$ (*) or 0.01 (**) based on single-degree-of-freedom orthogonal contrasts.

Table 3. Effects of whole tree substrate and starter fertilizer rate on *Tagetes patula* 'Hero Spry'.

Substrate	Fertilizer[z] (lbs/yd^3)	LG[y]	Flower (ct)	Root Rating[x]	Dry Weight[w] (g)
100% WPT[v]	0	39.4 d[u]	13.4 a	2.9 abcd	3.9 e
100% WPT	2	43.6 bcd	14.5 a	3.0 abcd	5.5 bcd
100% WPT	4	44.6 abcd	13.4 a	3.4 ab	5.8 abcd
100% WPT	6	44.2 abcd	13.0 a	3.5 a	5.3 bcd
WPT and peat (4 : 1, v/v)	0	44.1 abcd	13.9 a	2.7 bcd	5.1 de
WPT and peat (4 : 1, v/v)	2	46.3 abc	16.3 a	3.0 abcd	6.8 abc
WPT and peat (4 : 1, v/v)	4	45.6 abc	14.3 a	3.3 abc	6.5 abcd
WPT and peat (4 : 1, v/v)	6	46.4 abc	14.9 a	3.3 abc	6.3 abcd
WPT and peat (1 : 1, v/v)	0	43.2 cd	11.8 a	3.1 abcd	6.0 abcd
WPT and peat (1 : 1, v/v)	2	46.7 abc	15.6 a	3.1 abcd	7.1 a
WPT and peat (1 : 1, v/v)	4	45.9 abc	11.9 a	2.9 abcd	7.1 a
WPT and peat (1 : 1, v/v)	6	45.0 abcd	10.6 a	3.1 abcd	6.8 abc
Peat, perlite, and vermiculite (8:1:1, by vol.)	0	49.7 a	12.9 a	2.5 d	6.7 abcd
Peat, perlite, and vermiculite (8:1:1, by vol.)	2	48.5 abc	11.9 a	2.8 abcd	7.2 a
Peat, perlite, and vermiculite (8:1:1, by vol.)	4	48.6 abc	12.3 a	2.4 d	6.8 abc
Peat, perlite, and vermiculite (8:1:1, by vol.)	6	49.4 ab	12.6 a	2.6 cd	6.1 abcd

Table 3. Continued

	Fertilizer Rate Response				
100% WPT	0, 2, 4, 6	L**[t]	NS	L*	L**Q*
WPT and peat (4 : 1, v/v)	0, 2, 4, 6	NS	NS	L**	L*
WPT and peat (1 : 1, v/v)	0, 2, 4, 6	NS	NS	NS	Q*
Peat, perlite, and vermiculite (8:1:1, by vol.)	0, 2, 4, 6	NS	NS	NS	NS

[z]Supplemental starter fertilizer (7N-1.3P-8.2K) incorporated at 0, 2, 4, or 6 lbs per cubic yard (0, 1.19, 2.37, or 3.56 kg $\cdot m^{-3}$).

[y]Leaf greenness (chlorophyll content) quantified using a SPAD-502 chlorophyll meter (average of 4 leaves per plant).

[x]Root rating on a scale of 0 - 5 where 0 = no roots visable at substrate container interface and 5 = roots covering 100%.

[w]Plant shoot dry weight in grams.

[v]WPT = substrate made form 12-year-old *Pinus taeda* mechanically processed to pass a 1/4-inch screen.

[u]Means followed by same letter within columns do not differ significantly ($P < 0.05$, Tukey's Honest Significant Difference).

[t]Non-significant (NS), linear (L), or quadratic (Q) response at $P < 0.05$ (*) or 0.01 (**) based on single-degree-of-freedom orthogonal contrasts.

Application of Lean Manufacturing to Nursery Stock Production at Johnsons of Whixley©

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INTRODUCTION

Lean manufacturing is a simple and effective way of improving systems. The costs of the lean approach are proportionate to the scale of the business. However, the lean way of operating must be embraced by organisations as a whole; trying to apply it to selected parts of an organisation will not be effective. The processes of plant production can be analysed and improved in just the same way as those in any other industry. The fact that the product is a living organism is no justification for inefficiency on the nursery. This paper will cover the basic principles of lean manufacturing, the practicality of its application, and the reality of trying to operate under the philosophy of a lean regime in an industry where investment cash is scarce.

THE PRINCIPLES OF LEAN MANUFACTURING

Henry Ford developed the concept of lean manufacturing to increase quality and workers' pay while reducing the price to the consumer. Subsequently, Toyota's Taiichi Ohno developed Ford's principles to "Just in Time." Lean manufacturing is different from supply-driven batch and queue production where products are delivered in batches then queued for the next process. This batch-and-queue system is imposed until the product is shipped. In contrast, the trigger for lean is a pull from the customer.

Five Lean Basics. Lean manufacturing is based on five simple precepts:

Value. Value relates to ends, not the costs of the means. Consumers of 3-L plants are not interested in the processes that occur from 9-cm liner to the finished product. They just want a nice garden.

Stream. It is the whole chain, and the interaction of processes within that chain, that controls efficiency, not the separate elements. Processes need real-time mapping, and those that do not add value should be stripped out.

Flow. The process stream must be continuous, without batching and queuing.

Pull. It is only demand that should dictate quantity of product and timing of delivery.

Perfection. The driver for all processes can only be quality. In both product and process management, compromise solutions are not acceptable.

Seven Wastes. Waste reduction underpins lean manufacturing. Waste is anything that does not add value to the customer. Eliminating waste allows more to be done with less — less capital equipment, floor space, operator effort, direct labour, indirect labour, inventory, and lead-time. There are seven key elements of waste:

Overproduction. Too much too early.

Waiting Time. Arises when the flow is not continuous and customer pull is lost; neither product, staff, nor customer should ever be kept waiting.

Transportation. Any movement of people, vehicles, product, or equipment. Movement always incurs cost**.**

Inappropriate Processing. Excessive equipment capacity and repeated activities.

Stock. Stock acts as a buffer for inefficient process control. But storage and maintenance of stock is costly and reliance on stock obscures the need to tackle underlying inefficiencies.

Motion. Operator bending, stretching, lifting, carrying, or moving that is detrimental to productivity and to health and safety.

Scrap. Maintaining defective product incurs progressively greater costs, which can be avoided by early action.

New Wastes. Contemporary production has identified new forms of process waste. Untapped and lost human potential follows when poor managers fail to bring forward innovations suggested by more junior staff and where talent is not channeled by proper training. Mutual respect allows upward as well as downward management, and training delivers the next generation. It is not a matter of "what will happen if I train them and they leave," but rather "what will happen if I do not train them and they stay." A better-trained staff should also enable useless activities and overblown bureaucratic regulations and systems to be stripped out.

Previously abundant resources such as materials, energy, and water are now scarce and increasing in cost. Abandoning non-essential processes, reducing usage rates, and embracing recycling technologies will improve profits.

Customer choice opens opportunities for business expansion; while time and money spent regaining lost customers is a wholly avoidable resource waste. Nowadays, customers see time as their most valued resource. Customer time is wasted by complaints, returns, repeated queries, inadequate customer databases, and silly phone answering systems. Customers should not be made to wait or waste their time.

Sustainability. The lean framework for sustainability requires change. The business processes are redesigned to increase product life, to reduce product maintenance, to ease recycling activities, and to avoid pollution. Reductions in energy and materials used in manufacturing and product care are identified and implemented, while ensuring the highest possible proportion of what is produced is despatched to the customer. As much as possible of anything not despatched should be recovered, recycled, or re-manufactured.

The Workplace. The first essential for managing change is correct targeting. This in turn needs an acute understanding of the business' processes, and its people. This understanding comes from on-site observation of the workplace, direct personal contact, first-hand knowledge, and getting involved.

NURSERY APPLICATION OF LEAN

Johnsons of Whixley is a large producer of nursery stock for both the retail and landscape/amenity markets. It has completed lean projects relating both to nursery production and office systems. Implementation has not proved costly, but the benefits are proving substantial. The company uses the following steps:

1) Identification of the process to be examined, and the clear delineation of the boundaries of the target activities.
2) Mapping the processing in real time to identify which steps add value and which do not. This requires close observation, a critical attitude, direct involvement with the resources employed, and honest admissions to failings. Notes, diagrams, and charts are helpful in mapping.
3) Analysis. First the mapping is analysed in a general way to (a) show the proportion of time spent on value-adding steps, (b) identify the time split between different tasks, (c) highlight the issues and problems and pinpoint causes of waste, (d) show the areas where there is greatest opportunity for change, and (e) give benchmarks from which to work. Next, after the general analysis has been completed, further questions can be asked about the value of each point in the process under study. Does it add value for the customer? Does it add value to the process? Does it add value to the business? Does it add value to the service? Does it add any value at all?
4) Implementation of changes should be immediate. This requires support from the whole organisation for adopting a lean approach to operating. There needs to be a confidence in the decisions that have been made and a determination to make them stick.
5) Review and repeat. The process of lean is ongoing. Once started, it should be maintained as a continuous culture. This needs senior management drive and the embracing of lean by the whole organisation.

In reality the most difficult part of lean is in maintaining this last step. Discipline and maintained enthusiasm is required throughout the company, from the very top to the very bottom. It is at this stage that there must be a real commitment from the top to ensure that the lean philosophy has been taken on through the whole business. It is helpful to choose one section of the operation at a time, train the people in the techniques, get them comfortable with the philosophy, and give them the time to look at the processes that they are involved in. The gains in efficiency, effectiveness, and professionalism will be apparent to everybody, and once one sector is operating under a lean regime others will want to follow.

CONCLUSIONS

Positive results have been seen in all the horticultural businesses that have undertaken lean projects. A real long-term benefit comes when a change in culture occurs such that lean becomes the norm.

There is a danger of assuming that products from nurseries, commanding a relatively low unit price, justify low quality production processes. But this leads to inefficiencies and higher production costs. Low quality product will continue to demand a low price and be costly in its production. However, aiming for perfection by implementation of the five lean basics, using high quality inputs (including the human resource), and eliminating waste will attain a high quality, high value output for less input cost.

The philosophy of lean is based on perfection, elimination of waste, and improvement of profit. The result of lean implementation is continual improvement in systems: managers spending their time managing and the workforce becoming more motivated as they begin to achieve. People begin to think differently about what they are doing and why they are doing it. It is not true that horticulture needs be inherently wasteful of the resources that it uses, and such ideas should not be used as a convenient, but erroneous, excuse for inefficiency and an unwillingness to embrace change.

Ditch Systems for Biological Filtration of Recycled Irrigation Water©

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INTRODUCTION

GroeiBalans is a small company operating in The Netherlands supplying advice on sustainable crop management to nurseries. This paper describes a biological water treatment system that it has been developing with a number of nurseries in The Netherlands.

The Importance of Water Treatment. The health of the water used to irrigate the plants on the nursery is fundamental to the health of the soil or container medium in which the plants are growing. It is important for introducing and maintaining good soil biology. With healthy, biologically active water the introduction of beneficial microorganisms, including mycorrhizas, is more successful. Growers need to recycle irrigation run-off in order to meet government regulations and restrictions and because there is a limited supply of good quality water. It is important that recycled water is treated in a way that maintains or improves its biological quality.

Aims of Biological Water Treatment. Biological systems of treating and filtering irrigation run-off should:

- Improve water quality by reducing calcium bicarbonate $Ca(HCO_3)_2$ levels.
- Result in a more efficient and economical use of water supply.
- Prevent build-up of algae.
- Suppress disease.
- Improve capacity in comparison with other filter systems.
- Be adaptable to existing water storage.

These aims are achieved with the filtration ditch system through aeration and biological activity.

FILTRATION DITCH SYSTEM

Ideally the filtration ditch system is constructed at the same time as installation of a water recycling and storage system. The active components of the ditch are aeration, water movement, UV light (sunlight), *Iris pseudacorus*, waterweed (*Elodea densa*), predatory fish, and water snails.

The ditch is divided into compartments to contain the different active species. Arranging the compartments on a series of interconnected levels and allowing the water to flow from higher to lower levels over a weir results in more aeration. Aeration is important to maintain biological activity and reduce calcium bicarbonate levels in hard water areas. Allowing the water to run over a weir also improves its exposure to sunlight, which kills harmful organisms.

The water plants absorb the excessive amounts of nutrients, which would otherwise give rise to problems with algae. Electrical conductivity levels drop as a result so that it is easier to accurately manipulate liquid feeding in the resulting

irrigation water. The plants also help to maintain a good habitat for biodiversity, which is important for disease suppression. Active bacteria, which grow on the root systems, suppress pathogens. *Phytophthora* for instance is present in every water storage system, but biologically active water treatment prevents it from becoming a problem.

The waterweed is important for oxygenating the water, while the predatory fish are there to remove plant pests. The snails remove other sources of harmful organic matter in the system.

RESULTS OF INSTALLING FILTRATION DITCHES AT THE ROELANDS BROTHERS NURSERY

The soil and growing media on this tree propagation nursery has become more biologically diverse and has improved colonisation with ectomycorhizae following inoculation into the growing media. With the improved mycorrhixal colonisation of the seedlings and the use of compost tea to stimulate other beneficial microorganisms in the root zone, the nursery has been able to reduce its use of fungicides dramatically and problems with damping off have been eliminated. For example the nursery has saved eight to nine chemical applications in its *Cytisus scoparius* crop, which is very sensitive for leafspot, phytophthora, and fusarium.

The Application of Advanced Irrigation Technology in Hardy Ornamental Nursery Bed Systems©

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Precise control over plant water status can provide growers with a means of using controlled water deficits to beneficially modify growth, development, and quality. Infra-red (IR) thermographic technology allows remote monitoring of leaf temperature, which can be a good indicator of plant water status because leaf tissues heat up as transpiration is reduced by closure of stomata (a common response to shoot or substrate water deficit). Precise methods of delivering irrigation and nutrients, based on IR imaging and gantry booms that tailor dose to the needs of individual plants, are being developed as part of a new Water-LINK project (Department for Environment, Farming and Rural Affairs). Expected benefits compared with existing nursery systems include minimal water run off, increased crop uniformity, a lower reliance on growth regulators, and less need for nurserymen to monitor the water status of beds. The technology is compatible with a number of emerging technologies in irrigation and plant monitoring.

INTRODUCTION

Most hardy ornamental nursery stock (HONS) growers in the U.K. rely on overhead sprinkler irrigation systems. These are relatively easy to install and require little maintenance. However, they have numerous disadvantages:

- Far more water is applied to the plant than is required to satisfy the demand from evapo-transpiration. This problem has become more important as the cost of water is increasing and extraction licenses are becoming restricted. It also leads to a reduction in crop quality, since the plants grow tall and unbranched and crop uniformity suffers.
- Sprinklers often have an uneven delivery when compared to other systems such as drippers. This leads to a proportion of the crop needing extra irrigation, achieved either by over-watering of other sections of the bed or by the use of hand-held hoses.
- Plants on the edge of a bed have a greater irrigation demand than those within the crop. This is not easy to compensate for with an overhead fixed sprinkler system.
- Constraints on space require growers to have numerous species on a bed, each with a different irrigation requirement resulting in over- or under-watering of most species.
- The foliage gets wet every time the irrigation is applied, and this can lead to greater risk of fungal disease, sun-scorch, and greater water loss through evaporation.
- Any area of bed without a crop on it also receives irrigation, and large quantities of water can be lost as a result.

In addition to these disadvantages, overhead irrigation is generally associated with manual assessment of plant/soil water status, which adds additional labour costs to the overall cost of production.

More efficient and uniform irrigation systems are available, and as the cost of water and labour continues to increase they are becoming more desirable alternatives to overhead systems. Dripper systems deliver irrigation directly to the growing medium and thus have greater control over the volume of irrigation delivered per plant. Gantry systems are starting to receive greater attention and are already being used by HONS growers in Germany and Holland.

GANTRY IRRIGATION FOR HONS

A gantry system consists of a mobile boom to which irrigation spray nozzles are attached. The boom travels over the crop while the nozzles release the water. With appropriate controls, water can thus be delivered to specific areas of the crop or even to individual plants.

This delivery system can be much more precise than overhead irrigation and has the potential to be modified and calibrated to suit the needs of the nursery. The gantry nozzles and locomotion can be controlled by a computer linked to sensors so that it can be programmed to account for edge effects, to differentiate between different species and their irrigation demand, to recognise bare ground, to apply water-deficits, and to add fertiliser treatments in the irrigation stream (fertigation).

Water Status Sensors. There are number of commercially available sensors that could easily be installed to control the irrigation delivered by a gantry system. Sensors that measure the soil dielectric can be used to determine the soil moisture content and these can be successfully linked into irrigation systems. Also, sensors that measure the evaporative demand received by a crop (e.g., evapo-sensors, SKYE Instruments) can also be incorporated into control systems. Leaf temperature (as an indicator of stomatal conductance) can be measured using thermocouples attached to a leaf of a sample plant to compare air temperature to leaf temperature. However, thermocouple sensors can be difficult for nurserymen to install and are too delicate to be used in unprotected environments. These and other sensors can only feasibly measure several points within the bed at most.

Thermal Imaging. Thermal imaging of crops to assess leaf temperature has the potential to measure plant water status and stress levels individually and adjust the water delivered to those plants accordingly. As soils dry, the leaf stomata close and the resulting lack of evaporation leads to a rise in leaf temperature. Although the difference in leaf temperature between well-watered and drought-stressed plants can be as little as one or two degrees, this can be clearly picked up if the sensors are calibrated correctly. A stress-induced rise in leaf temperature can happen rapidly after the stomata close and is therefore one of the first drought stress indicators, with the advantage that it can be assessed at a distance. An additional advantage of using leaf temperature to measure water stress is that species that have adapted to arid environments will close their stomata at much lower soil moisture contents than species that require very moist media to continue to grow. Therefore, the degree of stress in each species should be roughly equal once leaf temperatures have risen.

With prices of thermal imaging cameras dropping in the past few years it means that the technology is coming into the range where it will become economically feasible to use on HONS nurseries. One challenge is to develop a method of scanning beds that relies solely on the temperature of the foliage. The camera will also pick up the growing medium, container, and ground surface temperatures, and the data analysis must be capable of ignoring these areas of the image when making a calculation for the irrigation to deliver.

Image analysis software (Jones and Leinonen, 2004) can identify pixels in the electronic image that correspond only to the foliage. Reference surfaces can be used to differentiate between shaded and sun-lit foliage, which strongly influences leaf temperature (Jones 1999).

By logging the delivery of water supplied over a set period it can be determined if a plant has been over- or under-watered. If the thermal image temperature readings are more or less than expected for the amount of water supplied this will indicate if there is a problem with that particular plant (for example, a rise in temperature caused by disease stress). A warning message could then be generated for the grower to advise checking the plant located at a specific grid point on the bed.

If the thermal-imaging system is to be used outdoors, it would need to be able to cope with the effects on the plant temperature of increased wind speed and wetting effects from rain, fog, and dew. Problems can occur when trying to detect stress-induced high leaf temperatures in humid environments or with high airflow. Under these conditions leaf cooling due to transpiration is severely reduced. These hurdles will be overcome during development of a working demonstration rig for the LINK project.

Species Considerations. There are a number of species that will have to be given special considerations, as their leaf temperature doesn't relate to water status in the same way as that of most plants. Some species do not regulate their internal water status by closing stomata as soon as drought stress occurs. These species, termed anisohydric species, first lower internal water potentials before stomatal conductances are significantly affected. In these species, the thermal cameras may not be able to detect mild stresses as is the case in normal (isohydric) species. We are currently finding out which of the most commonly grown ornamental species fit into which of the two categories. When a large number of species from several plant families have been sampled, it is hoped that we will be able to develop a means of determining which groups of plants have the ability to act isohydrically and see if there is an evolutionary link from the response.

Another set of plants that needs special consideration are the species belonging to the arum lily family (Araceae), which have inflorescences that are thermogenic — the temperature of the inflorescence increases dramatically as the flowers ripen (Skubatz et al., 1990). Therefore, any thermal scanning system would confuse this with stress-induced heating and provide far too much irrigation. Other potential problems with the use of thermal imaging may arise if the plants are experiencing other types of stresses, such as viral attack, waterlogging, and frost damage, which are known to reduce stomatal conductance. These stresses will result in increased leaf temperature, but should not be treated with increased irrigation (Chaerle and Van Der Straeten, 2001; Wan et al., 1998).

CONCLUSION

Thermal imaging technology has the potential to provide great advances in the HONS sector by reducing water waste, but most importantly increasing quality and uniformity of plants. Signs of drought stress can be picked up early, and irrigation can be individually tailored to thousand of plants on the beds with gantry boom sprayers. There are still significant challenges faced in the development of such systems, but the technology is now at the stage where demonstration rigs are being developed and commercialisation is foreseen in the near future.

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Experience Using Controlling Seed Moisture Content During Stratification to Improve Germination on the Nursery©

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INTRODUCTION

My business offers seeds and seed treatment services to the large number of tree nurseries in the Zundert area of The Netherlands and produces plug-grown nursery stock seedlings. We use a seed stratification technique based on controlling the moisture content in the seeds. The aim is to reduce premature germination while increasing the proportion of seeds which go on to break dormancy and germinate after sowing.

This paper explains how the technique is applied to *Acer platanoides* and *Fagus sylvatica*, with reference to the traditional stratification treatments for each species. The treatments and germination results shown are based on our own trials and experience.

SPECIES

Norway Maple (*Acer platanoides*).

Traditional Treatment. Seeds are dipped twice in 24 h in water, mixed with sand or peat, and kept at 4 °C for 8 weeks, moistening lightly once a week.

The disadvantage of traditional stratification is that it is difficult to control. It can result in the premature germination of a proportion of the seeds during the stratification period but does not bring all the seeds out of dormancy after sowing.

Moisture-Controlled Stratification.

- Weigh seeds into bags (a large number of smaller bags makes it easier to take samples for moisture checking during the stratification period).
- Take a sample of each batch of seeds to calculate the initial moisture percentage.
- Weigh the sample and then place in an oven for 17 h at 105 °C to remove all moisture but not the oils. Weigh the sample again. The difference in weights is used to calculate the moisture content as a percentage of weight for the seed batch. This figure is used to work out the amount of water to add to the batch to maintain a given moisture content.
- The optimum moisture content to maintain for *A. platanoides* is 36%. This does need to be strictly controlled because 34% is too low, causing the seeds to dry out, while 38% is too high, sufficient to trigger premature germination.

- Add the required weight of water and mix with the seeds in the bag.
- Place the bag of seeds in a refrigerator or cold store at 4 °C for 16 to 20 weeks.
- Re-mix and check the moisture content of the seeds being treated every week.

The advantages of moisture-controlled stratification are:

- Seeds can be kept under the cold treatment for twice as long as in traditional stratification. This allows time for a higher proportion of the seeds to break dormancy, resulting in faster and higher percentage germination of the batch after sowing and enables the seeds to germinate over a wider temperature range.
- All viable seeds will break dormancy because of the longer cold treatment period.
- Controlling the moisture content prevents germination during stratification.

One disadvantage is that the treatment takes up more space in cold storage because of the small number of seeds per bag, especially with winged-seeded species such as *A. platanoides*. The other is the need for precise measurements and accurate calculations required to maintain the moisture content of the seeds within tight limits.

Germination Results. Fifteen weeks of cold treatment results in 34% germination; 19 weeks results in 78%.

European Beech (*Fagus sylvatica*).

Traditional Treatment. As for *A. platanoides* above, except that seeds are stratified for 8 to 12 weeks, at which point the first seeds may start to germinate.

This type of stratification has the same disadvantages as when used with *A. platanoides*. In addition, premature germination is particularly likely if the seeds are kept in stratification beyond 12 weeks. Seeds sown from this treatment may exhibit low germination rates if soil temperatures are high.

Moisture-Controlled Stratification. Seeds are weighed and bagged and moisture content determined as for *A. platanoides*.

The optimum moisture content for *F. sylvatica* is 30%; 28% is too low and will result in the seeds drying, while 32% is too high and will lead to premature germination. This should be maintained as described for *A. platanoides*.

Stratify at 4 °C for 16 to 18 weeks, checking moisture content and re-mixing weekly.

The advantages are the same as for *A. platanoides*. The disadvantage is the precision required to maintain the correct moisture level.

Germination Results. Ten weeks of cold treatment gives 54% germination; 16 weeks gives 82%.

Liquid Sorting and Film Coating: Techniques for Improving Tree Seed Performance©

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INTRODUCTION

Tree seed performance has benefited considerably from the development of controlled methods to overcome dormancy. Traditionally tree seeds have often been stratified outdoors. Depending on the types of dormancy, stratification starts before or during summer and continues during winter, or it starts before winter. Seeds become ready to germinate during winter, and they may start to germinate before sowing. Reducing the water content of the seeds during pre-treatment can prevent this premature germination.

If premature germination is prevented, treatments at slightly reduced and controlled moisture content (MC) can be prolonged. As a result, percentage, rate, and uniformity of germination increase. Moreover germination proceeds over a wider range of seedbed conditions. So far, controlled MC treatment has been developed for about 20 species, both broad leaved and conifers.

Seed quality is often a limiting factor in tree seeds, which are often collected from the ground. The prevention of premature germination during controlled MC treatment leads to new possibilities for seed enhancement techniques, including liquid sorting and film coating. Both techniques have been proven successful in agricultural and horticultural seeds. Liquid sorting is a technique that aims to remove poor quality seeds by sorting on specific gravity. Temperature and water potential can be controlled to provide conditions which are optimal for the species. Film coating with fungicides aims to protect the seed against soil-borne diseases, thereby increasing the percentage of usable plants.

The aim of the present study was to investigate effects of liquid sorting and film coating with fungicides in some tree species.

MATERIALS AND METHODS

Dormancy Breaking. To overcome dormancy, seeds were pre-treated in a controlled way. Cold pre-treatment at 3 °C occurred at controlled MC without medium in plastic bags. Warm pre-treatment of fully hydrated seeds was in a sphagnum peat and sand (1 : 1, v/v) mixture in plastic boxes. Three volume parts of medium were mixed with one volume part of seeds. Moisture content of *Larix kaempferi* seeds was not controlled, as premature germination is not possible during the relatively short cold pre-treatment of this species. Pre-treatments of the different species are shown in Table 1.

Germination and Sowing Conditions. Four replicates of 50 seeds were sown in plastic boxes or Petri dishes on one layer of wet thick paper or wet filter paper. Germination of *L. kaempferi* was tested at 15 °C. Germination of the other species in the liquid sorting experiments was tested at 10 °C. Germination in the film coating experiments was determined at 17 °C. Germination tests were finished

Table 1. Treatments to overcome dormancy in the different species.

Species	Pre-treatment
Acer palmatum	12 w 3 °C, 37% MC
Acer pseudoplatanus	15 w 3 °C, 46% MC
Carpinus betulus	6 w 20 °C in sphagnum peat/sand followed by 16 w 3 °C, 28% MC
Crataegus monogyna	10 w 25 °C in sphagnum peat/sand followed by 24 w 3 °C, 22% MC
Fagus sylvatica	20 w 3 °C, 30% MC
Larix kaempferi	10 or 6 w 3 °C, fully hydrated
Prunus avium	8 w 20 °C in sphagnum peat/sand followed by 18 w 3 °C, 28% MC (liquid sorting)
	Or 2 w 20 °C, 6 w 3 °C, 2 w 20 °C, 2 w 3 °C, 2 w 20 °C, 14 w 3 °C, 28% MC (film coating)
Tilia cordata	8 w 20 °C in sphagnum peat/sand followed by 24 w 3 °C, 43% MC

Note: Abbreviations: w = weeks, MC = moisture content.

after 4 weeks. Field emergence was determined at an experimental field or at commercial nurseries.

Liquid Sorting. In the first experiment seeds were sorted either before or after dormancy breaking; in the second experiment seeds were only sorted before dormancy breaking. Before liquid sorting, using liquids with different specific densities, air was removed from the seeds.

Film Coating with Fungicides. Different film coatings with fungicides were applied after dormancy breaking. The fungicides used were a combination of fosetyl-aluminium (Aliette, 3 or 6 $g \cdot kg^{-1}$ seed) and iprodione (Rovral Aquaflo, 3 or 6 $ml \cdot kg^{-1}$ seed); and a combination of propamocarb hydrochloride (Previcur, 6 or 12 $ml \cdot kg^{-1}$ seed) and thiophonate-methyl (Topsin M) (4 or 8 $ml \cdot kg^{-1}$ seed). In *Fagus sylvatica* these fungicides were also applied individually.

RESULTS

Liquid Sorting. Germination often correlated with the specific density of the seeds (Fig. 1). In general, low-density fractions showed the poorest germination. Sometimes, the heaviest fraction showed poor germination too. By removing these fractions the performance of a seed lot can be improved. In most species liquid sorting was successful before and after dormancy breaking (data not shown). In *Prunus avium* and *Crataegus monogyna*, liquid sorting after dormancy breaking was disturbed by loose fruit parts. In 2005 complete fruits of *Acer pseudoplatanus* were sorted. Sorting in water allowed removal of the lightest fraction. However, this fraction still showed 70% germination (Fig. 1). In 2006 de-winged and winged fruits of *A. pseudoplatanus* were sorted. Results were comparable (Table 2). In contrast to 2005 liquids with a specific density higher than 1 were required to remove the heaviest fraction in *A. pseudoplatanus*, which showed poorer germination than the lighter fractions (data not shown).

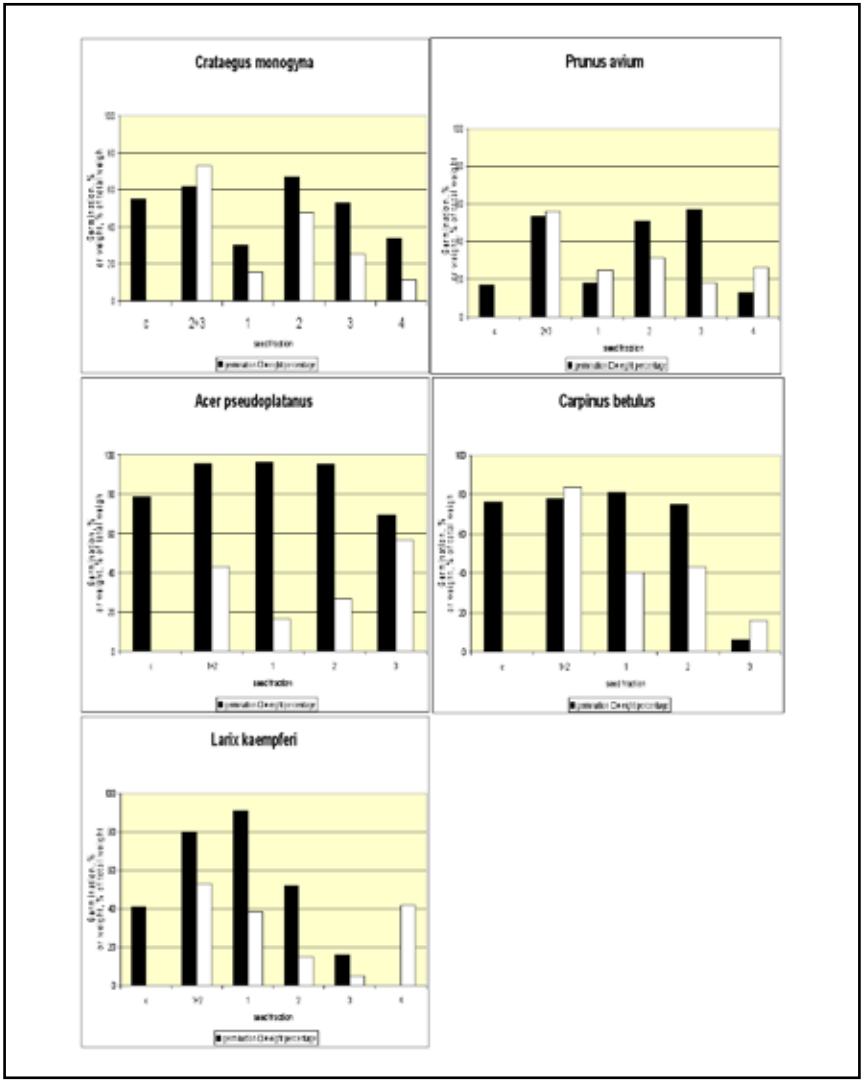

Figure 1. The effect of liquid sorting on germination of seeds of *Crataegus monogyna*, *Prunus avium*, *Acer pseudoplatanus*, *Carpinus betulus*, and *Larix kaempferi*. Before (*Crataegus*) or after (other species) dormancy breaking as indicated in Table 1 seeds were divided in different density fractions. c = nonsorted control. *C. monogyna*: 1 > 1.300, 2 = 1.260 – 1.300, 3 = 1.175 – 1.260, 4 < 1.175; *P. avium*: 1 > 1.220, 2 = 1.200 – 1.220, 3 = 1.155 – 1.200, 4 = 1.100 – 1.155; *A. pseudoplatanus*: 1 > 1.060, 2 = 1.000 – 1.060, 3 < 1.000; *C. betulus*: 1 > 1.225, 2 = 1.190 – 1.225, 3 < 1.190; *L. kaempferi*: 1 > 1.110, 2 = 1.075 – 1.110, 3 = 1.025 – 1.075, 4 < 1.025. Germination of all fractions was tested at 15 °C (*Larix*) or 10 °C (other species).

Table 2. The effect of liquid sorting on laboratory germination and field emergence of different seed lots of different species. Dormancy breaking and germination as in Figure 1.

			Germination			Field emergence		
Species	Provenance/seed lot	Year	Non-sorted	Sorted	Benefit	Non-sorted	Sorted	Benefit
Acer pseudoplatanus	Eastern Europe	2005	89	94	5			
	Vaartbos (NL)	2005	83	98	15			
	Zeewolde (NL)	2005	71	98	27	44	58	14
	Vaartbos de-wing	2006	33	55	22	31	25	-6
	Vaartbos wing	2006	31	52	21	21	19	-2
Carpinus betulus	Hilversum (NL)	2005	76	80	4	68	74	6
	Eastern Europe	2005	22	29	7			
	Hilversum (NL)	2006	3	52	49			
	Eastern Europe	2006	17	14	-3			
Crataegus monogyna	Italy	2005	42	57	15			
	Italy	2005	55	62	7			
	Romania	2005	47	49	2			
	Italy	2006	34	45	11	47	69	22
	Eastern Europe	2006	19	20	1			
Larix kaempferi	China	2005	45	84	39			
	DK Sostrup 2000	2006	61	89	28	43	57	14
	DK Sostrup 2002	2006	48	55	7	32	36	4
Prunus avium	Eastern Europe	2005	15	37	22	52	73	21
	Vaartbos (NL)	2005	8	23	15			

Table 2 shows that the benefit of liquid sorting on laboratory germination differs from seed lot to seed lot.

Some seed lots were sown outdoors. The results in Table 2 show that liquid sorting improved field performance in several seed lots. In 2006 field performance of *A. pseudoplatanus* did not benefit from liquid sorting, whereas laboratory germination did.

Film Coating With Fungicides. The combination of Aliette and Rovral Aquaflo and that of Previcur and Topsin M had no phytotoxic effect on seeds of *A. palmatum* and *Tilia cordata*. On *P. avium* phytotoxic effects were found in laboratory tests, on *Fagus sylvatica* phytotoxic effects were seen both in laboratory and field emergence tests. Single fungicides also produced phytotoxic effects in laboratory tests of *F. sylvatica*.

In the field only Aliette was phytotoxic. Positive effects of Previcur on reduction of damping-off were seen in *F. sylvatica*; positive effects also resulted from both tested combinations on *A. palmatum* (data not shown). In general, there were only low levels of damping-off on the untreated plots in our trials, so it was not possible to draw final conclusions about the effectiveness of the film coatings against damping-off.

Prunus avium seeds with a film coating of Aliette and Rovral Aquaflo were also sown at two nurseries. In one nursery film-coated seeds gave significantly better field emergence (Table 3). Only a few seedlings showed damping-off.

Table 3. The effect of a film coating with Aliette (6 $g \cdot kg^{-1}$ seed) and Rovral Aquaflo (6 $ml \cdot kg^{-1}$ seed) on laboratory germination and field emergence of *Prunus avium* seeds.

Treatment	Laboratory germination	Field emergence		Damping-off
		Nursery 1	Nursery 2	Nursery 2
Control	89	53	49	6
Film coating	90	52	73	1

DISCUSSION

Liquid sorting resulted in seed fractions with different specific densities (Fig. 1). By removing fractions with poor germination, the performance of a seed lot can be significantly improved (Fig. 1, Table 2). The benefit of liquid sorting varied from seed lot to seed lot and depended on the initial quality of the seed lot and the dormancy-breaking pretreatment.

A safe film coating with fungicides has been developed for *A. palmatum*, *P. avium*, and *T. cordata*, but not yet for *F. sylvatica*. So far, few conclusions can be drawn about the effectiveness against damping-off. In one nursery, field performance of film-coated seeds of *P. avium* was better than that of control seeds (Table 3). Further research is required to develop a safe film coating for *F. sylvatica* and to confirm effects against damping-off.

Biofumigants and Green Manures for Field-Grown Nursery Stock©

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INTRODUCTION

This paper considers the general benefits of green manures, cover crops, and biofumigants for the nursery industry and reviews the three green manure/biofumigant crops currently of interest to growers in Great Britain and Ireland.

It is important to understand the distinction between a green manure, a cover crop, and a biofumigant crop:

Green Manure. The soil incorporation of any crop (green or soon after flowering) for the purpose of soil improvement.

Cover Crop. Any crop grown to provide soil cover, regardless of whether it is later incorporated. The crops are primarily grown to prevent soil erosion by wind or water.

Biofumigation. Growing and incorporating a crop in a way that exploits its defensive enzymatic systems or biocidal activity, as a strategy to control weeds or soil-borne pests or pathogens.

General Benefits of Green Manures and Biofumigant Crops. These crops can help improve soil structure and moisture retention and provide a supply of organic nutrients to the following cash crops. They also help improve the diversity of populations of beneficial microorganisms.

Used as part of an integrated pest management (IPM) programme they offer: reduced risk of development of pesticide/fungicide resistance; reduction in pesticide costs; reduction in staff exposure to chemical applications; an energy source for beneficial microorganisms; an opportunity to break the pest or disease life-cycle; and direct suppression of weeds, pests, and diseases.

BIOFUMIGANTS

Mustard.

Benefits.

- Attracts naturally occurring beneficial insects during flowering.
- Root penetration aids soil structure.
- Soft seeded.
- Some types are fairly frost tolerant.
- Easy to grow.
- Produces biofumigant iosthiocyanates (ITCs) when tissues damaged, for example by chopping, which control a range of pests and diseases.

Mode of Action. Isothiocyanates were discovered in mustard seeds in 1840 and play a role in the plant's defence system against insects and microorganisms. They are produced in the green tissues of many members of the brassica family. When the tissue is mechanically damaged, stored glucosinolates are exposed to degrada-

tive enzymes, which break them down to produce ITCs. Synthetic ITCs include pesticide products such as metam-sodium.

Fertiliser applications can have a direct effect on glucosinolate concentrations.

Research in the U.S.A. and U.K. has shown that mustards used as biofumigants can help control pests and diseases of a range of crops including verticillium wilt, fusarium, pythium, sclerotinia, replant disease, nematodes, and slugs as well as weeds.

Caliente is a mustard variety with a particularly high glucosinate content.

Factors to Consider When Using Mustard. Mustard is best grown as a summer crop so may need irrigation during dry periods. It requires a moist soil before and after sowing. The crop can be vulnerable to brassica pests and diseases. Average seed rate for use as a biofumigant is 15 $kg \cdot ha^{-1}$; rising to 18 $kg \cdot ha^{-1}$ for fixed bed crops.

The highest concentration of ITCs is in the flowers so timing of chopping and incorporation is crucial — the plants should be allowed to flower but not seed.

The green material needs to be incorporated immediately after chopping — 80% of the volatile ITCs are lost in first 20 min. After incorporation, the field must be left for 21 days before planting young crops.

French Marigold.

Benefits.

- Wide range of nematodes removed/suppressed.
- Associated rhizobacteria/fungi likely to increase and reduce nematode numbers through competitive exclusion and predation.
- Produces naturally occurring broad-spectrum biocides.
- Inter-row planting capability.
- Can be grown prior to a susceptible crop.
- Potential for diversification into flower/seed sales.
- Attracts naturally occurring beneficial insects during flowering.
- Easy to grow.

Mode of Action. Root cells react to damage by producing terthiophenes which block nematode metabolism, inhibits egg hatching and development of juveniles, and reduces nematode root penetration.

Factors to Consider When Using French Marigold. Certain species of nematode may only be controlled by a certain species of marigold. The nematicidal compound is only effective if the crop is grown in the soil requiring treatment and control ends after incorporation.

French marigolds are not frost tolerant. They require a moist soil before and after sowing. Bulk seed may not be readily available. Seed rate for use in nematode suppression is 3 to 4 $kg \cdot ha^{-1}$.

A combination of *Tagetes erecta* (African) and *T. patula* (French) gives the most effective nematode suppression. Other marigold species used have been shown to be too vulnerable to nematodes.

Sudan Grass.

Benefits.

- Tolerant to drought and heat.
- Deep penetrating root system can loosen subsoil.
- Significantly reduces nematode populations.
- Significantly reduces verticillium wilt levels.

- Attracts predators during flowering and beneficial microorganisms during decomposition.
- Is not vulnerable to any significant pest and diseases.
- Rapid establishment and growth is ideal for short growing windows.

Mode of Action. The growing crop releases sorgoleone, a root exudate that suppresses weed growth while tissue damage on chopping and incorporation releases of hydrocyanic acid and glucosinates.

Factors to Consider When Using Sudan Grass. Sudan grass is still used mainly as a game-cover crop in the U.K., so there has been little research into its biofumigant activity, including varietal glucosinolate levels. It is not frost tolerant and should not be grown where cattle or sheep will graze. The seed rate is high — 45–60 $kg \cdot ha^{-1}$ to improve its ability to smother weeds. Levels of glucosinolates are higher in young tissue so it should be cut twice during the growing season. Sow at higher rates to increase weed smother ability.

Pre-Planting Recommendations for All Three Crops.

1) Test soil prior to sowing to check nutrient levels — the amount of fertiliser has a direct effect on the amount and quality of organic matter produced for any green manure effect required.
2) Sow from mid-May onwards.
3) Control any early weed seed at crop seedling stage.

Approximate Costs of Seed 2006 (U.K.).

- Caliente mustard: £100 per ha (£ 6.67 per kg).
- French marigold: £456 per ha (£114 per kg) with tails or £536 per ha (£134 per kg) without tails.

Seed Suppliers (U.K.).

- Marigold: Thompson and Morgan (wholesale), Suffolk, U.K.; Sahin BV, The Netherlands.
- Sudan grass: Church's of Bures, Suffolk, U.K.; Oliver Seeds, Lincoln, U.K.; King's Seeds, Colchester, Essex, U.K.
- Caliente mustard: Plant Solutions Ltd, Surrey, U.K.

Bionomics for Woody and Herbaceous Perennial Plant Production©

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INTRODUCTION

Until recently chemistry was seen as the best way to understand and work with crop production, turning it into an industrial process: seeds and chemicals are the inputs and the crop is the end product. But what happens in the middle is biology — and bionomics is about looking at soil chemistry from a biological standpoint.

Biology is mostly about organic molecules rather than inorganic chemical salts or ions. Nitrogen, phosphorus, potassium, and the trace elements are important for the crop's nutrition. From these elements plants can synthesize all they need. It is the soil's organic compounds however that determine the availability of these nutrients to a crop.

Soil bionomics is about the soil economy and the maintenance of soil organisms, which in turn maintain the nutritional quality of the soil. Bacteria and fungi prepare the nutrients in a form suitable for everything else living in and from the soil. Economics is based on numbers and counting to measure financial health and you can also keep an account of the health of your soil by measuring the amount of fungal or bacterial biomass in the soil and counting the number of different species present. Dr. Elaine Ingham from Soil Foodweb Inc., Oregon, U.S.A. has researched the soil economy and how to manage it in agricultural practice around the world. The soil foodweb analysis she designed, based on the most accurate microbial biomass assessments available, shows us a collection of numbers crucial for soil foodweb management. Her desired ranges make soil life evaluation easy.

Most nutrients needed by living cells are universal; bacteria need them and plants need them. Hunting the soil for what they need, soil microbes find food for plants as well. Some bacteria can take in nitrogen from the air. Some fungi can make phosphate soluble where plants cannot. Protozoa and nematodes predate bacteria and fungi — like can openers they unlock the rich nutrients stored in bacterial cells. These predators excrete surpluses like all animals do, which make excellent plant nutrients, easily absorbed by the roots. The amounts of protozoa and nematodes are directly indicative of the amount of plant nutrients that are made available for the crop.

As an adviser I have helped many growers manage the foodweb in their soils. Some of the results they report include:

- Greater yields and improved uniformity.
- Grading time shortened from 12 to 7 h a day in cut flowers.
- Grafting take increased by 20%.
- Crops less susceptible to stress.
- Pot plants less susceptible to over- or under-watering.
- Improved soil structure.

CONSTITUENTS OF A HEALTHY SOIL FOODWEB

Bacteria and fungi are the primary organisms in the soil food chain as they degrade all material that falls on or in the soil. The number of different bacterium species in the soil is expressed in millions and the number of fungal species in thousands. The more different species that are living in a soil, the more tasks can be performed by the different specialists and the better the soil ecosystem is protected against disruption — either by an incoming pest or pathogen or an environmental change such as drought or waterlogging. Hardly any erosion occurs where a good soil foodweb is established. Root exudates from plants provide the microorganisms with food they can't make themselves, so there is mutual dependence in a healthy foodweb.

The oldest fossils from plants living on land contain mycorrhizal fungi, showing that as soon as plants evolved to live on dry land, they began to use the microorganisms that already lived there. And by the same token, microbes in the soil immediately started to make use of all the opportunities plant life brought to their habitat. This mutual dependence evolved over the last 450 million years into a sophisticated system that can survive almost everywhere to produce biomass in a highly efficient manner using water, air, and sunlight.

Processes That Damage the Foodweb.

When the ionic concentration outside a microorganism is higher than its internal ionic concentration, the microorganism dries out and dies. Chemical fertilizers add ions into the soil and kill microorganisms when applied in dosages higher than 200 $kg \cdot ha^{-1}$. Chemical pesticides and herbicides kill many nontarget beneficial organisms. Fungi consist of threads that are rather brittle and break when the soil they live in is cultivated.

When Dutch researchers started to monitor microbial life in the soil they did not include an assay for fungi because they did not find any in Dutch agricultural soils. It took some time before the absence of fungi was recognized as a result of agricultural practice and probably the cause of many disease problems. When a healthy soil foodweb is established, there is less need to work the soil structure mechanically. Soil life can break hard pans, keep air in the soil, and regulate moisture. A spading machine works the soil more gently than normal tilling and therefore is kinder to soil life.

THE ROLE OF SOIL ORGANISMS IN CROP NUTRITION

Chemistry turned agriculture into an industrial process, but this in turn has reduced the amount of life in agricultural soils. More chemistry has been needed to replace functions that were once the beneficial result of soil biological activity. It is possible to manage the soil to repair what has been lost but without turning back time and losing the benefits of a scientific approach to agricultural and horticultural production.

Soil microbes can replace much of the chemical fertilizer now used. This is achieved by feeding the microbes really well in order to make them very productive. The microbes will then make available a wide range of nutrients and stimulants around the plant roots — both mineral nutrients and more complex bioactive molecules. Such bioactive substances stimulate the roots and many can be used by the plants as nutrients.

The best crop performance occurs with a good foodweb in the soil rather than when they are grown with large amounts of mineral nutrient. Plants can respond to nutrient deficiency by releasing exudates from their roots into the soil to stimulate the growth of certain microbes that release the required nutrients.

There is still a place for additional chemical fertilizers. But small doses of chemical fertilizers in a rich soil foodweb will be utilized very efficiently. Feeding the soil foodweb and letting that feed the crop is more cost effective than supplying chemical fertilizers to try to feed the plants. In addition this approach will reduce leaching of fertilizer nutrients, which not only reduces fertilizer cost, as less has to be applied, but reduces the costs associated with prevention or repair of environmental damage caused by leaching.

Plants need so much more than NPK and trace elements. They respond very positively to vitamins and amino acids, but such nutrients are hardly considered in industrial agriculture today. When nitrogen is available as amino acids, the plants can use more energy for growth and development instead of to make their own amino acids.

Fertilizer salts do not contain all mineral nutrients plants need nor the agents that make trace elements available to plants. Plant health and development is stimulated when nutrients are contained in organic molecules. Humus and microbes make taking in nutrients so much easier for plants. Although a plant can live on mineral nutrients alone, this is not the optimum situation. A nutrition source based on organic molecules demands less energy of the plant.

THE ROLE OF SOIL ORGANISMS IN CROP HEALTH

When crop plants are well fed and grow in soil rich with microbial life, they have optimum natural resistance against disease. For example, bacteria taken up from the soil into the plant's vascular system help to induce resistance. Also, a highly diverse population of bacteria and fungi in the soil makes it more difficult for individual plant pathogenic species to establish large populations above infection thresholds. They are eaten, barriers are formed against their entering plant tissue, and their nutrients and environmental niches are taken up by other species.

Chemical fungicides, apart from killing pathogens, also attack the organisms that help the crop resist diseases. By optimizing natural defence mechanisms the use of chemical pesticides can be reduced.

There is still a place for the use of chemical fungicides and pesticides but if they are used then the soil foodweb should be re-established afterwards. This can be done with applications of compost or compost tea. Good composts, and the teas brewed from them, contain replacement organisms and nutrients for them.

Compost applied to the soil contains biochemical molecules, which are a source of nutrition for bacteria and fungi. The nutrients provided to the microorganisms, will end up in the crop. As they grow the microorganisms make something else that's very important for a healthy soil: humus.

This is the fraction of the soil that consists mainly of humic and fulvic acids, and it plays a central role in nutrient exchange between soil, microbes, and plants.

Its electro-chemical properties enable nutrients to be dissolved and taken in by plants. At the same time it is beneficial to microbes and the soil structure.

HOW TO MANAGE SOIL BIOLOGY

The first step is to know what you are starting with. Find a laboratory able to undertake a soil foodweb analysis and send a sample. Developed in the U.S.A. the results apply universally because microbial degraders and their predators operate in basically the same way all over the world.

The analysis looks at:

- Total and active bacterial biomass (direct counting through microscope).
- Total and active fungal biomass (direct counting using microscopy).
- Hyphal diameters (mean hyphal diameter as met during total fungal biomass assessment).
- Protozoa numbers and community structure (different dilutions of the sample are incubated on soil agar and checked for presence of flagellates, amoebae and/or ciliates and from these results their numbers are calculated).
- Nematode numbers and community structure (nematodes are extracted from the sample, counted, and identified with microscopy).
- Mycorrhizal colonization of roots.

Each parameter has an optimum range of numbers or measurements so the assays can be used to diagnose and monitor the soil foodweb and predict its functions. Once an analysis has been performed the laboratory should be able to suggest what can be done to improve the situation when a parameter is outside the desired range.

Good compost can be used either to adjust the soil ecology to address problems identified by the analysis or to maintain the soil. Compost can be made to contain more bacteria or more fungi, depending on requirements identified by the analysis report.

How to Identify a Good Compost. First look for a good crumb structure. The microorganisms that establish this crumb structure will also give your soil the required structure. If the compost does not have a good structure it means it does not contain the right balance of organisms.

Looking at compost, it should not be possible to identify the original material it is made off. That should be really well digested by the microbes.

Moisture content is important. Too much water often makes compost anaerobic. Too little makes it hard for the microbes to survive. Aim for a moisture content of 55% to 65% — this can be estimated by hard squeezing, which will release just a drop of water when the moisture is right.

Good compost will smell of forest soil, sweet and pleasurable. An unpleasant smell means the compost has the wrong balance of microorganisms. The unpleasant smell indicates toxics formed by anaerobic processes.

When temperatures have been high during composting, the materials become "burned." Black compost means charcoal has been formed when the temperature was too high.

The carbon found here as charcoal would have been incorporated into organic molecules if it was in good compost.

When you buy compost you should ask for laboratory test results. Compost can be analysed at by the same assays as the soil foodweb analysis, except for mycorrhizal colonization, and the results should fall within optimum ranges for compost.

Some laboratories grow microbes and sell them in packages, but in this author's opinion this is not as beneficial to soil as good compost. The number of different microorganisms is what matters: enough species to undertake all the different tasks and to ensure a functioning ecosystem survives any changes in the soil environment. Not all commercially available microbes are as well equipped for soil survival in a competitive situation as compost microbes are.

Making your own compost has many advantages, the main one being that you are in control of the raw material, the process and therefore the quality of the end product.

Collecting raw materials to make compost will get easier the more you do it. Most materials are delivered to you free because others consider it waste. The composting process takes 6 to 8 weeks.

If using solid compost is a problem, for example in container growing, it is possible to apply your microbes and the nutrients they need in liquid form through a sprayer, as compost tea.

Brewing compost tea takes about 20 h. The resulting liquid is a living material and should be used as soon as it is ready. It is made in a container with water and compost. It should be well oxygenated by blowing air through the water as the tea is brewing. Like compost, compost tea is rich in microorganisms and nutrients. The organisms in the tea will cover your crop with a layer of micro-life to protect it against diseases.

Compost and Compost Tea in Organic Greenhouse Horticulture Using the Soil Foodweb Approach©

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INTRODUCTION

Vzw Lochting-Dedrie is a nonprofit organization that offers employment to people who, for a wide variety of reasons, aren't able to be part of the regular work force. On average, we have about eight people working in the organic growing section lead by two instructors. The organization is supported by national and local government in the form of wage subsidies and the use of land; 30% of the income is in the form of wage subsidies but 70% has to be earned selling what is grown.

The organisation has a 1-ha greenhouse and 25 ha of outdoor land, which is used to grow leeks. The greenhouse activities are almost exclusively carried out by our own work force. Work on the fields, apart from harvest, is outsourced.

Since 2005, our aim is to base the entire fertility management on the soil foodweb approach as developed by Elaine Ingham. She is the founder and director of the Soil Foodweb Institute, Corvallis, Oregon, U.S.A.

SOIL FOODWEB APPROACH

The basic concept is that in order to grow healthy and productive crops, the complete foodweb has to present in the soil. The lowest members of the web are bacteria and fungi. The beneficial bacteria and fungi that live in the root zone use plant exudates to grow. The nutrients that these organisms "store" are released when there are appropriate numbers of higher organisms (protozoa, nematodes, and microarthropods) to start a nutrient cycle. If there are, for instance, too few protozoa this acts as a bottleneck for the nutrient cycle, and it will result in plants not growing well. A grower following foodweb principles would then try to increase the number of protozoa.

Soil Chemistry Analysis. Soil foodweb management starts with the determination of several different functional groups of organisms in the soil and their activity or diversity. An example of such analysis is shown in Table 1. In addition, a soil chemistry analysis is required to determine the total, exchangeable and soluble pool of nutrients. This type of analysis shows whether an element is really too low for good growth or whether the element is present in adequate amounts but probably doesn't become available to the crop because the organisms required to transfer it to the soluble pool are not present.

In this example, all the records apart from amoebae numbers were below that required for a healthy soil.

Compost. Good compost adds both organisms, and food for those organisms, to the soil. In order to know what contribution to the functional groups the compost presents, an analysis analogous to the soil analysis should be made. Compost also raises the level of organic matter in the soil. In Belgium, it is hard to find good compost, so growers following this approach would need to undertake their own composting.

Table 1. Soil foodweb analysis.

Dry weight of 1 g fresh material	0.81
Total nematode numbers (number/g)	3.24
Active bacterial biomass ($\mu g \cdot g^{-1}$)	42.6
Percent mycorrhizal colonization of root	7
Total bacterial biomass ($\mu g \cdot g^{-1}$)	340
Total fungal to total bacterial biomass	1.13
Active fungal biomass ($\mu g \cdot g^{-1}$)	27.7
Active to total fungal biomass	0.07
Total fungal biomass ($\mu g \cdot g^{-1}$)	386
Active to total bacterial biomass	0.13
Hyphal diameter (µm)	2.5
Active fungal to active bacterial biomass	0.65
Flagellates (numbers/g)	17148
Plant available n supply from predators (lbs/acre)	100–150
Amoebae (numbers/g)	7118
Root-feeding nematode presence	Cyst, root-knot
Ciliates (numbers/g)	72

Compost Tea. The use of compost tea is another way of adding organisms and food to the soil (or to the crop's leaves). Compost tea is made by blowing air into a mixture of a relatively small amount of compost, plus appropriate foods for the compost organisms, in a tank full of water. Compost tea can be used when it is difficult to apply compost, for example when the crop is planted or when the fields are very large so the amounts of compost become impractical to apply. The time of the brewing process depends on the type of compost brewer and the recipe for brewing. A microscope is needed to assess whether the compost tea contains organisms suitable for your needs.

Composting at Vzw Lochting-Dedrie.

We produce about 1000 m^3 of finished thermal compost per year. For our feedstock, we recycle all the organic waste products that we generate ourselves: spent aubergine, tomato, and cucumber plants, weeds, and leek leaves. Because these materials become available gradually, the initial compost piles are built in layers. The bottom layer is always a 10 cm straw layer. Then, layers of green and brown material are added over time. Brown material is either straw or wood chips. We aim for a mixture of 40% green and 60% brown material. Once the piles are large enough they are turned by machine, which is rented as necessary.

Piles are turned based on temperature, CO_2, and moisture measurements. Turning is needed when temperatures get too high (65 °C or more), when oxygen is too low (4% or less), and when the material gets too dry (less than 50% moisture). The number of times the pile has to be turned depends largely on the initial composi-

tion of the pile. Too much green material generates a lot of heat, so turning may be needed more than once per day. For a well-designed pile, turning once per day in the first week is usually enough. After that, a few turns may still be needed, some with the addition of water.

The cost for making compost, including the purchase of some raw materials, time spent measuring and turning the pile, and rent of the equipment, is about €25 per m^3 finished product. This cost is often prohibitive for farmers. The volume reduction in composting for a well-designed pile is in the best case 66%. The more green material added, the more the volume decreases in the process. Too much green material also reduces nutrient availability for the compost microorganisms.

RESULTS FROM USING COMPOST ON CROPS IN 2006

Aubergine (*Solanum melongena*). The crop was planted 5 May at a density of 1.1 plants m^{-2}. Most were planted in holes filled with compost. The holes were about 20 cm in each dimension. Some plants were planted in plain soil. No obvious differences were seen in plant growth between the two methods.

Plants were grafted on resistant rootstocks as a protection against root disease and nematodes. Aphids were controlled by natural introductions of ladybirds, and predators and parasites against other insect pests were purchased. There were almost no white flies. Spider mites grew fast after mid-August. Thrips were controlled by predator mites, although as we came to the end of the season, we saw more fruits with thrips damage.

About 5% of the plants were killed by wilt, which is common for aubergine whether conventionally or organically grown. In part of the greenhouse, there was stunted growth caused by cyst and root-knot nematodes.

Figure 1 shows the direct cost distribution for the 2006 aubergine crop. The plants and planting costs account for more than half the total costs. The plants are expensive at €2.2 each because they are grafted.

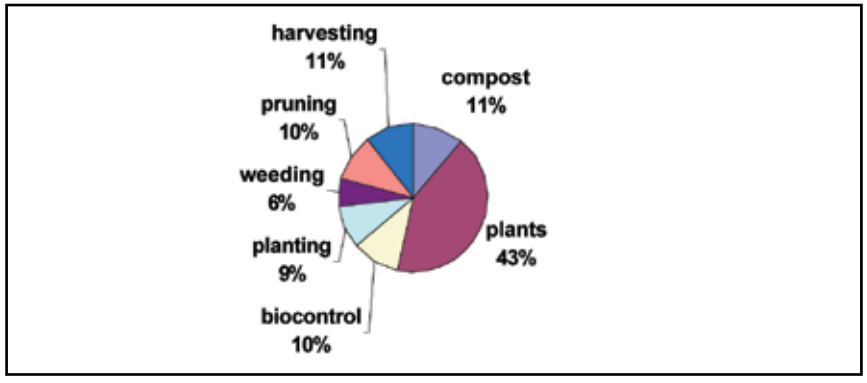

Figure 1. Cost distribution for aubergine.

We started harvesting 5 weeks after planting and by the end of August had achieved 4.5 kg per plant, which is considered excellent by normal commercial standards in Belgium. The progress of the harvest is shown in Figure 2. Gross profit is €11.5 m^{-2} over a period of 5 months.

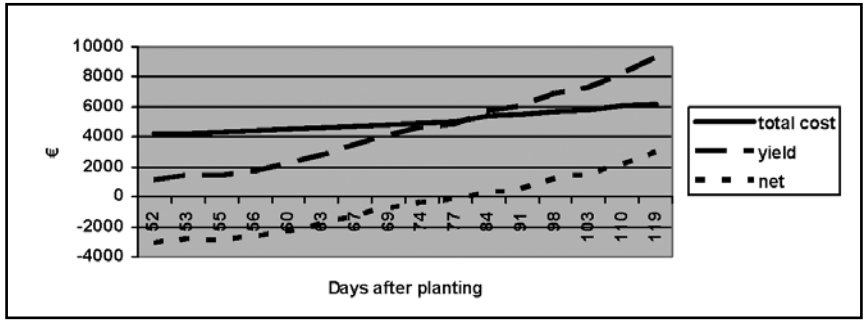

Figure 2. Progress of harvest for aubergine.

Tomato (*Lycopersicon esculentum*). The crop was planted at the same time and density as the aubergines. Compost was applied at 100 m^3 per ha into the holes. Some plants were planted without compost but again no noticeable difference was seen in plant growth.

Plants were grafted as a protection against root disease and nematodes. Leaf miner was present but was controlled by introduced parasites. Powdery mildew was controlled using sulphur pots.

Figure 3 shows the direct cost distribution for the 2006 tomato crop. We expect to harvest the last tomatoes by mid-September [i.e., 2 weeks after this presentation, ed.]. As with the aubergines, half of the direct costs are related to planting. Again, the plants are expensive (€2.2 per plant) because they are grafted.

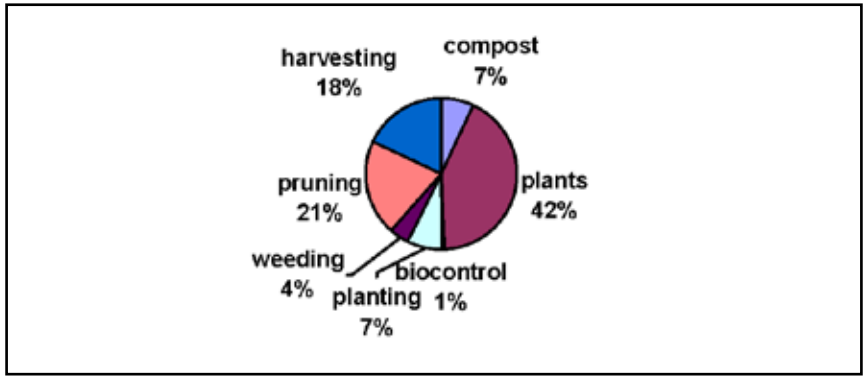

Figure 3. Cost distribution for tomato.

We started harvesting 9 weeks after planting and by the end of August had achieved 7.8 kg per plant. We do not expect to reach 10 kg per plant, which is what can be reasonably expected commercially. According to our tomato consultant this is probably due to a slight lack of nitrogen in the early stages of the crop. The progress of the harvest is shown in Figure 4. Gross profit is €9.4 m^{-2} for a period of 5 months.

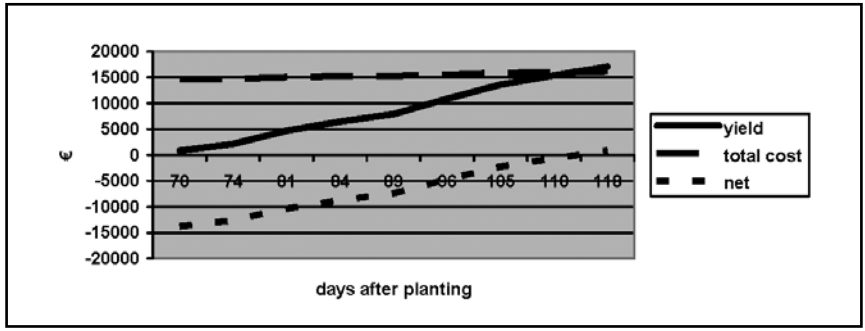

Figure 4. Evolution of harvest for tomato.

Bell Pepper (*Capsicum annuum*). The crop was planted on 27 April at 6.4 stems m^{-2} in the same size planting holes as the aubergines. Most plants were planted in holes filled with compost, the remainder in plain soil. Again no noticeable difference was seen in plant growth.

The plants are not grafted. There were no insect pests or disease problems recorded up to the end of August. The direct cost distribution is shown in Figure 5 to the end of August, when the season still has 2 months to go.

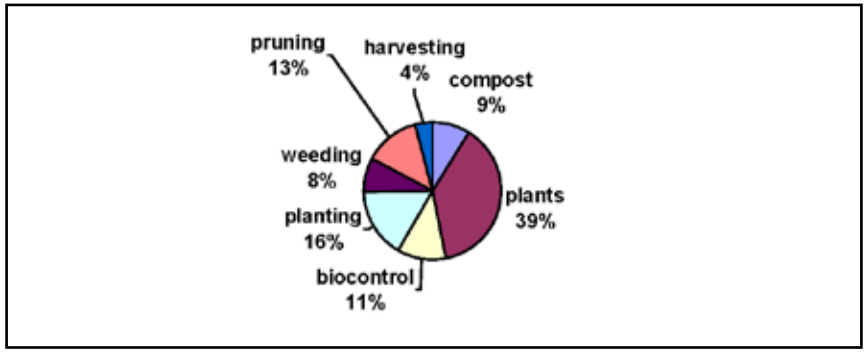

Figure 5. Cost distribution for bell pepper.

This crop did not grow well. The planting soil was too cold for this type of plant, so growth was slow and the leaves and stems pale. Later in the season, two heat waves caused greenhouse temperatures to reach 40°C in the afternoon, too high for bell pepper. As a consequence we have only harvested 1.3 kg m^{-2}. We hope we can add 1 kg in the last 2 months but at least 3.5 kg m^{-2} should be obtained for the crop to be profitable.

Acknowledegments. City of Roeselare for their support of vzw Lochting-Dedrie. Soil Foodweb Institute, www.soilfoodweb.com, for supporting us through a 2-year consulting program.

Practical Experience with Active Compost and Compost Tea in Container Production©

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INTRODUCTION

A number of European environmental laws are making it more difficult to produce nursery stock. In particular, the availability of pesticides and fertilizers is being reduced to prevent pollution of the water supplies. To counteract this trend, a number of nurseries are beginning to work with compost and compost tea, which can contribute to a more environment-friendly way of growing nursery stock.

In partnership with my wife, I run a nursery at Jabbeke. We specialise in liners propagated by grafting. Our customers are street tree growers, container nurseries, and, for some lines, garden centres.

Our propagation program has two main elements: summer grafting from August to the end of September and winter grafting from January to the end of February. In winter, bench grafting is done with the hot-pipe callusing system. In summer we work with potted rootstocks in P9s, which are grafted under polyethylene tents. All grafts are potted in P14s in March and covered with tunnels till mid-May. The cover is then removed, and the plants are caned and placed in trays. They are regularly tied to the cane as growth progresses, and weeded, during the summer. In autumn all orders are picked up and placed in a cold glasshouse to overwinter.

ORIGINS OF OUR USE OF COMPOST TEA

Early in Spring 2004 we had a major failure: 70% of the summer grafts made in 2003 died, caused by dried up roots. Tests indicated that water capacity in the substrate was not sufficient. That event, combined with a chance meeting with an organic grower of blueberries, was the start of a new development on our nursery.

The blueberry grower told me about an experiment that was done at the Belgian Institute for Agricultural and Fisheries Research (ILVO: Instituut voor Landbouw en Visserijonderzoek) with strawberries. It compared strawberries grown with chemical fertilizers on a classical substrate with strawberries grown on a substrate with controlled microbiological compost. Neither received pesticide or fungicide treatment. The result was astonishing. The "classical" strawberries had plenty of diseases and pests. The strawberries grown on compost showed none. The results convinced me to use active composts in my nursery.

The aim was a healthy, stress-resistant plant that would result in a better take of the grafts and better survival over winter. We regarded any reduction of pesticides and fertilizers as a beneficial side effect.

INTRODUCING COMPOST AND COMPOST TEA ON THE NURSERY

Our first experiments were done in the spring of 2004 with rootstocks for summer grafting in P9s. We used commercially available controlled microbiological compost fractioned at 10–20 mm. This compost was mixed in a normal substrate with peat at 10%. No chemical fertilizers were added. Every 2 weeks compost tea was made and

sprayed over the rootstocks at 20 L of tea per 100 L of water applied over 1000 m^2. Organic fertiliser was applied each week in between the compost tea applications (Black Gold, Triple Ten and Kelp, all supplied from Nu Tech). The feed was to support the microorganisms on the leaves and in the substrate, not to feed the plants directly. These treatments were repeated until we started grafting in mid-August.

The rootstocks were not as thick as previous years but the roots were very good. Fungal diseases and pests didn't cause any problem during that growing season. For example we had a major attack of black aphids on *Euonymus europaeus* but within 2 weeks they disappeared without any control measures being taken. During overwintering of the grafted plants we saw a lot of fungal fruiting bodies on the substrate, an indication of a good development of beneficial fungi in the substrate. The take of the grafts was excellent; in total there was an increase of 10% compared to previous seasons.

FURTHER TRIALS

The following spring we divided the crop in two parts. The first was potted in a peat substrate with our previous standard chemical fertilizers and the second was potted in a substrate with compost at 15% (v/v) without chemical fertilizers. In the compost organic fertilizers were mixed to feed the plants. The portion of the crop growing in the substrate containing compost received compost tea every week. Each of these treatments included organic fertilizers diluted in the tea to stimulate growth and avoid thinner plants as we had the year before.

This method was working well, in my opinion, due to the addition of organic fertilizers. Plants were growing very well, and we saw increased taxa differences in leaf colour compared with previous seasons. Dieback of twigs during winter (e.g., *Liriodendron*) was not seen, and spring re-growth was perfect. Only *Magnolia* had some nitrogen deficiency. Internodes were shorter on plants grown on the 15% compost substrate compared to the ones grown using chemical fertilizers. In general I found that plant quality was significantly better in the portion of the crop grown in the compost substrate and treated with compost tea — although the quality of the plants grown using chemical fertilizers was also very good. For example, we normally use a bamboo cane of 60 cm with a grafted *Fagus*, we had to replace it with a bamboo of 105 cm and even that was too small. Micorrhizal and beneficial fungi were very evident on the plants roots.

OUR OWN COMPOST RECIPE

However the story was not so straightforward. In 2005 I began using a tea made from a compost of my own, and the effect was not the same as the year before, when it was bought from a commercial firm in Holland. We had more troubles with fungal diseases, especially on *Quercus*. Also the take of the summer grafts was not as good as the year before. Something was wrong, but we didn't know the cause.

In the winter of 2005/6 two lectures were organised for Belgian growers with Dr. Elaine Ingham of Oregon State University. She is an authority on compost and compost tea, and she told us to use a microscope to control the tea.

Soon enough the explanation came why the tea made from our own compost was not working as well as the one made from the commercial compost. Our compost was made of pieces of bark, and it was almost impossible to extract fungi out of them into the water.

We had to look for another kind of compost to make tea.

That was found in a heap of compost made the previous year that was mixed with peat and had lain there for almost 6 months. It happened to be excellent compost from which organisms could be extracted very easily into the water.

After further research earlier this year we have perfected our recipe to make the tea, and we can see good growth of fungi during the brewing process.

Every brew is sampled and checked under the microscope to ensure we have a good population of beneficial microbes. It gives an indication of what is going on and helps us to understand what is happening and how we can manipulate the brewing process further to improve results.

We still have to research how to use compost in the substrate as well as compost tea to improve nitrogen availability to the plant. We will aim to achieve this by improving the nutrition of the microbes in the system. Nowadays, I'm more a mushroom grower than a tree grower.

Suggestions for Using Compost Tea in Cuttings Propagation©

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INTRODUCTION

Compost tea is a liquid extract of humic compost containing large numbers of beneficial microorganisms. It is already in use in many nurseries in Europe as an aid to pest and disease management in plant production, but this paper highlights some potential uses in propagation.

STOCK PLANT MANAGEMENT

Good quality finished plants begin with good quality cuttings, which in turn depend on healthy, well-maintained stock plants. Compost tea can be applied to stock plants as a foliar spray or a soil or compost drench.

Spraying the stock plants with compost tea every 10 to 14 days helps to suppress botrytis and bacterial leaf spot pathogens. These pathogens are therefore less likely to be carried through into the propagation house when the cuttings are taken.

Drench treatments increase the humic acid content of the soil or growing media, which in turn improves nutrient uptake by up to 30% leading to stronger shoot growth and healthier cuttings which root and grow away quickly.

PROTECTION OF CUTTINGS

Cuttings carrying a healthy microflora on their leaves are less susceptible to botrytis during propagation. Microorganisms also produce carbon dioxide as they respire. The microflora on the leaves therefore acts as a CO_2-enrichment system, which helps to increase photosynthetic rates in the cuttings. If a cutting assimilates carbohydrates more quickly through photosynthesis it has more energy to channel into producing a root system.

The larger the root system the cutting produces the less likely it is that a pathogen causing damage to a part of it will damage the plant as a whole.

EFFECT OF COMPOST TEA IN ROOTING MEDIUM

It is important to make nutrients available to the rooting cutting as soon as it needs them. That timing can be critical and if the nutrients are not there when the cutting needs them growth may be checked, quality may suffer, and it is not possible to reverse the effects.

If the cutting is rooting into a medium containing a healthy microflora the microbes will be stimulated by exudates from the first roots the cutting produces. These exudates feed the bacteria and cause them to grow and multiply, releasing organic nutrients for the new roots to absorb. This is the start of the soil foodweb.

EFFECT OF COMPOST TEA ON PROPAGATION HOUSE HYGIENE

Any prop house structure is alive with air-borne spores of microorganisms including pathogens such as botrytis. These are not removed by spraying the plants with fungicides. Compost tea sprayed in the house will reduce this disease pressure by creating a more diverse ecology. It can almost eliminate over-wintering botrytis.

Comparison of Ground-Cover Materials for Container Growing Systems: Horizontal Versus Vertical Drain©

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This paper reviews the materials most commonly used as ground covers on Belgian container nurseries and reports on trials comparing their drainage characteristics. Older materials tend to discharge water horizontally (surface run-off), while newer materials are designed to drain vertically (below-surface run-off). The choice has implications for water management in the crop and for recovery and recycling of irrigation water.

INTRODUCTION

Before the 1980s, azaleas and most nursery plants in Belgium were field-grown. Since the 1990s much of this has been replaced by container-growing either on specially prepared drained beds or on covered soil.

The advantages of container production have been considerable for the Belgian industry. Plants grow much more hygienically, so pesticide and herbicide use is reduced (Alkemade, 1995). Containers stay clean, so less washing is needed before marketing. Working conditions for nursery staff are improved.

However one of the most important advantages, both environmentally and economically, is being able to recover the irrigation water draining from the beds. Depending on the type of covering system it is possible to recover some 50% of the irrigation water and almost 30% of the fertilizer applied to a bed. This enables growers in Belgium to meet local regulations regarding discharge of water from nurseries into soils or rivers. If the water is treated, for example by UV-lights or slow sand filtration, it can be recycled.

HORIZONTAL DRAINAGE (SURFACE RUN-OFF) COVER SYSTEMS

The soil is covered first by a plastic sheet over which a ground-cover material is used. The slope of the field should be approximately 1.5%. In some systems capillary matting is used between the plastic sheet and the ground cover (Pauwels, 2002). Aquafelt Plus is currently the only such material on the Belgian market. Other systems, such as Lysdrain and Hygromat, combine the three materials (plastic sheet, capillary mat, and ground cover) in one integral matting.

Plastic Sheet Plus Ground Cover. This system is the one most commonly used in Belgium when a horizontal drainage pattern is required. Weight ranges from 100 to 140 $g^{-1} \cdot m^{-2}$ with water permeability between 12 $L^{-1} \cdot m^{-2}$ and 20 $L^{-1} \cdot m^{-2}$. During dry seasons, the disadvantage of having no capillary matting is that more irrigation is needed. This also leads to significant variability in moisture content of the substrate between plants at the top of the bed and those at the bottom. On the other hand, during wet seasons, some capillary matting can retain too much water.

Plastic Sail + Aquafelt Plus + Ground Cover. Aquafelt Plus is a needlefelt with a fibre-blend of 100% polyester fibres and bicomponent fibres. This capillary matting is 1.1 to 1.6 mm thick. The absorption capacity is 0.6 $L^{-1} \cdot m^{-2}$, and it weighs 80 $g^{-1} \cdot m^{-2}$. In drier seasons or climates use of capillary matting as part of the groundcover system leads to a faster and more even distribution of the water and a greater water retention. But for wet seasons, there are disadvantages associated with too much moisture in the substrate for long periods.

Lysdrain. Lysdrain and Lysdrain Plus are polypropylene cover systems that combine plastic sheet, capillary mat, and ground cover in one integral cover. Lysdrain Plus is heavier than Lysdrain. Lysdrain weighs 245 $g^{-1} \cdot m^{-2}$and has a water absorption of 0.4 $L \cdot m^{-2} \cdot sec^{-1}$, Lysdrain Plus weighs 283 $g^{-1} \cdot m^{-2}$and has a water absorption of 0.8 $l\ m^{-2} \cdot sec^{-1}$. In trials at Proefcentrum voor Sierteelt and elsewhere, this cover system gave very promising water retention results, during both dry and wet seasons (Pauwels, 2004; Morel and Berthier, 2005). However the sheets are not easy to connect when using them to construct larger container fields.

Hygromat. Hygromat also combines plastic sheet, capillary mat, and ground cover in one integral system. But its water retention capacity is too high to be suitable for a humid climate. Trials have also shown that this cover system is quickly colonised by algae.

VERTICAL DRAINAGE (BELOW-SURFACE RUN-OFF) COVER SYSTEMS

As in the horizontal systems, soil is covered first by a plastic sheet. The material on top of this sheet is designed for more vertical drainage, and the slope of the beds used with these systems can vary between 0% and 1.5%. Vertical drain systems result in more efficient watering and more air circulation. Sand beds were traditionally used in nursery stock where vertical drainage characteristics were required (Springer, 1998). Currently gravel or flex, bubbledrain, and lava (or crushed rock) are the most commonly used vertical drain systems in Belgium.

The ground cover material used for vertical systems is heavier than for horizontal systems. The lightest cover is 137 $g^{-1} \cdot m^{-2}$ with a water permeability of 20 $L^{-1} \cdot m^{-2}$. Mostly a cover of a weight between 205 and 230 $g^{-1} \cdot m^{-2}$ is used.

Gravel or Flex. On top of the plastic sheet, a 3-cm layer of gravel is laid and stabilised by a net and covered with a ground cover. For fields with a 0% or a minimal slope, drain tubes are necessary. Optimum bed width is not more than 25 m.

Bubbledrain. This system is based on a high density polyethylene bubble sheet, laid on top of the usual plastic soil-cover sheet in strips, perpendicular to the drain direction. Although the Bubbledrain is impermeable, the plastic sheet beneath is still needed, because a 5-cm expansion gap is required between the strips. The bubbles are 8 mm deep.

The Bubbledrain is overlaid by a firm 1-mm-thick groundcover material. The method of fixing the ground cover at the bottom of the container bed is important to avoid accumulation of water below the bed (van den Berg, 2005).

Lava. A 5- to 10-cm layer of lava (1 to 11 mm) is laid on top of a plastic sheet (Molenaar, 2004). The bed slope in these systems is usually 0%, and drain tubes at the bottom of the bed remove the drain water. A medium- to heavy-grade ground cover

lava + GC (200K) Irrigation on top	lava + black-white GC Irrigation on top	bubbledrain +aquasorb Irrigation on top	bubbledrain + GC (137K) Irrigation on top	bubbledrain +aquasud Irrigation on top	porous material Irrigation on top
plastic + aquasorb Irrigation on top	bubbledrain +aquasorb Irrigation from below	bubbledrain +aquasud Irrigation from below	lysdrain plus Irrigation on top	plastic +GC Irrigation on top	gravel Irrigation on top

Figure 1. Scheme of different cover materials outside the greenhouse.

Figure 2. Plants in the beds outside the greenhouse.

is laid over the lava but not so heavy that it supports weed growth. In these systems it is important to irrigate the bed before containers are stood down, especially in dry seasons; otherwise the lava will draw water from the containers.

TRIALS AT PROEFCENTRUM VOOR SIERTEELT

At the Research Station for Ornamentals at Destelbergen, Belgium, an experiment was carried out over several years to compare the performance of different

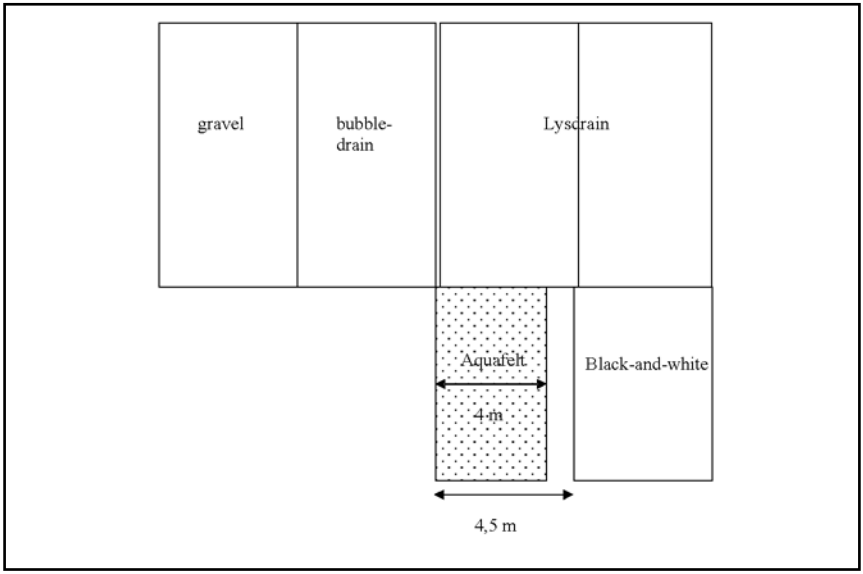

Figure 3. Scheme of different cover materials inside the greenhouse.

cover materials, including both horizontal and vertical drain types, both outside and under protection.

Materials and Methods. Outside, 12 beds each of 100 m^2 were covered (Figs. 1 and 2). Each bed had its own collection tank of 1500 litres. Irrigation was applied to a container crop on the beds based on irradiation sum. This sum was equal for all horizontal systems. For the systems with Bubbledrain, the sum was lower (faster irrigation), and for the lava, flex, and the porous material, the irradiation sum was even less.

There were also six beds inside a greenhouse (Fig. 3), each of 150 m^2. Again, irrigation to a container crop on the beds was based on irradiation sum.

For both the outdoor and greenhouse beds we measured the amount of irrigation ($L^{-1} \cdot m^{-2}$); moisture content of the substrate in the container (HH2 moisture meter); temperature in the container; nutrient analysis in growth medium; nutrients analysis in the run-off water; root growth and plant quality.

RESULTS AND DISCUSSION

The irrigation frequency on each bed depended on the irradiation sum. The number of litres for each irrigation was the same, namely 8 $L^{-1} \cdot m^{-2}$. Generally Bubbledrain needed approximately twice as much irrigation as any of the horizontal drainage beds. Flex, lava, and porous material needed between two and three times more irrigation than the horizontal-drained beds.

The average drain percentage (i.e., the proportion of water applied to the plants that is recovered from the drain) for the horizontal systems was 30%. Draining was faster in the vertical systems, and the average drain percentage was approximately 60%. The capacity of the water recovery system and disinfection installation required will depend on the drainage percentage.

The moisture content of the growing medium also depends on the irrigation and on the drainage characteristics of the bed. We recorded remarkably small differences in moisture content of the substrate between plants at the top and bottom of the bed with vertical draining systems.

Temperature differences in the pot were small between systems. Temperature fluctuations were smaller for vertical systems, because of the more frequent irrigation.

There were few and small differences between nutrient analysis in the growth medium and in the drain water for any of the systems but the porous materials resulted in higher proportions of sulphates in the drainage water.

Root growth was always better in crops grown on vertical-drained systems, but other aspects of plant quality did not differ. Hygromat resulted in more plants attacked by *Cylindrocladium scoparium*.

CONCLUSIONS

Currently, the cost of a horizontally drained container bed is approximately 10 € per m^2 (all inclusive). Use of special ground covers such as coated Aquasorb and Lysdrain or Bubbledrain adds a little to the material cost. The most expensive materials are lava and gravel, for which the material costs are approximately equal to the total cost of a horizontal-drained bed.

Vertical drain systems are very satisfactory, certainly for wet seasons when the water can be drained more easily. Rooting is mostly better for these systems. Lava, firm Bubbledrain, and gravel are convenient for automated beds.

For environmentally responsible production both systems should only be used as part of a collection and recycling regime for the irrigation water.

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The Influence of a Dynamic Climate on Pests©

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The influence of a dynamic climate on pests is at present not well investigated. During the last years, some Danish growers have observed that problems with pests have diminished when they shifted from the traditional rigid climate control to a dynamic regime. This tendency was also observed in experiments where different dynamic climate strategies were tested. A recent experiment has shown that the influx of thrips from outside was diminished when a dynamic climate regime was compared to a traditional rigid climate regime. Another experiment revealed that the development time of *Myzus persicae* was longer under a simulated dynamic climate compared to a static climate. Knowledge of how the development of a pest is influenced by a temperature regime makes it possible to use climate management as a tool for pest control.

INTRODUCTION

Pests are exposed to and react to the present greenhouse climate, which depends on the crop-specific climate regime. Greenhouse climate regimes were originally designed to serve the crop optimally, and pests or their biocontrol agents were not taken into account. Commonly the greenhouse temperature is rigidly controlled to constantly attain the crop-specific optimum temperature. However, dynamic temperature regimes have been developed. Within those dynamic climate regimes, initially developed for energy-saving purposes, the greenhouse climate is allowed to fluctuate more within days, weeks, and seasons.

Recently the influence of dynamic climate regimes on pests and beneficial organisms has come into focus as some growers in Denmark have observed that, by changing the traditional rigid climate control to a dynamic regime, pest problems decreased and consequently the need for treatments, both chemical and biological. The growers claim that their use of pesticides has diminished after they have changed to a dynamic climate regime. This tendency of fewer pests has also been reported from scientific experiments where different dynamic climate strategies were investigated (Jakobsen et al., 2003).

IntelliGrow is a Danish-designed dynamic-climate control concept in which the climate is controlled according to the outside irradiance and the microclimate of the plants within the greenhouse. Heat and CO_2 are supplied only when the plants can make optimal use of it, i.e., when the light intensity is sufficient for a high photosynthesis rate. Set points for CO_2 and temperature are calculated using a

leaf photosynthesis model (Aaslyng et al., 2003) from which the system generates a two-dimensional array of photosynthesis rates as a function of a range of selected temperatures and CO_2 concentrations at the measured photosynthetic photon flux density (PPFD). The maximum photosynthesis rate is determined from this array. The magnitude of production can be controlled by reducing the photosynthesis optimization level.

To find some explanations for the decrease in pests observed by growers, two experiments were carried out: one looking at the influx of pests into the greenhouse from outside and the other to compare the development time of the peach aphid *Myzus persicae* (Sulzer) (Hem: *Aphididae*) under static and fluctuating temperatures.

INFLUX OF THRIPS

This experiment, which is described in detail in Jakobsen et al. (2006), showed that the choice of climate strategy influences the level of pest influx into a greenhouse from outdoors. The experiment was conducted during the natural flying period of the thrips (Thysanoptera), from late March to the middle of September 2004, in which time the influx of the pest in small greenhouse compartments (25 m^2) was monitored by use of sticky traps. The experiment compared the effect of two climate regimes on pest influx: a dynamic regime (simulated IntelliGrow) and a traditional climate regime with fixed set points for heating and ventilation of 18 °C and 20 °C, respectively.

The two different climate regimes resulted in differences in the degree of vent opening. Over the entire 25-week period, the vents opened on the average 6.9% under the dynamic regime and 33.4% in the traditional climate. When calculated on a weekly basis, this difference was highly significant ($P<0.0001$). The influx of thrips into the greenhouse was found to be linearly correlated to the density of pests outside the greenhouse ($P<0.0001$), as well as with the degree of opening of the greenhouse vents ($P = 0.0038$). Due to the smaller degree of vent opening in the dynamic climate, significantly ($P = 0.0026$) fewer thrips were monitored on sticky traps in the dynamic climate compared to the traditional climate (except during week 32) (fig. 1). The average weekly differences (counts on traps from the dynamic climate minus counts on traps from the traditional climate) varied from -0.1 to 9.4 thrips per sticky trap. These results thus confirm tendencies seen in earlier experiments and in commercial greenhouses of fewer problems with pests under a dynamic climate strategy.

DEVELOPMENT TIME OF PEACH APHID

This experiment examined the effect of a dynamic climate regime on the development of the peach aphid, *Myzus persicae*. The experiment was conducted in climate cabinets under a simulated dynamic climate (8 h at 20 °C followed by 8 h at 15 °C followed by 8 h at 25 °C) and a constant climate regime (24 h at 20 °C), respectively, with a photo/darkness period of 16 : 8 and a humidity of 40%–70%.

Adult aphids were placed for progeny production on a hibiscus leaf positioned with the underside up on non-nutrient agar in a Petri dish. After 24 h at 20 °C adult aphids were removed and Petri dishes placed in the climate chambers. Each Petri dish was checked once a day for recording of number of adult aphids; adults and new offspring were removed. The experiment lasted 18 days and three repetitions were carried out.

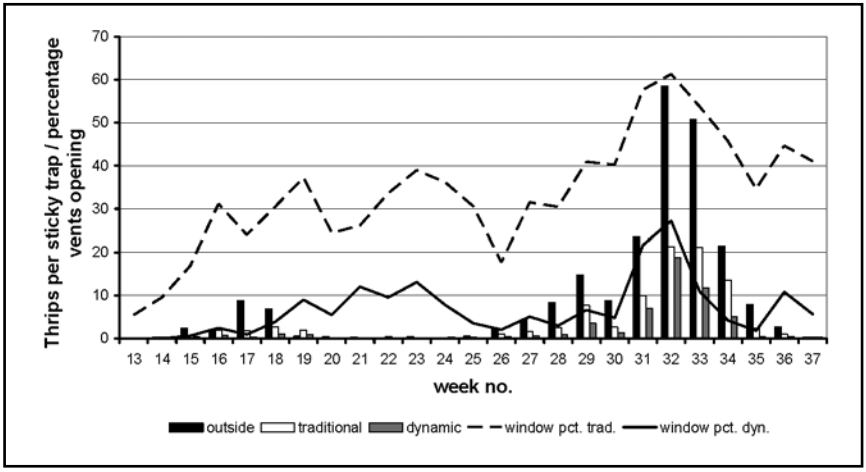

Figure 1. Average number of thrips per sticky trap in a dynamic climate regime, a traditional climate regime, and outside the greenhouse, as well as the percentage vent opening in the two climate regimes between Weeks 13 and 37, 2004.

The experiment showed that the development time of *M. persicae* was longer ($p<0.0001$) under a dynamic climate compared to a constant climate (Table 1) even though the average temperature was the same.

Table 1. Development time for *Myzus persicae*.

Climate regime	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Development time (days)
Constant climate	20	20	20	9.094±0.033a (53)
Dynamic climate	20	25	15	10.367±0.041b (49)

Note: Values followed by different letters are significantly different. Round brackets are the number of individuals in the experiment.

Other experiments have shown that fluctuating temperatures compared to static temperatures can have varying effects on development of pests and beneficials. Studies revealed that the development of *Anthocoris sibiricus* Reuter (Het.: *Anthocoridae*) was significantly faster at fluctuating temperatures compared to a constant climate (Hofsvang, 1976). Likewise Tommasini & Benuzzi (1996) showed that the development time of *Orius laevigatus* (Het.: *Anthocoridae*) was shorter at fluctuating temperatures (29 °C /5 °C) compared to a constant temperature of 14 °C. In contrast to the above-mentioned studies, Petitt et al. (1991) found that the development time for *Liriomyza sativae* Blanchard (Dip.: *Agromyzidae*) was not significantly influenced by fluctuating temperatures. Yet another study showed that the influence of fluctuating temperatures on development time of *Heliothis zea* (Boddie) (Lep.: *Noctuidae*) egg depended on the mean temperature, because at low temperatures (21.1 °C) the development time was decreased by fluctuating temperatures

and at high temperatures (35 °C) the development time was longer at fluctuating temperatures compared to static temperatures (Eubank et al., 1973).

The current study indicates that not only the average temperature is important to consider when estimating the development time for a pest. The effect of fluctuating temperatures on the development time of a pest or beneficial depends on the optimum temperature and the upper and lower threshold of the pest or beneficial in question. Knowledge of how the development of a pest is influenced by a temperature regime makes it possible to use climate management as a tool for pest control. Similarly biological control might be improved by selecting beneficial most optimally adapted to a certain climate regime.

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Viruses in Plants — Fascinating but Treacherous©

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INTRODUCTION

Plant viruses are fascinating pathogens that can induce beautiful symptoms on their hosts but also cause serious damage to commercial crops. To prevent damage from viral diseases it is important to understand and control virus spread. Recent research has given new insights into the mechanisms of plant defense against virus infection. This has enabled researchers to generate resistant plants. In addition, studies of viral defense reactions have contributed to the understanding of gene regulation.

PLANT VIRUS IMPACTS ON HUMAN LIFE

Plant viruses have affected humans in many ways. The first written evidence of this is found in a poem from 752 by Japanese empress Koken, who describes the yellowing of the leaves of pye-wye weed as follows: "For the plant I saw in the field of summer the color of the leaves were yellowing, looking like the effect of frosting during summer." The virus causing these symptoms is named eupatorium yellow-vein virus (Saunders et al., 2003).

Later in the years of tulipomania, which occurred from 1593 to 1638, the European upper class was fascinated by the flower-color-breaking in tulips caused by the potyvirus tulip-breaking virus (TBV) (Lesnaw and Ghabrial, 2000). At the peak of this madness, the price of 12 bulbs reached 13,000 Dutch guilders (equal to 1,500 dollars or the price of a big house). However, the market for these rarities collapsed when it was realized that grafting readily transferred the trait. In the same period, the flower-breaking symptoms inspired many artists, who painted still lives of vases with diseased tulips. Though Rembrandt is not famous for his tulip paintings, Rembrandt has lent his name to tulip cultivars with flower-color-breaking sold today. The slogan "recreate tulipomania in your garden" is even used by the Dutch company Breck's in their advertisement of an improved Rembrandt tulip mix. The flower-breaking of these cultivars is not caused by TBV but by mutations.

Viruses also cause severe damage to plants, causing wilting of trees, failure of grafting, discoloring of fruits, and necrotic lesions on leaves. In developing countries, viral diseases threaten income and food production. Examples include cocoa swollen shoot virus, which has killed many cocoa trees in Central Africa, and cassava mosaic virus and cassava brown-streak virus, both of which affect cassava production.

CHARACTERISTICS OF PLANT VIRUSES

Viruses are different from fungal and bacterial pathogens that affect plants. Both fungi and bacteria are cellular pathogens that are visible under the microscope. To understand what a virus is, it is necessary to look at what goes on inside the cell. In a eukaryotic cell like the plant cell, the chromosomes are located in the nucleus. The chromosomes carry the genes that hold the information for all the processes necessary for proper cell function and coordination of developmental processes.

The genes are controlled by transcription of the information into messenger RNA (mRNA). The mRNAs are transported from the nucleus to the cytoplasm where the information on the mRNAs is translated into protein. The proteins in turn conduct various processes necessary for growth, development, and reproduction. Most plant viruses are composed of an mRNA-like molecule (the viral genome) that is surrounded by protein. This complex of RNA and protein can exploit the cell to produce virus-specific proteins and to make new replicas of the virus RNA genome. In this process normal cell functions are compromised, and as a result, growth is reduced and disease symptoms develop.

TRANSMISSION AND CONTROL

In order to protect plants against virus infection, it is important to know how they spread from plant to plant. As indicated above, plant viruses depend on living plant cells, and therefore viruses have developed different strategies to be transmitted from one plant to another. In the plant, the virus spreads from cell to cell through plasmodesmata, but passage from one plant to another requires traversal of the plant cell wall.

Some viruses are transmitted through wounds that are generated by plants rubbing against each other, by the activity of humans or animals, or by handling during production and harvest. Collectively this type of transmission is known as mechanical transmission.

The particles of mechanically transmitted viruses are often very stable, and the most important control measure against these viruses is to develop work routines that prevent wounding and contact between plants.

Other viruses have specialized in transmission by vectors, which take up the virus during feeding. Insects are the most important viral vectors, but in addition mites, nematodes, and zoospores of fungal-like organisms in the soil can transmit plant viruses. Some viruses are retained in the feeding organs of the vectors and can be released shortly after acquisition. Other viruses must continue into the intestine and pass through the hemocoel to the salivary glands before they again can be released. The two types of association between virus and vector are referred to as stylet-borne and circulative, respectively. Tomato spotted wilt virus (TSWV) is an example of a virus that is transmitted in a circulative manner by thrips (Whitfield et al., 2005). The TSWV is taken up by thrips in the larval stage and persists in the insect for the rest of its lifetime. To control TSWV it is therefore important to detect thrips early using insect traps. It is also possible to monitor for the appearance of the virus by placing indicator plants in the greenhouse. Indicator plants are species that react with strong and characteristic symptoms. Petunia or faba bean are used as indicators to monitor TSWV because they display distinct symptoms shortly after infection.

Nematode-transmitted viruses can persist in the vector for up to a year, and zoospore-transmitted viruses for up to 10 years. This long persistence and the presence of the vector in the soil make control of these viruses difficult. Control is further complicated if the virus has a broad host range, which allows the virus to survive in wild species during crop rotations.

Several of the nematode-transmitted viruses cause severe diseases, and plants for propagation must be under strict control to ensure they are virus-free. One example is tomato ringspot virus (TomRSV), which causes apple union necrosis in

apples and prunus stem pitting in stone fruits. Symptoms appear as infected trees reach bearing age. Bud break is often delayed in the spring, and leaves are small and sparse. Terminal shoot growth is reduced, with shortened internodes. Infected trees flower heavily and set large numbers of small, highly colored fruit. The cause of the symptoms is found at the graft union, which turns dark as a result of a defense reaction in the scion towards virus spreading from the rootstock. This disease is only a problem on grafted trees where the fruiting variety is resistant to TomRSV and the rootstock is tolerant.

PLANT DEFENSE REACTIONS

While the defense reaction against TomRSV becomes the main cause of disease, the plant defense reactions and resistance to viruses are usually beneficial to plant production. To understand how plants combat virus disease it is necessary to outline what goes on inside a virus-infected plant cell. As indicated above most plant viruses are composed of protein and RNA that can replicate in the plant cell. Both viral protein synthesis and viral RNA replication require participation of host factors. When a virus particle enters the cell, the viral RNA is liberated and initially the virus exploits the host translation system to produce virus proteins. Then the virus proteins recruit host proteins to replicate new virus RNA. Initially, a strand is synthesized, which is complementary to the viral genomic RNA. This in turn serves as a template for production of new copies of the virus genome. The new viral genomes are either encapsidated to form virus particles or they move to the neighboring cell through plasmodesmata—a process that also requires host proteins.

It appears that plants use two strategies in defense. One is to initiate defense reactions upon recognition of viral proteins or double-stranded forms of viral RNA that are produced during replication (Soosar et al., 2005). In many cases the plant can recognize virus proteins and induce a defense reaction involving programmed cell death, which prevents further progress of the virus. If this reaction is quick it will prevent the virus from spreading from the first infected cell. This type of resistance is usually inherited as a dominant character. The other strategy is to eliminate or alter a host protein the virus requires at some stage of infection. An example is the modifications of translation initiation factors, which result in recessively inherited resistance (Robaglia and Caranta, 2006). The role of plant translation initiation factors in virus infection is still not clear, but experimental evidence suggests functions in translation and replication as well as cell-to-cell movement.

The plant can also recognize structures in the viral RNA, and initially this strategy was considered as specific towards viruses but now appears to be used against other pathogens as well. The defense relies on recognizing and targeting double-stranded RNA (dsRNA) for degradation. Depending on how efficient the degradation process is, the plant will be more or less resistant. The defense is initiated by an enzyme called DICER that recognizes and cleaves dsRNA into smaller fragments known as small interfering RNA (siRNA). The siRNA associates with an enzyme complex called RNA-induced silencing complex (RISC), and the siRNA guides RISC to cleave single-stranded RNA with complementarity to the siRNA. In this way both single-stranded viral RNA genomes and dsRNA generated during replication are disarmed (Voinnet, 2005). This RNA mediated defense is known as virus-induced gene silencing (VIGS) if a virus induces the RNA degradation. The term RNA interference (RNAi) is used if other types of dsRNA induce degradation.

GENERATING RESISTANT PLANTS

Even before the VIGS mechanism was fully elucidated, researchers started to speculate if this defense could be enforced to completely prevent virus infection, for example by generating plants with preformed RISC ready to target the single-stranded virus genome for degradation before it starts replicating. Early it became evident that transforming plants with only a fragment of the virus genome was sufficient to induce virus-specific RISC, and later it was realized that the fragment was most efficient when constructed as an inverted repeat, which base pairs to form dsRNA (Waterhouse et al., 2001).

The best described application of this strategy is development of papaya resistant to papaya ring spot virus in Hawaii (Gonsalves, 1998). Around 1990 papaya ringspot was becoming a serious problem, and at this time Dennis Gonsalves and coworkers generated the first resistant papaya plants based on transformation with a piece of the virus. After testing to secure consumer and environmental safety, resistant papayas were released for commercial use in 1998. Virus-resistant transgenic papayas are sold as Rainbow and SunUp papaya.

PLANT VIRUSES AFFECT PLANT DEVELOPMENT

The RNA-mediated resistance in transgenic plants is efficient because the virus is targeted for degradation more efficiently than in unmodified plants. In unmodified plants, viruses can suppress the defense reaction by expression of proteins known as silencing suppressors. These proteins act by interfering with the function of DICER or RISC or by binding siRNAs. In the last decade it has become clear that probably all viruses encode proteins that suppress RNA-mediated defense. Also the study of these proteins begins to reveal why some viruses induce spectacular symptoms like those induced by TBV.

The formation of dsRNA is a signal to the cell to degrade the RNA by the action of DICER and RISC. In addition to virus defense this RNA degradation mechanism is used to regulate gene expression and control developmental processes. The dsRNA can be generated by base pairing of a mRNA with a small RNA known as a microRNA (miRNA). DICER generates miRNA from larger precursors (pre-miRNA) containing imperfect inverted repeats. Similar to siRNAs, miRNAs act by guiding RISC to mRNA with complementarity to the miRNA strand. RISC either cleaves the mRNA or it prevents translation of the mRNA. The processing and function of miRNAs thus have striking similarities to the siRNAs during viral defense. This explained why virus infection sometimes alters developmental processes because the viral silencing suppressors may also interfere with the function of the miRNA pathway (Voinnet, 2005).

UNDERSTANDING HOW VIRUSES INDUCE SYPMTOMS

With the knowledge that viral silencing suppressors affect plant development it is tempting to speculate that flower-breaking in tulips is caused by the action of a silencing suppressor expressed by TBV. While this has not been demonstrated experimentally, similar color-breaking on the seed coat of virus-infected soybean has been shown to result from the activity of silencing suppressors expressed by soybean mosaic virus (SMV) or cucumber mosaic virus (CMV) (Senda et al., 2004). Most cultivated soybean varieties have yellow seeds because chalcone synthase is silenced in the seed coat. In black-seeded cultivars the activity of chalcone synthase

lead to production of anthocyanin and proanthocyanindin pigments. The silencing in yellow-seeded cultivars is due to a duplication of the gene encoding chalcone synthase. The gene duplication gives rise to transcripts that form dsRNA, which through formation of siRNAs targets the chalcone synthase mRNA for degradation. When yellow-seeded soybeans are virus infected, the silencing suppressors from SMV or CMV interfere with silencing and chalcone synthase is again expressed in sections of the seed coat. This gives rise to the dark colored areas on the seed coat.

As the example above indicates, basic research in plant virology has contributed much to the understanding of RNA-mediated gene regulation in plants. In addition virus vectors can be applied to the study of gene function by targeting mRNA sequences of specific genes for silencing (Watson et al., 2005).

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Hygiene Problems in Plant Tissue Culture Propagation©

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INTRODUCTION

Plant tissue cultures have been used for various purposes such as mass propagation, production of disease-indexed plants, and genetic engineering. Plant tissue culture is defined as culture of plant cell, tissue, or an organ under sterile conditions in an artificial medium under aseptic conditions. This statement clearly indicates that for a successful tissue culture operation there should not be any contamination by microorganisms during the entire culture period. Contamination by microorganisms will not allow the plant cultures to grow, and the contaminants will eventually destroy plant cultures. Therefore, it is important to be aware of the major contaminants, the sources of such contaminants, and the methods available for sterilizing plant material before the introduction into tissue culture medium and to know the methods for an overall hygiene in a tissue culture operation.

Contamination caused by some common microorganisms can result in large losses during micropropagation, and their control is the most serious problem encountered in many commercial laboratories. In plant tissue culture practices, contaminants can also interfere with plant performance and final results. Therefore, it is imperative to detect and eliminate all contaminants before introducing plant material in vitro and also to be aware of the methods for avoiding contamination during routine sterile operations.

CONTAMINANTS

Fungi. Fungi are common contaminants in tissue culture at the establishment operations. Fungi could enter the system with improperly sterilized plant material or they could creep in during handling of plant material or preparation of culture medium. Infection by fungi can become apparent within a few days of culture.

Bacteria. Bacteria are the most troublesome kind of contaminants both at the establishment stage and during routine operations. Numerous genera of bacteria are found in plants grown in vivo, and these can cause problems in tissue cultures (George, 1996). Even harmless bacteria found in plants grown in vivo can interfere with the growth of in vitro cultures and cause death of tissue. Bacteria can be introduced along with the plant material or during culturing and transferring operations. In addition, some bacteria are reported to be there from the endogenous system of the plant material. This kind of infection could be plant-species specific. If this problem crops up, systemic sterilants have to be used to eradicate the infection.

Yeast and Other Microorganisms. Some common yeasts and mycoplasmas can also cause problems. However, these are not commonly found in tissue culture systems**.** Plants grown in outside environments may be systemically infected with fungal, bacterial, and virus diseases. These plants certainly carry more surface con-

taminants. Plant material can also be cultured without noticing the presence of microorganisms. Such latent or hidden contaminants can become a problem later on.

Pests. Pests such as mites and aphids can cause problems by themselves or by introducing fungal and bacterial spores into the culture vessels.

EFFECTS OF CONTAMINANTS

Once the contaminants enter the culture vessels where the plant cultures are grown it will most likely lead to a total loss of cultures. The culture medium is a highly suitable medium for most of the contaminants to establish and flourish rapidly within a short time. Once the cultures are contaminated, re-sterilization of the cultures will most likely not give successful results. Therefore, it is very important that the initial cultures are free of any microorganisms and subsequent transfers of the cultures are done with extreme care. Saprophytic fungi could grow very fast and destroy the cultures making retrieval of infected cultures extremely difficult or impossible.

Some contaminants stay hidden and cause several defects such as growth retardation, reduced root formation, and altered morphology (Long et al., 1988; de Fossard, 1977; Hanus and Rohr, 1987). In such cases, it is advisable to re-initiate cultures from the beginning. Although there have been some reports of beneficial microorganisms, such organisms are not common (Hamill et al., 2005). Clean and disease-free cultures are more vigorous and grow faster than infected cultures.

MAIN SOURCE OF CONTAMINANTS

Plant material is the main source of contaminants. The culture medium has to be properly sterilized and stored away under favourable conditions such as a clean area at low temperature for safe and long-term storage. The instruments used for cutting and transferring the cultures have to be properly sterilized. The overall sterile techniques have to be perfect to avoid any contamination.

STERILIZATION OF PLANT MATERIAL

Several sterilization techniques are used for surface sterilizing the initial plant material before introducing them into the culture medium**.** The most common sterilant is sodium hypochlorite (NaHOCl). The 1% to 2% of active chlorine present in this compound usually eradicates most contaminants on the surface when treated over 15–20 min. It is advisable to use a wetting agent as well during the sterilization process. There are other sterilants, such as calcium hypchlorite and mercuric chlorite, that can be used for such purposes. Additional steps such as sterilization under vacuum can be used for more recalcitrant contaminants. It is important to prepare the mother plants free of diseases, and the plants must be in good healthy condition. Greenhouse-grown plants are better sources than plants grown outside because the plants from outside will usually have more contaminants.

There are some commercial sterilants such as Alcide (Alcide Co., U.S.A.) that can be used for certain hidden contaminants. Antibiotics and chemicals such as Plant Preservative Mixture can be added to the culture medium during the growth of cultures to control the contaminants. Plant Preservative Mixture is reported to be a heat-stable biocide that can control several contaminants. However, the side effects of these chemicals on the plant performance have to be checked.

STERILE TECHNIQUES AND EQUIPMENTS

It is very important that the sterilized plant material is handled carefully by practicing proper sterile techniques. For this, sterilizer units such as Bunsen flame or electric sterilizers along with appropriate instruments such as long handled forceps and scalpels have to be used. In addition, a sterile air-flow cabinet will be useful for 100% guarantee.

CONTAMINATION DETECTION

Visual inspection of the cultures will enable the detection of most of the common fungal, yeast, and bacterial contaminants. Fungal growth usually dominates if the cultures are not sterilized properly in the first instance. Some bacteria are slow to grow, and it may take a few weeks to see such bacterial growth. Sometimes, the latent bacteria can be detected only after several months.

Plant tissue culture medium contains compounds that will favour rapid growth of many common microorganisms. Occasionally, the type of culture medium can also influence the growth of the contaminants. For example, a contaminant may show up easily in liquid culture medium, while the solid medium could prevent its visibility. Also, some compounds in the medium may inhibit the growth of the contaminant, but the contamination will show up when the cultures are transferred to new medium without such compounds. It is advisable to culture explants at the beginning and during culturing in microbiological media to detect bacteria that could be concealed in plant tissue. This procedure is called indexing, and in this method a portion of the plant tissue is transferred to a bacteriological medium and incubated to check for the growth of any microorganisms. Several endogenous and disease-causing organisms can be detected by this technique. More recently, molecular techniques have also been developed for detecting and identifying contaminants (Cassells, 1991, 1997; Hamill et al., 2005; Lata et al., 2006). Because surface sterilization mainly eliminates epiphytic organisms, any infection within the tissue (systemic infection) must be detected and treated accordingly.

CONTROL MEASURES

Considering the facts given above, careful steps taken through appropriate methods is a good strategy for avoiding the contaminants in the first place. In case of difficulties in controlling common fungi at the start of culturing, fungicides can be used in the medium. It is also important to examine the cultures on a regular basis and discard all infected cultures. The initial explants can be cultured in a medium containing yeast extract and peptone to encourage the microbial growth, and this way any escapes from the initial decontamination procedures can be detected at an early stage (Leifert and Cassells, 2001).

Heat therapy and meristem cultures can be used to eliminate virus-like organisms and other microorganisms such as mollicutes. Antibiotics can also be used to control some microorganisms (Lata et al., 2006). In some cases regeneration of plants through callus phase helped to eliminate mycoplasma-like bodies (Ulrychova and Petru, 1975). Meristem is known to be free of microorganisms; therefore cultures established using meristem are free of microorganisms including all systemic contaminants. Meristem tip culture in combination with heat-therapy could help in getting virus-free cultures.

Cultures have to be checked regularly while they are in the growth rooms or cabinets for any contamination and pest infestation. Pests such as common dust mites could cause serious damage to the cultures. In a study conducted in a commercial laboratory, three species of mites have been identified as vectors of fungal contaminants (Terras et al., 1991). These mites have pouches in which fungal spores are carried and the spores could be planted on tissue culture medium. Spores germinate readily in the medium, and the excessive fungal growth will destroy the entire cultures. The mite population will grow rapidly by feeding on the mycelium, the mites will continue to infest other culture vessels, and eventually a room full of cultures could be completely destroyed in a very short time. Frequent checking, removal of old and infected cultures, cleanliness, and use of miticide spray for the growth room will help to control such losses. All contaminated cultures should be kept away from the culture area and destroyed by autoclaving.

CONCLUSION

In order to avoid hygiene problems in plant tissue culture, the best advice is to start off the practice with effectively sterilized initial cultures and exercise good contamination control procedures, which should also include routine inspection of cultures and the growth environment in which the tissue cultures are grown for any contaminants.

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Regeneration of *Farfugium japonicum* Through Adventitious Shoot Formation from Leaf and Petiole Explants©

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Donor plants were produced from meristems on half-strength-MS medium supplemented with 0.5 mg·L^{-1} BA. From the in vitro plant, leaves and petioles were excised, and leaves were divided into two halves, distal and proximal ones. The petioles were successively divided into three segments. These were used for explants. Direct adventitious shoots were actively formed from these explants on the MS medium supplemented with 1 mg·L^{-1} thidiazuron (TDZ) and 0.1 mg·L^{-1} naphthaleneacetic acid (NAA). In the divided half of leaf, the position forming most actively adventitious shoots was the proximal end (cut section) of distal half. In petioles, the number of adventitious shoots increased toward the proximal direction. Such a polarity was considered to be due to a gradient in age of petiole tissue. The adventitious shoots rooted easily in the hormone-free medium. The regenerated plants flowered after about 1 year from the beginning of the explant culture.

INTRODUCTION

Farfugium japonicum, a perennial in the Asteraceae Family, is a plant native to Japan. The plant grows indigenously in the forest areas of the southeast coast of Japan and has yellow flowers in autumn. The long petioles of the plant have a nice taste when boiled with soy sauce. Therefore, the plant is not only utilized as an ornamental in the garden, but also cultivated in the field for food.

The plants are usually propagated by division or from seeds. Meristem aseptic culture is also used for clonal propagation in some nurseries. The micropropagation is expected to be effective for rapid propagation of elite clones. From this point of view, the authors reported on the propagation by in vitro division from the crown segment explants and through the formation of adventitious shoots from petiole explants (Yamamoto et al., 1999). Furthermore, micropropagation by direct formation of shoots from hypocotyl segments and two halves of cotyledons of donor plant were reported (Yamamoto et al., 2000). In these experiments, it was found that thidiazuron (TDZ) in the medium had promotive effect on the direct formation of adventitious shoots from the explants. In general, it is found that the explants from different organs or from different tissues within an organ vary in morphogenic capacity (George, 1993).

Therefore, we investigated the relationship between the potential formation of adventitious shoots and the position within two halves of leaves, as well as from successively divided petiole explants of *F. japonicum*.

MATERIALS AND METHODS

Farfugium japonicum growing on the campus of Minami-Kyushu University was used for experimental materials. The meristem tissue of the plants is formed on the crown in soil. After being excised from the crown tissue under a stereomicroscope, meristems were cultured on half-strength MS medium (Murashige and Skoog, 1962). The effect of BA on the development and growth was examined. As shown in Table 1, the survival of the meristem was the highest (81%) in the half-strength MS medium supplemented with 0.5 mg·L^{-1} BA. Accordingly, the medium was used for meristem culture to obtain donor plants in vitro.

Table 1. Effect of BA on the development and growth of plantlets from meristem cultures.

Benzyleadenine (mg·L^{-1})	Survival (%)	Number of leaves	Length of petiole
0	12	2.0	0.4
0.1	41	24.0	1.3
0.5	81	23.3	0.5

Each value was scored after 50 days of culture, medium 1/2 MS, length of petiole (cm)

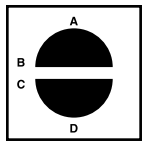
When the plant derived from the meristems attained approximately 4 cm in height and had several petioles with leaves, the leaves and petioles were excised from the plant. The leaves of about 1.5 cm in length were divided into two halves, distal and proximal ones. The position of distal and proximal ends and cut sections were symbolized as A, B, C, and D as shown in Table 2. These explants were cultured on MS medium supplemented with TDZ and NAA. The concentrations of hormones are shown in Table 2. The petioles of in vitro donor plants were successively divided into three segments (1 cm in length). The divided sections of the segments were symbolized as E, F, G, H, J, and I in proximal direction. The segment explants were cultured on MS medium supplemented with TDZ (1, 2, or 3 mg·L^{-1}) and 0.1 mg·L^{-1} NAA.

All the basal media used contained MS salts and 3% sucrose, and were solidified with 0.2% Gelrite. The pH was adjusted at 5.75 before autoclaving. All the cultures were kept at 25 °C and under 3,000 Lux with fluorescent lamps.

RESULTS AND DISCUSSIONS

Table 2 shows the number of adventitious shoots from the ends of two halves of leaves after 60 days of culture. The adventitious shoots were most actively formed from the proximal end of the distal half, which is, the cut section denoted B, and successively at the proximal end of proximal half which is close to the petiole. These results were observed commonly in both the two hormonal conditions shown in Table 2. Since no callus was found, these shoots were considered to be directly formed from the tissue. In the C and D areas formation of adventitious shoots was not observed.

Table 2. Number of adventitious shoots formed from the end of two halves of leaves. Numbers after TDZ and NAA are mg·L^{-1}.

End		TDZ (1) NAA (0.1)	TDZ (3) NAA (0.1)
A		0	0
B		9.6±2.0	9.0±4.1
C		4.4±1.7	1.3±0.3
D		6.4±1.3	3.8±1.3

Before dividing the leaves, the positions B and A contained identical tissue. After dividing the leaves, however, a difference was found in the potential of adventitious shoot formation. Such a tendency, that is, the higher activity of shoot formation of the cut section B than that of C has been recognized in our research, for example, with *Evolvulus glomeratus* (Yamamoto et al., 1996), *Eustoma grandiflorum* (Yamamoto and Watanabe, 1997), and *Primula sieboldii* (Yamamoto et al., 1999).

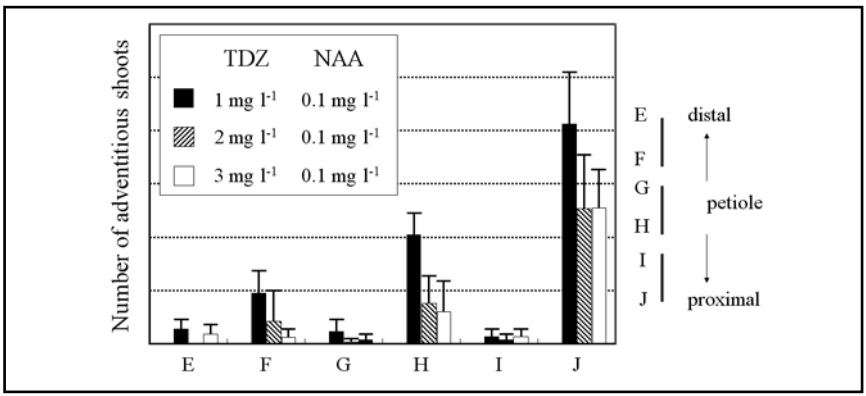


Figure 1. Polarity in the potential of adventitious shoot formation from petiole segments of *Farfugium japonicum*. Each value was scored 12 weeks after culture. n = 16.

Figure 1 shows the number of adventitious shoots formed from the cut sections of each segment of petiole. The combination of 1 mg·L^{-1} TDZ and 0.1 mg·L^{-1} NAA gave the best results for shoot formation. In each segment, adventitious shoots were more actively formed from the proximal section than from distal one. Furthermore, Fig. 2 shows the very clear tendency that the number of adventitious shoots formed increased toward the direction of proximal petiole. This was commonly observed in the three different concentrations of TDZ with 0.1 mg·L^{-1}.

NAA in the Media. No callus was observed in any of these cases. Such a polarity in the potential of direct adventitious shoot formation of petiole can be explained from the gradient in age of petiole tissue. In *F. japonicum*, the petiole tissue is younger in the more proximal position. In younger tissue, cell division is more active than in older tissue. Therefore, it is natural that proximal part of petiole of *F. japonicum* produces more shoot primordia than the distal part. We may ascribe the reason for polarity shown in Fig. 1 to a gradient in age of petiole tissue.

Adventitious shoots formed from the leaf and petiole explants were transferred to the MS medium without hormone where shoots rooted easily. The regenerated plants were transferred to vermiculite in plastic pots for acclimatization. Thereafter, the plants were grown in a greenhouse and flowered in November as shown in Fig. 2. We could obtain these flowering plants after about 1 year from the beginning of explant culture. The color and shape of flowers of the regenerated plants were same as those of indigenous plants.

Figure 2. Flowering of *Farfugium japonicum* regenerated through the methods of the present research.

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Welcome©

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Good morning and welcome to the 56th Annual Meeting of the International Plant Propagators' Society Eastern Region in Grand Rapids, Michigan.

We have an outstanding program and an action-packed 3 days planned for you.

I would like to inform you that we have members attending from the Southern and Western regions as well as Saskatchewan, British Columbia, Netherlands, Great Britain, plus five attendees from China. We also have members and representatives from Quebec where next year's meeting will be held.

I would like to ask all the new members to stand as well as all of you who have signed up to be their buddies during the meeting. Please meet each other at the registration desk at the break. It's important that we spend time with our new members and make them feel welcome among us. That also holds true for all of the students that are attending. The students are the next generation of I.P.P.S. members. We welcome you and hope you find your time here interesting and rewarding.

I would especially like to thank the Local Site Committee for a superb job organizing this meeting. Those of you who participated in yesterday's tours know what I am speaking of.

The local site committee includes Dale Deppe, Gail Berner, Kraig Brolick, Shirley Bruin, Mike Corbett, Jeremy Deppe, Lloyd Jurries, Tom Kimmel, Tim Wood, and Gary Van Slooten.

Please also thank Darrel Apps for putting together a tremendous program. It takes countless hours to put together this event. Darrel has brought us an impressive array of the most interesting subjects and speakers available. This is also the first year we have had the involvement of our new program coordinator, Charles Heuser.

Charles has been an invaluable asset following up with all speakers and making sure all details of our program fell into place. Thank you Charles.

Thanks also to Brian Maynard, our second Vice President. Brian was in charge of our poster session. This year we have close to 30 posters. Brian has also put the foundation in place for our meeting in Montréal next year. The program is nearly complete a year ahead of time. It was especially important since we are trying to acquire a grant that will allow us to have the ability to offer simultaneous translation in Montréal. Also I want to inform you that we are well on the way to having our program and tours set for our joint meeting with the Western Region in September 2008.

Special thanks also have to go to our executive director, Margot Bridgen, for all the work it took over the course of a year to put this meeting together. Margot is the reason why things work so smoothly around here.

This year we have a new team of AV operators. Dave Sanford and Scott Clark have been relieved of their duties and were offered help with providing our AV needs. This year I would like to thank Bob McNiel, Paul Cappiello, Win Dunwell, Chris Cash, Scott Clark, Bob Geneve, Dave Sanford, Brian Maynard, and Mark Bridgen.

At this time I will announce the names of those members who have passed on within the last year.

- Robert Mori of Mori Nurseries, Ltd. in Niagara-on-the-Lake, Ontario. He had been a member since 1977.
- Chico Haramaki, Penn State University, a member of 48 years, since 1958.
- Edward Rezek, Coniferare Gardens, Malverne, New York, member since 1972.

Is there anyone who knows of others who have passed on?
Let us please honor them with a moment of silence.
I would now like to call on Jim Johnson to conduct our awards ceremony.
Please respect our speakers by turning off your cell phones.

Some Thoughts from Inside and Outside the Propagation House©

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It's a time of flux for the nursery business. Market and external factors are affecting what we grow and how we grow it. Here's a look at seven major factors and how they're changing the face of nursery production.

LABOR

Labor has become the number one issue facing nursery growers today. This is being affected by the nation's current fervor over the immigration issue. This season agricultural crops have been left to rot in the fields because there was no one to harvest them.

Many worry that greater immigration enforcement measures will affect business owners. Well guess what — this is already the case.

Tougher enforcement and placing more burdens on employers is already happening, no matter what compromise Congress comes up with.

The Department of Homeland Security announced new rules regarding Social Security Administration (SSA) mismatch letters. Previously there were no legal obligations for employers who receive such notifications. This has all changed.

Since 11 Sept. 2001, SSA has diligently sent letters notifying businesses when employees' names and social security numbers don't match. This could be a clerical mistake (such as putting Charlie on the I-9 form instead of the employee's legal name Charles). Or it could also be that the employee isn't a legal U.S.A. worker and made up the social security number.

The Department of Homeland Security now says employers who ignore these mismatch letters could face legal action for having "constructive knowledge" that they have hired an illegal alien. "Constructive knowledge" means a reasonable person could conclude the person is an undocumented worker. "Actual knowledge" means the employee shows up to work wearing a T-shirt that says, "Hey look, I'm an illegal alien."

The Department of Homeland Security gives employers 14 days to act, such as finding clerical errors and informing SSA. If no such errors exist, they should tell the employee to follow SSA's directions on the letter.

The employee then has 60 days to act from the time the employer received notice. If the situation still isn't solved after this time, the employer has 3 days to take action, which could include termination of the worker.

FUEL COSTS

Fuel prices have been on the downswing, but transportation costs are sure to be expensive for the foreseeable future. This is affecting how plants are grown and where they're shipped.

We're starting to see more growers pay more attention to local markets — those within 250 miles. It's as if we're returning to the nursery industry of 50

years ago where each metropolitan area had a core group of nurseries that serviced that market.

But that's not to say that there won't be any national shippers of nursery product. It will just be more difficult.

Freight costs are also affecting new products being brought to market. Plant breeders report that large growers' often look at how well a potential new plant will ship — how many can be put on racks and then placed on trailers — as a primary consideration of whether they grow that plant.

GARDENING DEMAND

Some fear a decreasing demand of nursery products on the market. I say a closer look at the numbers may reveal the contrary.

In 2004, National Gardening Association reported retail plant sales dropped from $9.6 million to $9.2 million. However, this reveals only sales at the retail level. It doesn't reflect the massive increases people are spending on professional landscape design and installation.

American Nursery & Landscape Association estimates professional landscape sales increased 13% per year from 1998–2003. Demand isn't down. People are just lazy and want professionals to do the work for them.

A MATURING MARKET

However, signs indicate the nursery industry is a maturing market. Sales are leveling, and margins are shrinking. There's oversupply, and there has been overexpansion of the nation's nurseries.

These ain't the roaring 1990s anymore, where it was much easier to sell plants.

The three options for nursery growers are:

1) Become the low-price leader.
2) Partner with other growers to expand what you can offer customers.
3) Differentiate.

eBAY

Is eBay competition, an opportunity, a threat, or maybe all three? Thousands of plants are sold on this Internet auction site daily — some by traditional nursery growers, some by hobby gardeners selling plants dug from their gardens.

A quick search on the site for "daylily" returned more than 2,000 items for sale, from single plants to hundreds of divisions sold in blocks. "Redbud" returned 81 items from unrooted cuttings to 6-ft trees.

And eBay does not end at the U.S.A. border. Shoppers on the site can buy plants from international sellers as far away as Europe and Asia, and not all plant materials are accompanied by phytosanitary certificates.

Stay tuned.

EMERALD ASH BORER AND OTHER BUGS

With international commerce, it's inevitable that more foreign pests and disease would enter our continent. In the past decade, with Asian longhorn beetle, emerald ash borer, and *Phytophthora ramorum*, we've seen what these foreign invaders can do to the nursery industry.

A solution is developing standard protocols regarding how to deal with these new pests and diseases. Without them, we have individual regulators (state departments of agriculture, etc.) responding with knee-jerk reactions, much like we saw with *P. ramorum* in 2004.

PROMOTION ORDER

They've been silent for about a dozen years, but once again a portion of the industry is calling for a promotion order.

In the face of declining margins and a shrinking gardening population, they say a national marketing campaign would do wonders to our bottom lines. Just like "Got Milk?" promotes dairy, the green-industry promotion order would increase demand for all types of landscape plants.

The last time these promotion thumpers were this loud was 1995, when the now-defunct Garden Council tried to get Plants for America passed. But this proposal was squashed by an 85% margin when the nation's ornamental-plant growers were asked to vote for or against it.

But this isn't the mid 1990s anymore. Would growers vote differently today? Any proposal for a promotion order has to include the following:

- A reasonable, fair means of collecting funds.
- Collection of enough money to make a difference.
- A promotional message that would benefit growers of all types of landscape plants.

Fund collection was the biggest downfall of Plants for America. Garden Council's solution was to tax growers' container and burlap costs. That makes no sense because crops grown in identical containers can have vastly different values. And what do you do about bare-root growers?

If we decide to head down this path again, let's tackle the collection hurdle first. As far as dollar values are concerned, Plants for America's goal was $25 million annually. In today's dollars, is that enough money to reach our target audience with a continual message?

And would that message equally promote trees, shrubs, vines, perennials, annuals, etc., across the entire nation?

Basic Facts about United States Plant Patents, Trademarks, and Brands©

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The United States nursery industry is experiencing rapid changes in the way new plants are introduced into the market. As the industry evolves, the use of plant patents linked with a marketing campaign and branding is becoming necessary for consumers to connect to the value of the plants.

UNITED STATES PLANT PATENTS

To obtain a U.S.A. plant patent, an application with photo(s) of the plant, detailed specifications, and claims are needed. This information is filed with the United States Patent and Trademark Office. Under U.S.A. law, the individual filing the patent application has a duty to disclose all information known to be important to the patentability of a plant. The information disclosed must include prior patent applications overseas, publication, prior public use, sales, and offer of sale. In other countries, Plant Breeder Rights are used with similar protection. For this paper, I want to focus on U.S.A. plant patents.

Prior to application, criteria should be developed by you or your company to base decisions on whether to apply for a plant patent. A plant patent offers you legal protection from unlawful propagation by others for 20 years. The challenges you face are how to monitor illegal propagation and are you willing to take legal steps to protect your invention. Applying for U.S. plant patents such as protection of market share, supports the price of the product in the market and support independent plant breeders for the work they have accomplished.

As of 1 Oct. 2006, approximately 10,728 plant patents were active in the United States. Of these, 53% are annuals (including pot crops and tropical plants for interior use), 15% roses (shrub, climbers, cut, tea, pot, etc.), 13% fruits (apples, citrus, blueberries, etc.), 7% other (turf, etc.), 7% woody plants (trees and shrubs used in the landscape), and 5% perennials. In reviewing the 7% woody plants, less than 10% (approximately 80 plants) are available in general commerce for purchase by a consumer from mail order, retail garden centers (both independents and mass merchants/home centers), or a landscape contractor. These patented woody plants have not been maximized for their sales potential in the United States. The opportunity for these patent holders is to work in conjunction with companies that provide a national marketing and distribution network.

DISTRIBUTION

Many of the plants on the plant patent list may not be available due to the patent holder not maximizing the sales potential due to limited market distribution. Few nurseries in the United States have national distribution. Even nurseries with national distribution have a limited number of customers that purchase plants from these growers. A greater number of wholesale nurseries have the ability to sell

and distribute regionally but have not, historically, worked towards licensing their products to a national sales/distribution organization. New sales/distribution models are beginning to take place in the United States. Examples are companies such as Bailey, which are licensing key growers nationally and leveraging marketing to consumers. The successful consumer marketing program is Endless Summer® hydrangea. Other companies such as Ball Ornamentals are working on behalf of the grower through national product distribution and support breeders' world wide in patenting, sales, marketing, and product distribution. This sales/distribution model is advantageous to both the wholesale nursery and breeders. The nurseries have a source for new plants, with consumer marketing. The distribution is of the breeders in expanded market share, increased margin, and royalties direct to the breeder.

CRITERIA FOR APPLYING FOR U.S.A. PLANT PATENTS

Development of criteria for applying for a plant patent should be undertaken by companies prior to application. There are significant costs associated with application, infringement monitoring, enforcement, distribution, marketing, branding, and sales to achieve a return on the investment. There are other ways for the breeder to achieve monetary goals. Few companies choose to offer or are willing to pay a voluntary royalty for products. These royalties are usually for 3 to 5 years, because the nursery industry in the United States will often begin to self-propagate open sourced, unpatented products. As I mentioned earlier, for breeders to maximize their investment, look for companies that manage the entire supply chain including patenting the plant, marketing, distribution, and sales. This will offer the greatest return on investment. Some of these companies pay royalties in full to the breeder; others take a percentage of gross royalty income to cover overhead.

If you are applying for a U.S.A. plant patent, you should consult an attorney that has specialized in plant patents, employ a patent agent, or work with a sales/distribution company. Prior to making claims on the validity of patented plants, individuals should review the existing U.S.A. plant patent rules with an attorney that understands the nuances. The process and definitions change frequently for applying for U.S.A. plant patents, leading some individuals in the industry to have misunderstandings of the validity of a U.S.A. plant patents.

TRADEMARKS

A trademark is a name, word, symbol, package design, or any combination that distinguishes a product in the market place. In the United States, trademarks are used, and misused, in a variety of ways. Below are the most popular ways to denote a trademark. The trademark is not part of the botanical name and needs to be used as noted below.

Stand Alone Products.

- Common Law Trademark
  - Cracklin' Red™ red tip
  - *Photinia* 'Parred' PPAF (botanical name)
- Registered Trademark
  - Tiger Eyes® cutleaf staghorn sumac
  - *Rhus typhina* 'Bailtiger' PP#16,185 (botanical name)

Products as Part of a Brand Program.

- **Happy Ever Appster™ Daylilies**
  - *Hemerocallis* 'Just Plum Happy' PP#14,841
  - *Hemerocallis* 'Red Hot Returns' PP#13,499
  - *Hemerocallis* 'Romantic Returns' PP#13,481
  - Other cultivars of *Hemerocallis* are part of this program

BRANDS

There is a range of brands used within the nursery industry in the United States. Most of them are well known by people within the industry but may not be recognized to the general consumer. Some consumer brands are channel specific (Simply Beautiful® or Monrovia for independent garden centers) others are developed for products sold to independent garden centers, mass merchants, and home centers (Proven Winners®). A brand is a promise from the supplier for quality, service, experience, or other consumer expectations.

CONSUMERS

The consumer makes the decision about what to purchase. Consumers have little time to spend on a shopping experience that does not fulfill their expectations. The average consumer in the U.S.A. has few gardening skills; they do not know plants (nor do they care what the plants are). Consumers are focused on service and having an entertaining shopping experience that fulfills their expectations. The outdoors is the new kitchen and living room. Outdoor patios with grills, hot tubs, and outdoor fireplaces are a growing segment for homeowners. Plants are an afterthought that is used as decoration or to fill a functional need (screen plants). Linking the product to the consumer to meet their needs is critical if our industry wants to experience future growth.

SUMMARY

The past 10 years have been a time of tremendous growth in the nursery industry in the United States, with significant amount of acreage developed to service the home centers and mass merchant growth. During these years, plant-buying trips overseas have brought many new plants to the United States, often without the inventor gaining credit or compensation for their breeding/selection work. I believe the next 10 years the nursery industry will experience the need to have our products connect with the consumer. Conducting a professional approach to plant exploration will be used by more nurseries. Using patented plants and launching a marketing campaign will be critical to have consumers understand the value of these new products. A professional method in which plants are sourced, marketed, and introduced by the nursery industry will become the standard.

Why We Brand©

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What is another name for the green industry? I say it is a mature consumer products industry. We have become a mature consumer products industry, and that means today if we want to grow our business we need: (1) new products, (2) category management, and (3) production differentiation.

MARKETING AND BRANDING

They are all about:

- The consumer.
- Steak and sizzle.
- Strong plant brands enhance and sharpen the retail store's own brand.
- Added value leads to added margins and added turns.
- Branding provides the retailer with power and profit without the huge investment.

It's All About the Consumer. Since plant heads make up 5% to 10% of independent garden center customers, a sea of black pots intimidates and confuses most consumers. Now think outside the garden center; how do people buy everything else in their lives? Most consumers want differentiation, and brands provide differentiation.

How do people buy everything else in their lives? Co-branding is what they see. So, give the consumer what they want and:

- Make it easy!
- Make it important!
- Make it fun!
- Make it convenient!
- Make it a destination!

To quote Jim Bradley of MidUlster Garden Centre, "We expect too much from our consumers and cause them too much stress, and I'd probably go so far as to say we're embarrassing them."

Steak and Sizzle.

- Great garden plants that show well in the landscape.
- Plants that make it easy for the consumer to be successful.
- The steak has to sizzle not fizzle.
- Easy to read and understand packaging.

However, bad things can happen to good brands from poor display and sales.

Strong Plant Brands Enhance and Sharpen the Retail Store's Own Brand. Strong plant brands become the retail store brand; for example, Dunkin' Donuts does enhance the grocery store's brand. Effective brands increase the perceived value of the plant, which allows you to charge a higher price per plant. This leads to increased margins!

If the garden center has branded itself well—consumers expect the garden center to have the best brands. Also, if consumers walk into the garden center and see great brands they'll think it is a great garden center. This further leads to branded products enhancing the generic "black pot" products. For example, Endless Summer® hydrangea enhances the sale of all black pot hydrangeas and provides more excitement for the customer, which leads to greater sales and more visits by customers.

Added Value Leads to Added Margins and Added Turns. Branded plants create displays that become focal points in garden centers leading to added:

- Importance.
- Visibility.
- Traffic.

Branded plants distinguish themselves so completely that the price competitiveness with similar "generic" black-potted plants is non-existent. Table 1 below illustrates a comparison between unbranded and branded plants. As shown in Table 1 the branded advantage is 84.6%.

Table 1. Comparison of the income from unbranded and branded plants.

Unbranded plants	Branded plants
Retail price = $1.99	Retail price = $2.49
Whole sale price – $0.95	Whole sale price – $1.20
Gross margin = $1.04	Gross margin = $1.29
Units sold × 1,409	Units sold × 2,097
Income = $1,465.36	Income = $ 2,705.13

Branding Provides the Retailer With Power and Profit Without the Huge Investment. This provides added importance in an overwhelming environment of choice. In addition, brands can provide information and an interesting story to motivate consumers to open their wallets and purchase plants. Results have shown that when growers invest just pennies per plant in a well crafted marketing campaign, consumers responded by paying nearly 30% higher prices! Also, good brands get your plants noticed, which encourages the impulse sales that make up 65% of all plants sold!

FINAL THOUGHTS

Ten to twenty years ago consumers had more time and less choice of what plants to purchase; think carefully about that! This means that branding our plants is vitally important to us, to the garden center, and to the consumer!

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Some Computers and Half-a-Dozen Graphic Artists, Not! Marketing Opportunities with Patents, Trademarks, and Brands©

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INTRODUCTION

So what will it take? Are you ready to leap into branding?

- Today you have heard what patenting and trademarking does, doesn't do, and why.
- A grower perspective on why branding is important.

So let's get branding, this is easy, right? All we need is a colored pot and some Point of Purchase (POP) materials, and watch the dollars roll in. Well not so fast. The industry today is showing a decline in sales with sales per participating household slowing or not increasing.

THE CONSUMER

The New Consumer is Different.

- Young homeowners place considerable value on personal time.
- Young homeowners want projects done promptly. They want projects completed quickly, and if needed, they will hire a professional to get it done.
- Access to money is not a barrier, as our focus groups revealed; young homeowners do not consider money a significant barrier. One respondent eloquently summarized the prevailing attitude: If I want to do a project I borrow on my home equity line of credit. The interest rate is only 4%, and I get the tax deduction on the interest. The value of my home is going up 10%–13% a year — I'm going to get my money back and some more.
- Homes are investments. As a group, young homeowners see homes more as a mechanism to build personal wealth than as an expense or a place to "plant some roots." In our focus groups, most agreed that they would be in a different home in 5 or fewer years.
- Just acceptable is not good enough. Young homeowners want items that reflect their personal style.

The Changing Consumer. The following themes emerged when we asked focus groups to compare their home improvement preferences and skills to their baby boomer and post-war generation parents:

- Contemporary and unique styling. They do not want homes, furnishings, and landscapes that look like everyone else's.
- Willing to be more whimsical in design by using vibrant color, unusual artwork, and other eclectic decorating items.
- More meticulous with keeping the yard mowed and cleaned.

- Far less motivated to complete home improvement projects. They would rather spend discretionary time on eating out, socializing with friends, and traveling.
- Far less skilled than parents.
- Much more confident in admitting what they don't know, and not trying to complete complex projects without some help.

BRANDING

Do we understand what branding is?

What the Industry Says About Branding.

- The retailer's reputation is what drives plant purchases in independent garden centers and nurseries, 78%.
- Branding is an effective strategy to improve profit margins on plants, 55%.
- Plants are commodities, 55%.
- Consumers will pay more for branded plants, 52%.
- Branding and POP materials (pots, labels, signage) are the same thing, 18%.

Real Branding Requires:

1) Focus.
   - What is the plant's/brand's unique selling proposition?
   - What is the plant's core essence or personality?
   - What promise is the plant making to the purchaser?
2) A core essence.
   - Differentiating.
   - Why is your plant/brand different from others?
   - Compelling.
   - Will that difference make sense to the consumer, do they care?
   - Enduring.
   - Is this a long-lasting appeal?
   - Does it make you feel good?
3) Great alignment.
   - You need to translate brand's core essence into strategies and tactics that will determine how your brand will behave in the marketplace.
   - Who's the customer?
   - Who are you talking to, trade and/or consumer?
   - Is it a push or pull through the channel of distribution?
4) Cohesive linkage.
   - Instilling the brand strategy throughout the business system.
   - Yes, production needs to be in the loop.
   - We are a production-lead industry for the most part; branding is a marketing-driven approach.
5) Strategic planning, business planning, employee training, advertising, and all customer touch points are all coordinated to continually reinforce the brand's core essence.

Aren't Brands and Promotions the Same?

- Differences between promotions and brands are:
  Both are trying to do the following:
  - Customer demand.
  - Higher margins/retail price points.
  - Awareness/recall.
- Only brands have the following:
  - Endurance.
  - Real or perceived difference.
  - Long-term strategic intent.

Brand Differences:

- Differences between promotions and brands.
  - Customer segments.
    - Zealots.
    - Loyalists.
    - Indifferents.
- Mature channels of distribution.
- Emotive trigger.
  - Perceived or real and long term.

Most horticultural efforts are promotions.

In-store promotions are combinations of merchandising, point-of-purchase materials, in-store events, and possibly some advertising and direct mail with the sole purpose of "calling attention to the product." Most of what we do with branding in horticulture falls into this category. We have lots of plant programs but few true brands.

Still Want to Create a Brand?

So what's it going to take above all else — dollars and lots of dollars?

- Branding is not cheap and requires all this work and energy to be spent before you have sold a single plant.
- Branding can take time to return the investment.
- It's not easy.

Asking the Customer. Customer focus groups tell us:

- Primary promise is to remove fear of failure, guarantee product will "thrive."
  - Consider offering money-back guarantees.
- Big-box stores have "programmed" consumers to buy plants on impulse.
  - "If I'm there and it looks good, I'll buy it."
- "Higher-risk" purchases are the mainstay of independent garden centers.

Table 1. What the consumer said.

Physical	Cost
Full, bushy foliage	Good value for money
Rich color according to plant species	Not overly expensive
Blooming plants that contain unopened buds	Discounted if past prime
Sturdy stems without wounds	
Adequate moisture in soil/heavy soil in pot	
Dark soil with visible fertilizer	
Ample room in pot for root growth	
Insect and disease free	

Effort	Packaging
Low maintenance	Container in good condition
Drought resistant/low water requirements	Descriptive label telling how to care for plant
Plants that require less upkeep	

In summary, consumers shop for plants like produce.

PUTTING IT ALTOGETHER

Brand Promises.

- Information
  - Care instruction booklet.
  - Monthly newsletter on plant care and maintenance.
  - Where and how the plant was grown.
  - Color-coded tags profiling growing instructions.
  - Website with plant information and support.
  - Free in-store seminars given by a rep from the branding company.
  - Email updates on plant care.
- Keys to Successful Branding
  - Colorful packaging to make the plant stand out.
  - Advertising.
- I want it to look nice.
- Make it easy; I don't have lots of time.
- Eligibility for trips with purchase (e.g., Holland for tulips).
  - Ability to order more plants on-line at a website.
  - Catalog of products.
  - Biodegradable container/package.
  - Coupons and rebates.

- Plant Characteristics
  - Unique species.
  - Attractive appearance.
  - Consistent from plant to plant.
  - Low maintenance.
  - Healthy genetic origin.
  - Plant appropriate for hardiness zone.
  - Genetically improved to resist diseases (does not apply to vegetables).
  - Larger, long-lived blooms.

The Endless Summer Story.
Did Creating a Brand Work?

- The gardening public said 'yes' overwhelmingly.
- The biggest new shrub introduction ever.
- Bailey Nursery and our network partners have sold over 4 million plants to date.
- Everybody was sold out from coast to coast, even in the warm climates where the attraction was the amount of rebloom.
- Over 35 million dollars worth of "PR" was generated in 2004.

What Has It Done for Our Nursery?

- Created demand for our customer. Happy customers order more and other products.
- Excitement at Bailey Nurseries, Inc. for what we can do, we are the talk of the industry.
- Pulls in new customers eager to hear what we have coming next.

This Success Also Creates Challenges.

- Land and resources required to grow big numbers.
- Need to cover the market with enough plants, new growers, and cost and time to manage the brand.
- Required consumer advertising, consumer publications, consumer/trade advertising, info sheets, POP.

What's Next? The creation of the Endless Summer brand of plants.

- Continue to look for new plants to introduce.
- Introduce the brand around the world.

On the Way to the Market: A Retailer's Perspective on Plant Branding©

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INTRODUCTION

Members of the business world from outside horticulture emphasize the importance of branding products. Plant developers and growers frequently express that plant branding is the wave of the future.

Garden centers however, often convey differing views. I surveyed personnel at over 50 garden centers throughout northeastern United States. What follows is a synopsis of the information, ideas, and opinions expressed by plant retailers, peppered with my experiences working at a garden center in central Pennsylvania for 13 years.

BRANDING AND THE RETAIL PLANT INDUSTRY

While branding is extremely prevalent in most businesses, the plant industry has not embraced the concept to the same extent. Many in the green industry have chosen their career for their love of horticulture and have not focused on business-related concepts.

Garden centers have always carried branded nonplant products. Fertilizers, pesticides, soils, tools, even furniture, all bear evidence of branding. Customers recognize and ask for specific brands when they shop for hard goods, and garden centers realize the importance of offering them. Most garden centers look for brands not carried by mass merchandisers. Many sell one or several lines of major national brands but, because they cannot be price-competitive with large retail chains, do not promote them. Many garden centers indicate they increasingly focus on organic alternatives. They see an increasing market for these products. Organic, earth friendly options fit the philosophy and image of many garden centers. These products also provide differentiation from box stores.

Recently, many plant developers and growers have begun to create recognizable brands for their products. Plants with pots, labels, and wraps adorned with company logos and names are prevalent now.

While garden centers have sold and appreciate branding of fertilizers, soils, pesticides, and other hard goods, branding of plants is a relatively new phenomenon. Retailers offer a mixed review of plant branding. There is apprehension and skepticism expressed about the subject. Retailers have sold nonbranded plants for years, and many are resistant to change.

DO GARDEN CENTERS SELL BRANDED PLANTS?

Garden centers were asked first if they sold clearly branded plant material in their store and if so, was it by choice. Some garden centers replied yes, they sold branded plant material at their store by choice. For them, carrying the brands they chose was important.

The largest percentage indicated they sold some branded plant material largely by happenstance. They did not actively search out the brand. Perhaps the only way to acquire a particular plant was with branded packaging; or the most convenient source used branded pots and labels; or one of their venders offered a special program to try.

Some replied they sold branded plant material as a last resort, when it was the only way to get a plant their customers wanted. Garden centers that grow their own plant material often will not use pots branded with another company name in their own production. However, if necessary, they would buy in finished plant material with branded pots.

A couple replied they will not have any branded plant material in their store at all.

DOES BRANDING HELP SELL PLANTS?

When asked if branding a plant increased sales, the response was mixed. About half answered no, some with certainty. For this group, nonbranded plants sold just as well as the equivalent branded plant. The other half indicated that it depended on the brand. Some branding efforts help to increase sales while others have no effect.

The majority surveyed indicated that customers do not ask for branded plants by name. Most don't know or remember the brand names. However, customers have begun to recognize the brand packaging once in the store. Recognition generates familiarity and consumer confidence, encouraging sales of the product. Customers generally ask for a plant by name or description. When the plant name is part of the brand customers often know the brand but do not realize it is any thing other than the name of a plant.

WHAT FACTORS INFLUENCE THE EFFECTIVENESS OF BRANDING PLANTS?

Several factors were repeatedly offered as contributing to successful plant branding.

Advertising. Advertising is a key ingredient for brand success. Advertising can generate enthusiasm for a plant or group of plants. Garden centers do not often have the budget to advertise individual items. Yet, all know the value of gardeners excited about "hot" new introductions — the plants that everyone is asking for, the plants that bring customers to the store.

Quality. Plant quality is equally important. Brand names must be supported by quality. Inferior plants will reflect on the brand image. Poor quality plants do not sell, branded or not. Some garden centers indicate the only reason they carry a particular brand is because of the plant quality. In these instances, the brand name makes no difference.

Performance. Successful branding of products requires customer satisfaction. When the product is a plant, satisfaction depends not only on plant health when purchased, but also whether the plant performs as promised. When a plant does not reach the consumers' expectations, they are hesitant to repeat purchase of the plant or brand. Many garden center buyers believe the reason for the success of a particular branded plant is simply that it is a "great plant" and performs as specified.

Most garden centers buyers have been disappointment by plants that did not perform as promoted. Many believe that new plants are not tested well or tested for their climate. Dissatisfied customers lose not only confidence in the plant and the

brand, but also in the garden center. This erosion of consumer confidence is hard to overcome.

Clever Name. A catchy recognizable brand that identifies the plant is fundamental. Brand names that tell the customer something about the plant, that it is native, or you can walk on it for example, are more likely to be successful.

Internet Presence. A web site with product information provides the growing number of computer savvy customers assistance with their purchase from home — a clear aid to many garden centers. Web sites that enable users to locate a store carrying their plants are an aid to retailers. Sites that also sell the product directly to the customer were not appreciated, however.

BRANDING DILEMMAS

Plant branding has presented some new challenges and difficulties for retailers.

Store Image. Branded plants do not fit the image of many garden centers. Most want to be known for their uniqueness. When garden centers carry branded plant material found at other retailers, they lose some of that uniqueness. The uniqueness is what brings many customers to their store.

Many garden centers believe branded products look cheap and create the appearance of a mass merchandiser or discount store. The look of branded pots and other "point-of-purchase" (POP) materials does not fit the atmosphere of all stores, especially sophisticated upper end outlets. It is the ambience, the shopping experience, the feeling of the store that attracts customers to many garden centers.

Plant Availability. If a brand or plant is promoted there must be adequate, consistent stock available to meet the demand. Having the product when the demand exists is crucial. Public excitement over a new plant lasts for a limited time, and garden centers want to be able to capitalize on it. Garden centers are frustrated with the frequency that an advertised plant is not available, or only in limited supply.

Plant Selection. A branded collection of plants should have unique selections different than those already offered, otherwise the increase in cost couldn't be justified. New or novel plants in a collection are important, but should be superior performers. All plants in a collection must excel or brand reputation will not last.

Price. A few garden centers refuse to pay the extra cost for branded packaging believing it does not add value. For most, though, the increased cost for the branded plant is not a problem. However, plant quality and performance must justify the price increase.

Some retailers experience difficulty offering the same plant at different prices — the branded one higher than the nonbranded. Garden centers whose customers are price conscious find that the cheaper plant will always sell first. When price is no object for the majority of customers, in many cases the branded pot with the pretty tag was more likely to sell.

Branded Packaging.

Pots. Most garden centers prefer unmarked black, green, or terra cotta pots and believe plants sell equally well in them. Plants in a wide range of pot colors can create chaos on the sales floor. The pots often spoil the effect of the display or do

not fit with the style of the store. The packaging should not draw attention away from the plant. Some bright or multi-colored pots actually compete with the plant. Light colored pots are ugly when they get dirty especially when they are set on the ground as with shrubs.

A few garden centers indicate that certain branded pots have been very effective. Some have also questioned whether the aversion of garden center personnel to the colored pots is not reflective of the customer's impression. Many retail workers pride themselves on creating beautiful displays and consistent appearance throughout the store. These efforts may be lost on the end consumer.

Labels. Labels created for branded plants can also cause problems. Often the brand logo is the most visible information on the tag — taking the top spot. The plant name should be visible. If the name is on the bottom half of the tag, chances are it is buried in the soil. Pictures on labels are vital for sales, and larger is better. A few suggest that some labels are inappropriately big — dwarfing the plant.

Point-of-Purchase Materials. Several garden centers are delighted with the POP materials provided by plant developers and growers. The merchandizing tools attract attention and encourage plant sales.

For others, POP banners and posters are hard to use on their sales floor. They must withstand extremes of outdoor conditions — rain, wind, and sun. Most garden centers don't have the proper holders to mount large signage. Point-of-purchase materials come in many sizes, making it difficult for garden centers to devise a universal solution. A couple garden centers will not use any POP materials; they believe it is not compatible with the upscale image of their store. Point-of-purchase materials can also be very expensive and hence prohibitive.

Space. Smaller garden centers often can't devote space to individual displays for particular brands. When branded plants are mixed in with other plants, the effect of the brand is diluted. There is a limit to how many different brands any garden center can accommodate. A sales floor is confusing with too many.

Grouping plants by brand makes it difficult for customers to shop for a particular plant — especially when the same plants are in more than one display. Many garden centers alphabetize or group plants in a way that is not compatible with branded displays.

The Garden Center Brand. Many stores want to brand their own name. They want their customers to recognize their name first and be loyal to their brand. Some who grow their own plants use pots embossed with their name or logo. Often they promote their product as locally or home-grown plants that will thrive in the area. They do not want to advertise, promote, or even compete with other brand names in their own store.

WHAT CREATES PLANT SALES?

Even with all the aforementioned branding dilemmas, many retailers do not want to discourage growers from helping them be successful. Some branding efforts have been effective, and garden centers appreciate it. All agreed that advertising by plant developers and growers has generated increased sales. Garden centers can use help to increase plant sales.

When asked what factors influence plant sales, all garden centers put quality on the top. Premium quality plants will sell. Of equal importance for most was customer service. Knowledgeable sales staff can create sales. It is also important for garden centers to offer service to attract customers. Plants with blooms sell drastically better than those without. How plants are displayed also has a major impact. Most felt that price or plant brand was rarely a determining factor.

The best way growers can increase plant sales is to offer high quality plants and have an adequate supply of plants in bloom at the appropriate time. The grower that can provide this consistently will be the one chosen to supply the plant material.

FUTURE OF PLANT BRANDING

The final question addressed the future of plant branding. Do garden centers plan to sell more branded plants? Do they want to see more plants branded? Many answered no without hesitation. They believed there are too many brands already. Even some who have experienced success with branded plants suggest there is already an overabundance of plant brands. A few were indifferent, indicating they will inevitably sell more branded plants because more growers are using brands. Others are keeping an open mind and are willing to try new branding efforts.

One garden center manager plans to continue carrying branded plants but not the same ones. She believes most plant brands will not be effective for many years. Bringing in new brands while eliminating older ones will keep the shopping experience fresh and exciting. A few other garden centers also noted particular brands were at first popular then declined or leveled off in sales with time.

All garden centers articulated that they do not want to carry the same branded plants sold at the mass merchandisers. Many see the quality and selection of plants now offered at the box stores as a clear threat. The garden center needs to be unique to attract customers. Plus they often cannot be price-competitive. Several expressed dissatisfaction when plant brands initially offered only to independent garden centers went to a box store. When garden centers lose the original offer of exclusivity for a particular plant brand, distrust can develop. If they remain loyal to a brand by providing optimal sales space for the product and promoting the brand, they expect the brand developer to be loyal to the garden center in return.

CONCLUDING QUESTIONS

Why is indifference or rejection of plant branding common in the garden center industry, while branding of other commodities is accepted and welcomed by other retailers? Will garden centers discover the benefits of branding over time and embrace the idea? Or do the resistant garden centers know something about plant sales that transcend what the business world purports? Only the future will tell….

Alternative Strategies for Clonal Plant Reproduction©

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INTRODUCTION

Pick up any biology textbook and there will be a description of the typical sexual life cycle for plants. In higher plants, the life cycle starts with seed germination followed by vegetative growth leading to flower and gamete formation with the ultimate goal of creating genetically diverse offspring through seed production. The fern life cycle is more primitive but follows a similar progression from spore germination to the gametophytic generation leading to sexual union of gametes resulting in the leafy sporophyte, which in turn creates the spores.

Interestingly, plants have evolved unique alternative life cycles that bypass typical seed production in favor of clonal reproduction systems. This may seem counterintuitive because sexual reproduction should lead to greater genetic diversity in offspring compared to clonal plants. These sexual offspring should have a higher potential to adapt to new or changing environments, i.e., be more successful. However, investing in clonal reproduction seems to increase the likelihood that a species can colonize specific environmental niches. It has been observed that many of the perennial species in a given ecosystem tend to combine both sexual and clonal forms of reproduction (Ellstrand and Roose, 1987). Additionally, unique clonal propagation systems tend to be more prevalent in plants adapted to extreme environments like arctic, xerophytic, and Mediterranean climates.

Mini-Review Objectives. The objective of this mini-review is to describe some of the ways plants have evolved clonal reproduction strategies that allow unique plants to colonize extreme environments.

CLONAL REPRODUCTION ADOPTED BY PLANTS

There are two basic forms of clonal reproduction adopted by plants. Flowering plants and ferns can reproduce by modifications of vegetative structures (shoot, leaf, and root). Additionally, flowering plants can produce clonal seeds via apomixis. It is interesting that cycads and gymnosperms that are intermediate in their evolution between ferns and flowering plants do not display alternative clonal propagation strategies. It is possible that morphological adaptations in cycads and gymnosperms did not permit the plasticity needed for clonal reproduction.

Vegetative reproductive systems are incredibly unique, and their diversity is listed in Table 1 and illustrated in Figure 1. These reproductive structures can be aerial or subterranean modifications of stems, leaves, inflorescences, and roots. They range from basal stem modifications that slowly colonize local areas (like offset production in geophytes) to the production of detachable vegetative plantlets (like aerial bulbils) that can be disseminated much like true seed.

Unlike the structural anomalies obvious in vegetative clonal reproduction, there are no obvious outward signs that clones formed through apomixes differ from their sexual counterparts. Apomixis is the production of an embryo that bypasses the usual process of meiosis and fertilization (Hartmann et al., 2002). The genotype

Table 1. Clonal propagation strategies as alternatives to sexual seed production.

1.	Modified stems (basal)		
	a. Bulbs (offsets)	tulip	*Tulipa*
		lily	*Lilium*
	b. Tubers	potato	*Solanum tuberosum*
		wind flower	*Anemone*
	c. Corms (cormels)	crocus	*Crocus*
		gayfeather	*Liatris*
	d. Rhizomes	iris	*Iris*
		bamboo	*Bambusa*
	e. Stolons (runners)	strawberry	*Fragaria*
		red stem dogwood	*Cornus sericea* (syn. *C. stolonifera*)
2.	Modified stems (above ground)		
	a. Arial bulbs (bulbils)	European bittercress	*Cardamine bulbifera* (syn. *Dentaria bulbifera*)
		lily	*Lilium*
		monkey flower	*Mimulus gemmiparus*
	b. Arial tubers (tubercles)	meadow saxifrage	*Saxifraga granulata*
		devil's tongue	*Amorphophallus bulbifer*
		hardy begonia	*Begonia grandis* subsp. *evansiana*
		rosary vine	*Ceropegia linearis* subsp. *woodii*
		winged yam	*Dioscorea alata*
3.	Plantlets on leaves	mother of thousands	*Kalanchoe daigremontiana* (syn. *Bryophyllum daigremontiana*)
		piggy-back plant	*Tolmiea menziesii*
		hen and chick fern	*Asplenium bulbiferum*
		walking fern	*Asplenium rhizophyllum* (syn. *Camptosorus rhizophyllus*)
		bulblet fern	*Cystopteris bulbifera*
		button fern	*Tectaria cicutaria*

4.	Plantlets on roots	pawpaw	*Asimina triloba*
		blackberry	*Rubus*
5.	Plantlets on inflorescence	century plant	*Agave americana*
		wild garlic	*Allium vineale*
		spiderplant	*Chlorophytum comosum*
		orchard grass	*Dactylis glomerata*
		walking iris	*Neomarica caerulea*
		meadow grass	*Poa bulbosa*
		alpine bistort	*Polygonum viviparum*
6.	Roots on stems	English ivy	*Hedera helix*
		figs	*Ficus*
7.	Apomixis		
	a. Gametophytic	grasses	*Poa, Pennisetum*
		dandelion	*Taraxacum*
		crabapple	*Malus*
	b. Sporophytic (adventive embryony)	orange	*Citrus*
		mango	*Mangifera*

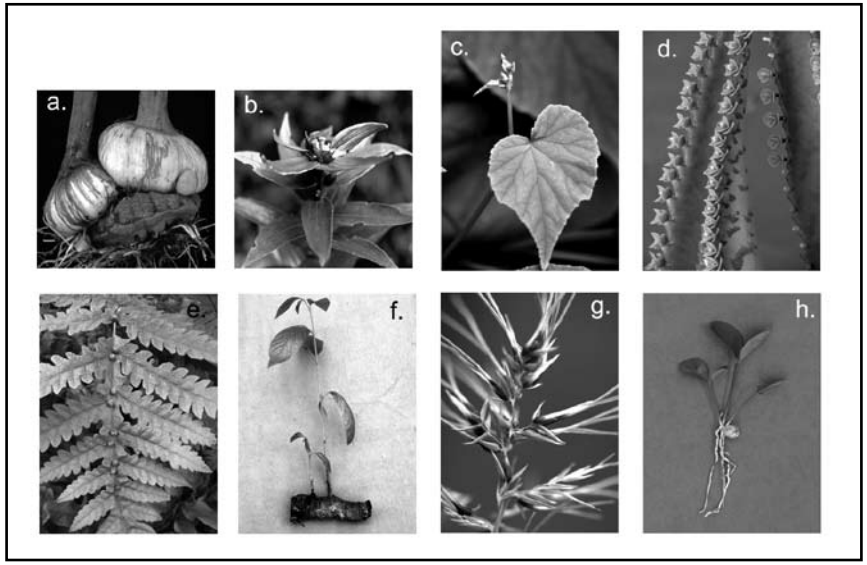

Figure 1. Examples of clonal reproduction systems. (A) Corm and cormel production in gladiola; (B) Aerial bulbils in lily; (C) Aerial tubers in hardy begonia; (D) Plantlets along the leaf margin in mother-of-thousands (*Kalanchoe*); (E) Aerial bulblets on the frond of bulblet fern; (F) Root suckers in pawpaw; (G) Aerial bulbils in the inflorescence of meadow grass; (H) Multiple apomictic embryos in citrus.

of the embryo and resulting plant will be the same as the seed parent. Seed production via apomixis is clonal. Some species or individuals produce only apomictic embryos; however, the majority of apomictic species produce both apomictic and sexual embryos.

Apomixis can be further divided into gametophytic versus sporophytic apomixis. In gametophytic apomixis, the megaspore mother cell fails to initiate or complete meiosis. However, the unreduced (2n) mother cell goes on to form an otherwise normal embryo sac. The egg cell divides to form an embryo but it was never fertilized by a male gamete. The result is clonal seed production.

In sporophytic apomixis, the megaspore mother cell does complete meiosis and forms an egg sac with reduced (1n) female gametes. These are fertilized and form normal endosperm and a sexual embryo. However, in addition to this single sexual embryo multiple clonal embryos spontaneously develop from nucellar (2n) tissue surrounding the sexual embryo sac but still inside the developing seed (ovule). The seed usually contains one sexual embryo and multiple asexual embryos. This type of apomixis is a form of polyembryony and is termed adventive embryony.

An obvious question for biologists to ponder is whether reliance on vegetative propagation with its inherent reduction in genetic diversity allows the flexibility for a species to adapt to a changing environment and avoid extinction. There are few cases where a species relies on vegetative propagation as its predominant means of propagation. For example, the Minnesota trout lily (*Erythronium propullans*) reproduces by means of a dropper (propagation bulb) produced at the end of a stolon. This general vegetative strategy allows trout lily species to colonize relatively large

areas. However, the Minnesota trout lily appears incapable of significant sexual reproduction to supplement vegetative propagation. It only rarely produces seeds and these seeds are thought to be hybrids with white fawnlily (*E. albidum*) (Banks, 1980). The result is significantly less genetic diversity in Minnesota trout lily compared to white fawnlily colonies (Pleasants and Wendel, 1989). Currently, this genetic bottleneck leaves the Minnesota trout lily an endangered species found only in two southeastern Minnesota counties.

In contrast to the Minnesota trout lily, there are numerous species that reproduce predominately by vegetative means, but still are capable of seed production. Genetic studies indicate that there is reduced genetic diversity found within local colonies of clonal species and that this diversity increases with geographic distance as the number of dominate clones also increases (Ellstrand and Roose, 1987). The mother plant (genet) can dispense both genetic (seedlings) and clonal progeny (ramet). When the clonal progeny is very adaptive to a particular environment, it becomes the dominant reproduction unit (Eriksson, 1997). An extreme example is in aspen (*Populus tremuloides*) populations that can have over 1000 clonal offspring (ramets) from a single dominant mother plant (genet) covering over 30 acres (Kemperman and Barnes, 1976). However, even in species where clonal propagation is dominant, sexual progeny from the mother plant provides the genetic flexibility to allow the species to adapt to a changing environment. Sexual reproduction provides essential genetic drift in a species that leads to greater adaptive capacity observed in clonal populations.

Some violet species may take the prize for combining the most genetic and clonal strategies for plant reproduction within an individual plant. Violets can produce two types of flowers. Chasmogamous flowers are produced in the spring or summer when pollinators are plentiful and active. Chasmogamous flowers open to permit cross-pollination between flowers and produce offspring (seeds) with generous genetic diversity. They also produce subterranean cleistogamous flowers in the autumn that never open and self-pollinate. Although this restricts genetic diversity, it does not require the same level of plant resources for seed production and provides insurance against poor seed production from earlier out-crossing flowers. Finally, these same violets produce stolons that serve to clonally reproduce successful mother plants. The result is mixed populations of violets that combine two levels of genetically diverse seedling populations and a means for local clonal colonization.

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Propagation Equipment 101©

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INTRODUCTION

This paper is a review of equipment used to provide the best environment for propagation. For some it may seem a rather basic review, but sometimes going back to basics is not a bad thing.

It has always been said by propagators "If you have the basic understanding of plant propagation and the required environment, you can root cuttings in any type of structure." History and I.P.P.S. tours have proven that sophisticated propagation structures are not always necessary to be a successful propagator. As many of us have learned over the years by attending I.P.P.S. meetings, no two nurseries have the same system or the same way to propagate and grow the same plant.

While most nurseries now use a mist or fog system for propagation, cuttings have been rooted for hundreds of years using very simple methods. These simple structures and systems were used before the advent of more automated systems like the mist system. The I.P.P.S. was founded at a time when mist propagation was in its infancy as a commercial system in the U.S.A., and the founding members played a significant role in its development. Mist propagation has frequently been viewed as a mechanical version of cold frame methods that involved manually applied overhead watering of cuttings.

The first reported use of mist for propagation was in 1936, but it was not until the 1940s that nurserymen were obtaining suitable results. The mist system as we know it today was developed in the 1950s with Harvey Templeton, Jim Wells, and other well known I.P.P.S. members perfecting the system. The interest in the use of mist for propagation was sufficiently great that at the 1954 annual I.P.P.S. meeting an entire session was devoted to mist propagation.

Propagation structures can range from the simplest structure of a cold frame, outdoor mist beds, a bed covered with poly, or a small covered poly house to a sophisticated structure controlled by computers. Whatever type of system you use, the same general principles apply to all propagation facilities.

The important factor with any structure used to root cuttings is to maintain the cuttings in a turgid enough state to prevent them from wilting or drying out. The propagation environment is made up of a number of factors including light, temperature, humidity, and air movement. This is usually achieved by maintaining a humid environment with the assistance of mist, fog, or covering the cuttings with a thin layer of poly, and by manipulating the temperature and light through shading and ventilation. Improper control of this environment can result in death of cuttings or poor rooting percentage.

PROPAGATION STRUCTURES

The structures used for propagation include:

- **A cold frame.** A low-cost structure.
- **An outside ground bed.** Usually used for summer cuttings.

- **A low hoop sun tunnel.** A low cost structure usually used for summer cuttings.
- **A low poly structure within a greenhouse.** This method allows the propagator to increase humidity and reduce mist frequency. This type of structure is frequently used for acclimation of tissue culture material.
- **Polyfilm laid directly over cuttings.** This method usually has limited applications because there is no mist system in place.
- **Greenhouse.** The most commonly used structure for propagation is a greenhouse. Quonset style houses are commonly used for propagation, and we are seeing more sophisticated greenhouses used due to the improved growing environment. Retractable-roof and retractable-side houses are among those that provide the improved environment.

The incorporation of labor-saving devices is becoming more important in the design and use of a propagation facility. The size and sophistication of the structures will depend on the size and complexicity of your propagation needs.

GREENHOUSE PROPAGATION STRUCTURES

Greenhouse Coverings. Glass has a very high initial cost but offers the best light transmission. You very rarely see glass used now. Polyethylene film is the most common covering because it has relatively low cost, but it needs replacing every few years. The use of a double polycover can give up to a 40% saving in heating costs.

Polycarbonate type material is often used for roof and end walls and other areas requiring a rigid covering. Polycarbonate is often used as a replacement covering for old glasshouses.

Greenhouse Floors and Benches. Benches come in various shapes and sizes: fixed bench systems, rolling bench systems, greenhouse floors used as benches, and sand benches.

Floors as Benches. Concrete is a good material for a propagation house floor because it is easy to keep clean and sanitized. Porous concrete was popular about 20 years ago, but has been found to be unsuitable for propagation house floors since propagation media will often clog the porous matrix and prevent drainage.

Gravel or dirt floors are inexpensive when compared to concrete. However, they cannot be cleaned or disinfected as easily as concrete. A compromise is often to use gravel and a weed-barrier-type material over dirt floors with concrete aisles. The use of floors as benches allows for the maximum use of available space. The disadvantage is the added back strain for employees.

Raised Benches. Many growers utilize fixed benches of various designs. The benches are laid out in a longitudinal design to minimize the number of aisles and increase percentage of bench space. Fixed benches are more commonly used, but we are seeing an increasing use of rolling benches. These benches can increase efficiency up to 90% of the available floor space. A crank at the end of the bench moves bench platforms. The high cost of installing rolling benches has been challenged by some growers, while others seem to have taken a leaf out of the commercial greenhouse growers' manual and proved their cost-effectiveness.

Raised benches can be made very simply out of wood, steel piping, concrete blocks, and wire mesh. Various types of prebuilt bench systems are also available. Consideration must be given if a bottom heat system is to be incorporated into the bench.

ENVIRONMENTAL CONTROLS

To create the ideal environment, propagators regulate water, humidity, temperature, light, and ventilation by various types of controls. They include simple time clocks, mist controllers, thermostats, mist sensors, humidistats, and computers. Before mist propagation became widely accepted, rooting was attempted by maintaining high relative humidity in the rooting zone and restricting sunlight by shading. Mist and fog systems break water droplets into very fine particles so that droplets surround the leaves of the cutting.

Mist Systems. Because the primary function of mist is to create a humid environment around the cutting and a continuous layer of water over the leaf, the first requirement of a mist system is to distribute the water as evenly as possible over the cuttings.

A mist nozzle must break water droplets into very fine particles so that droplets surround the leafy cutting. This must be done using the minimum amount of water to keep the cutting turgid without saturating the medium.

In designing a mist system there are many different things that must be taken into consideration: water pressure, nozzle spacing, nozzle height above the plants, type and capacity of nozzle, and air movement.

A good mist system should take into consideration every condition that is causing water to evaporate from the cutting — mist application, sunlight, temperature, and air movement.

Most mist nozzles use low amounts of water (2.5 to 5 gph), but require adequate water pressure to operate and provide the fine mist. Regardless of the type of nozzle used, they should be spaced to adequately cover the propagation bed or bench. Mist nozzles produce a round pattern, and fitting them to a rectangular bed or bench can be problematical, so adequate overlapping is needed.

Two types of mist lines are most common: overhead and in-bench systems and mist booms.

- **Bench systems.**
  - **Overhead systems.** These seem to be more common since they are easier to install and do not reduce the available space on the bench.
  - **In-bench systems.** Water pipes are either buried in the bed or the pipes are run below or on top of the bench with nozzles placed on an upright pipe attached to the water supply line.
- **Mist booms.** This is really a traveling irrigator. Uniformity is the biggest advantage of a boom mister. A traveling mist boom has a flat fan nozzle, so with proper spacing every inch of the cutting bed receives the same volume of water, thus providing for more uniform rooting.

Mist Controlling Methods. The two main types of control include:

- **A system without environmental controls.** Environmental conditions have no influence on misting frequency. This system will need close personal observation and frequent adjustments are needed as conditions change. A 24-h time clock turns the mist controller on and off at predetermined times. The mist controller can be as simple as a 10-min mister or a variable mister that allows for a set amount of mist at a predetermined interval.
- **A variable system dependent upon the environment.** With variable systems there may not be time clocks, but there are separate systems related to light, evaporation, humidity, or weight that control the cycle.
  - An electronic leaf maintains a uniform level of moisture at the leaf surface. Two electrodes imbedded in a plastic surface are wired to a control box connected to a solenoid. The electronic leaf is activated as water evaporates from the plastic surface and cuts off as water again covers the surface.
  - The weight system is a type of controller that when adequate water collects on a small stainless steel screen, the screen lowers and activates a switch, which closes the solenoid and turns off the mist. As water evaporates from the screen, it rises and turns on the mist. The screen balance is placed among the cuttings. The frequency of misting is controlled by a combination of the temperature, humidity, and light intensity.

There is no one best system. The system that works for one propagator may not work for another. In comparing different control systems, attention must be paid to their effectiveness and their adjustment and maintenance requirements. With a timer the onus is on the operator to adjust the settings in accordance with the weather.

While a mist is used to maintain a film of water on the leaves, it is important to use the minimum amount of water needed to keep the cuttings turgid without oversaturating the media.

Droplet size is also an important consideration; small droplets allow the mist to remain suspended as a cloud before landing on the leaf surface of the cutting.

A good mist control system should take into account every condition that is causing water to evaporate from the cutting — sunlight, temperature, and air movement.

Preventing Operational Problems in Mist Systems. Anti-drip devices should be installed between the mist nozzle and the supply line. The device prevents dripping from nozzles between misting cycles. Excessive dripping will saturate the rooting medium.

A pressure gauge is a useful addition to a system — operating pressure is between 20 and 80 psi. If constant water pressure is a problem, the addition of a pressure tank will assist with maintaining constant pressure. An in-line filter is recommended to reduce potential nozzle clogging.

Fogging Systems. Fog plays a very important role in the art of propagation, despite its advantages very few nurseries seem to have utilized its advantage fully. When used for cutting propagation fog provides an environment that reduces the

stress on plants while not over wetting the rooting zone. The plants are able to tolerate more sunlight and higher temperatures and therefore root faster.

The droplet size produced by fog is many times smaller than produced by mist. Fog droplets will remain suspended and float in the air and do not settle on the rooting media.

A fog system produces a visible fog that surrounds the cutting and maintains relative humidity close to 100%. This reduces evaporation and therefore transpiration loss from the cutting is virtually eliminated.

Fog uses less water than mist so the rooting media does not become over saturated.

Two main types of fog systems:

- **High-pressure fog.** High-pressure system as the name implies uses high-pressure water or a combination of air and water to create a very fine droplet size through a very small nozzle opening.
- **Spinning type atomizers.** Nozzles are fixed to an arm that spins at high speed. As water is released from the nozzles the droplet sizes are such that they stay suspended. A fan behind the system forces the fog into the propagation area. This type of system tends to produce a larger droplet size that may not stay suspended as long as a high-pressure system. This system is more flexible and cheaper.

Bottom Heat or Root-Zone Heating. Propagators have been aware of the importance of bottom heat for more than 100 years. Providing a warm environment at the base of the cutting will usually speed up the rooting process. Optimum temperature ranges for propagation benches is 68–70 °F. Since mist tends to lower media temperature, which can slow rooting, heat is usually added below the cuttings to keep the media at a predetermined temperature. Thermostats are used to control the temperature.

Bottom heat systems commonly used include a recirculation hot water system, electric heating cables or forced heated air.

Electric heating cables are generally used for small propagation areas. The hot water systems rely on hot water being pumped through a series of pipes buried in the floor or laid on the bench under the cuttings. This can be a very simple system utilizing a domestic water heater for small areas. The hot water system is the most common system used today and with the use of a highly efficient boiler can be very cost effective.

Forced air systems rely on a poly tube attached to a heater and blower, which forces the heated air under the bench.

A sensor connected to a thermostat controls the bed temperature at the base of the cuttings.

Shading, Ventilation, and Air Movement. Temperature control and light manipulation are both critical factors in cutting propagation, especially in the summer. Shading and ventilation are used to help maintain the correct environmental balance between humidity, temperature, and light intensity.

Air movement within the propagation house is important. This helps reduce disease and is often achieved with either a jet tube running the entire length of the house or with the use of horizontal air flow fans.

MATERIAL HANDLING DEVICES

Demands on labor costs represent the one of biggest single items of expenditure in a propagation department. Layout of a facility is critical although, unfortunately, this aspect is nearly always an "after the event" situation. Older units usually suffer from paths that are too narrow or have limited accessibility.

OBJECTIVES IN PLANNING A PROPAGATION UNIT

- Provide near optimum growing environment facilities for a wide range of plants.
- Maximize use of space.
- Use labor economically.
- Plan for efficient use of water, energy, and labor.
- Be innovative.
- Plan for success.
- Be profitable.

It Ain't Just Dirt©

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INTRODUCTION

Rooting of cuttings and growth of seedlings is dependent upon providing proper environmental conditions for root growth and anchorage for plants. The decisions include selecting the appropriate media components, type of pot, pot filling technique, and watering methods.

What Do Roots Need? The rooting process requires the presence of water and oxygen in a medium. Water is necessary to keep plants hydrated, allow for nutrient uptake, and for metabolic processes, which maintain cell processes. Oxygen is required for the process of respiration to occur in a rooting environment. For a root to function the proper balance of water and gas exchange must be provided. In addition to the necessary water and gas exchange, roots require appropriate temperatures for growth and nutrients available upon root initiation.

WHAT IS A MEDIUM? A medium is a substrate that provides for growth of roots. William Fonteno writes in the Ball Grower's Guide for Greenhouse Crops, "A major misconception is that media are responsible for setting up the air and water relations for the root system… actually, media account for only 25% of this responsibility. Seventy-five percent of the air and water relations for a plant … is controlled by the grower." In essence this is saying the grower chooses a substrate to grow in and manipulates it to provide the proper environment for rooting.

What Are the Properties of Media? Media are identified by physical and chemical characteristics. The physical characteristics include bulk density (weight per unit volume), porosity (air space), and moisture retention (water cohesion). The higher the bulk density the more anchorage a plant will usually have. Porosity or air space is necessary to provide gas exchange but also to provide room for roots to grow. Moisture needs to be retained and is affected by gravitational pull and cohesion of water to particles. The smaller the particles, the more water holding a medium will have.

The chemical characteristics of media of most significance are pH, cation exchange capacity (CEC), and soluble salt levels. The pH level of a medium will determine availability of nutrients. Cation exchange capacity is a measure of the nutrient-holding capability of a medium. Soluble salt levels identify mineral content of soil solutions and are detrimental if levels are too high.

Does Blending of Components Change Function of That Component? As Fonteno noted, "making media is similar to making soup." The sum of the components is not always equal to the parts. When media are mixed together they produce an entirely new product. A grower should be able to predict performance of a blended medium, but often mistakes are made. A simple example is the addition

of sand to improve drainage. Sand may provide drainage but it may in many cases decrease oxygen content of a medium by filling in air space in a medium.

GROWER DECISIONS. HOW DOES A GROWER OBTAIN OPTIMUM GAS EXCHANGE AND WATER IN A MEDIUM?

Medium Particle Size. Many growers have excellent success with media with single particle sizes. Single particle size provides for uniform drainage and water holding of a medium. When fine materials are blended with coarse materials this will usually decrease air space and increase water holding.

Container Height. The height of the container chosen will affect air and water relations. As medium depth increases, the column of water in a medium is subject to greater gravitation forces and thus more drainage. Deep media are relatively oxygenated at the surface while saturated at the base of the media. Shallow media have more consistent moisture throughout.

Pot Filling Activities. The method utilized to fill pots can significantly impact the function of medium air and water space. The actions of loose filling pots, tamping pots after they are filled or compressing media in a pot will change the air and water relationship of a medium. Loose filling will usually impart more air space, tamping will reduce air space and increase water holding, while compressing filled pots will give less air space in the upper portion of a medium.

Dry Pot Filling Versus Wet Pot Filling. If pots are filled with a dry medium and later moistened, this will often cause loss of air space. Many organic media will swell with application of water. If the medium swells in a pot it has no place to go except to fill the air space. Pre-moistening is most preferred so that characteristics of the medium are stabilized prior to use.

Use of Wetting Agents. Numerous growers utilize wetting agents as media additives. Wetting agents, which reduce surface tension of water, will assist media in absorption of water and relieve media of excessive moisture.

Long-Term Integrity of a Medium. Some media such as organic media will decompose over time. This decomposition will reduce air space for gas exchange, reduce space for roots, and increase water holding.

How Is Consistency Maintained in Working With Media? Employees need to be trained. If each employee is doing work slightly different the result will be variable quality. If all are trained than variation should be minimized.

COMMON MEDIA

Peat Moss. Peat moss is one of the most commonly known and used products. It has low pH and good water, air, and nutrient holding. Peat moss varies with location it is collected from, materials it is composed of, processing methods of harvest, and cut of the product. A fine cut is often desirable for seedling starting, while a coarser cut is desired for cuttings production.

Perlite. Perlite is an inorganic product that is available in various grades of size. Perlite is generally associated with improving drainage of media but can be utilized as a stand-alone medium.

Vermiculite. Vermiculite is an inorganic medium available in various grades from course to fine. Vermiculite has improved water holding and nutrient holding over perlite. Vermiculite does have aeration issues if it is compressed. This product, once compressed, will not "bounce back."

Coir. Coir is a coconut pith product. It has excellent water holding, aeration, and nutrient holding and is a fairly stable product. This medium is very similar to peat moss in its performance. The texture of the product makes it different from peat, which can affect root growth.

Sand. Coarse builders sand has been a standard of propagators for years. Quartz sand can be sterilized and re-used and is often affordable. Problems arise from sand in that it is not found to be consistent in particle shape, particle size, composition, cleanliness, salt content, and a host of other factors.

Pumice. Pumice is another product like sand or perlite. It provides excellent drainage and a texture that many growers find works well for them. The most common problem with the product is expense associated with acquiring it.

Bark. Bark is a common component of media. Properly composted bark provides many opportunities for drainage, water holding, and nutrient holding. Bark has a very good buffer and will resist changes. As with many organics, decomposition of the bark and salt accumulation can be an issue.

Rockwool. Rockwool is a melted spun rock, which by itself has water-retention properties similar to peat moss, but its water-release rate is different from that of peat. Rockwool is commonly used as a medium amendment or is manufactured in slabs or bricks with pre-determined aeration properties.

Other. Oasis, calcined clay, compost, Styrofoam, and many other products have been utilized as media.

Growers' Comments. George Cuzzolino the grower for Plainview Growers in Pompton Plains, New Jersey, comments that he looks for media that provides "easy wetting but dries well." His media are for soft succulent crops such as poinsettia and annual plug production. He requires a medium that is stable with no pH swings and holds up well. He specifically indicates that he needs a product that is easy to use with automated equipment and will be able to be shipped well. Many shipping companies have destroyed his crops. George indicated a preference for the Jiffy (Jiffy International AS) product Preforma. He prefers this product because, when compressed, it springs back to life, much like a sponge. This he has found is his shipping-friendly product.

ADDITIONAL GROWER DECISIONS

Now that the media issues have been decided, there are other issues that need to be addressed at sticking time for cuttings.

Depth of Sticking and Length of Cuttings. The depth of sticking of cuttings is a function of the medium composition and the location where roots emerge from a cutting. Rooting may develop from near vascular ring areas or from callus areas. As such, proper conditions need to be provided to those areas to encourage roots to develop. A simple analysis of rooting response may tell the propagator how the

medium is functioning. If rooting occurs high up on a cutting and the base of the cutting is rotting this indicates that the oxygen content is correct at the surface of the medium. Lower in the medium oxygen content is too low and water content is probably too high. Certain cuttings will only root where they have been wounded. So, if roots are occurring only at the base of a cutting, this is probably the case. If cuttings are rooting the entire length of the cutting, optimum conditions are being provided throughout the rooting medium.

Wounding. There are many theories as to why wounding encourages rooting. They range from wounding allows more uptake of water at the site of damage to rooting stimulates activity of cells. Wounding is commonly effective on woody tissue. One of the possible reasons for this is that woody tissue is lignified and difficult for newly emerging roots to penetrate. The process of wounding will remove the physical barrier of lignified tissue and allow rooting to occur.

Spacing. Issues outside of the needs of the plant primarily determine spacing of cuttings. If cuttings are to be direct stuck and shipped in that container, the spacing is determined by the container size. If cuttings are rooted in a propagation bench, they are often placed in close proximity to each other. The advantage of close spacing is that humidity is relatively uniform in close spacing, and cuttings will provide shading to each other. The limitation to close spacing is that lack of air circulation can negatively impact growth and encourage onset of disease.

Fertilization. Fertilization of cuttings is an issue that requires the grower to have product objectives. George Cuzzolino indicates, due to his water and shipping needs, he prefers calcium-based fertilizer. He indicates that the plants develop darker green color for him and ship tougher than plants that are fertilized with ammonium-based fertilizers. The ammonium-based fertilizers give his plants undesirable stretch and softness.

In addition to growth issues, application of fertilizers with nitrogen may encourage algae growth in the medium or greenhouse. The algae will plug up air space and may encourage the onset of fungus gnats, neither of which is desirable.

CONCLUSION

Deciding on a medium to use for rooting of plants or growth of seedlings requires the grower to consider the needs of the plant, the needs of the customer, and the ability of the grower to efficiently provide the components and environment that will stimulate rooting and later growth. The primary objective is to provide a rooting environment that recognizes the optimum water retention and oxygen needs of rooting.

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Wow! The Hormones Have Kicked In©

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In propagating plants from cuttings, rooting hormones can improve adventitious root formation, nutrients can influence plant health and growth rate, and various biological and chemical means can be pursued to combat pests.

ROOTING HORMONES

Plants naturally produce many growth regulators including auxins, cytokinins, gibberellins, abscisic acid, and other ancillary compounds. Some promote root formation, some inhibit it, and others seem to have little effect. Of these compounds, auxins have the most influence on adventitious root formation of cuttings. Indole-3-acetic acid (IAA) is an auxin produced in the buds and translocated down to the base of the cutting where rooting occurs. In some species, the presence of buds is necessary for root formation. For most species, rooting will not occur unless there is enough endogenous auxin present or supplementary auxins are applied to provide sufficient amounts.

The formation of adventitious roots occurs in two stages: (1) root initiation and (2) root growth and development. During root initiation, stem tissue dedifferentiates from stem tissue into root primordia. The addition of auxin during this phase can have a major impact on adventitious root formation. Once root initials are present, they will grow outward emerging through the epidermis while developing connections to the plant's vascular system. At this point, the addition of auxin has little effect on growth as there is generally enough endogenous auxin present to promote cell division and these roots are now capable of taking up water and nutrients.

Commercially, auxin is applied to cuttings to (1) increase the percentage of cuttings that root, (2) hasten root initiation, (3) increase the number and quality of roots that are formed, and (4) increase the uniformity among cuttings. The most widely used rooting hormones are the synthetic compounds indole-3-butyric acid (IBA) and naphthalene acetic acid (NAA). Although natural IAA may seem to be ideal, it must be extracted from plant tissue, an expensive process, and has a very short shelf life. In contrast, IBA and NAA are relatively stable and can be stored for longer periods of time when refrigerated in darkness. It is important to realize that both IBA and NAA can exist as either an acid or potassium salt formulation. The acid form must be dissolved in base, whereas the potassium salt form will dissolve in water. There are numerous formulations of these auxins available on the market as powders, liquids, or gels.

Auxins may be applied to cuttings in various ways. The most common methods include the use of powder or a quick dip (for a few seconds) in a concentrated solution. When cuttings are dipped into powder, the active ingredient, which is mixed in talc, adheres to the base of the cutting. In the quick dip method, cuttings are dipped for a few seconds into a solution. Powder applications are easy to perform, but the quick dip method usually provides better results because it is easier to evenly apply the active ingredient to the cuttings. Varying amounts of powder may adhere to

individual cuttings, which lessons uniformity. In addition, auxin present in powder must first dissolve before it can be taken up by the cutting, thus causing a delay in absorption. Other application methods include prolonged soaking (up to 24 h) in a dilute solution, foliar sprays, and incorporation into the media (Blythe and Sibley, 2003). Regardless of application method, woody plants are generally treated with higher auxin concentrations than herbaceous material.

FERTILIZATION

Fertilizer may be incorporated into the media, top-dressed during rooting, or applied in liquid form through the mist system or during irrigation. It is important to keep in mind that nutrients present before rooting occurs are often wasted because there are no roots to efficiently absorb the nutrients. Much is leached through the container. Nutrients do not promote root initiation, but promote root and shoot growth once roots are formed. Excess nutrients can cause a proliferation of algae due to the wet environment. When direct sticking, it often advantageous to mix a controlled-release fertilizer into the growing media prior to propagation.

PEST PROBLEMS

Any biological organism that can interfere with producing quality plants could be considered a pest. This includes bacteria, fungi, viruses, viroids, phytoplasma, insects, mites, weeds, parasitic higher plants, birds, and mammals. Common insect pests such as mealy bugs, aphids, white flies, and thrips are a nuisance because of their ability to fly, walk, or crawl to uninfected plants. *Pythium, Phytophthora, Fusarium,* and *Rhizoctonia* are examples of soil-borne pathogenic fungi, whereas *Botrytis* is an aerial fungus that affects foliage.

A goal of all propagators should be to keep stock plants, propagation houses, mist beds, media, and surrounding areas free of pests and pathogens through preventative measures instead of remedying the situation with the constant use of pesticides. Keeping the production pest free is a challenge because the warm, humid conditions found in a propagation house are ideal for the proliferation of bacteria and fungi. When problems do occur, the least toxic strategies should be used under the principles of integrated pest management to achieve the desired results. This practice may begin with the selection of cultivars that are resistant or less susceptible to specific diseases and pests. In addition, the resistant qualities of these plants will be passed on to the consumer.

Selecting healthy, clean plant material and sanitation of the physical propagation facilities is critical. Cuttings taken from branches near the ground are more likely to be contaminated with soil-borne pathogens than those removed from the upper portions of stock plants. Even so, it may be advantageous to dip cuttings in a disinfectant of fungicide solution before sticking. Traffic and visitors should be minimized through propagation areas and debris should be removed daily. All tools, working surfaces, flats, etc., should be disinfected with solutions such as sodium hypochlorite (Clorox) or benzylkonium chloride (Physan 20, Green-shield). Mist benches and growing areas should be kept free of weeds or any dead or diseased plant material. Water used in the mist system also should be free of pathogens. *Pythium, Phytophthora,* and *Rhizoctonia* are easily spread through surface water or intermittent mist systems (Hartmann et al., 2002). Treating water with Zerotol or hydrogen peroxide are two options to help alleviate this problem (Albert, 2003).

Propagation media must also be kept pathogen free. Perlite, vermiculite, pumice, and rockwool are usually sterile when received, but components such as bark, sand, and peat may harbor pathogens. All media should be pasteurized if reused. In the industry, the terms sterilization and pasteurization are often used interchangeably. In reality, sterilization involves heating the media to a minimum temperature of 100 °C (212 °F), a process that will kill all organisms. A preferable treatment is pasteurization with aerated steam at 82 °C (180 °F) for 30 minutes, a process that kills most harmful bacteria, fungi, insects, nematodes, and weed seed. Pasteurization at 60 °C (140 °F) is considered even more beneficial by some, because it kills pathogens, but many beneficial organisms remain alive to compete with pathogens when they are reintroduced. Chemical sterilization is another option, but products such as methyl bromide are scheduled to be phased out in the near future.

After cuttings have been stuck, some propagators use biological controls such as predator insects and beneficial nematodes, fungi, and bacteria to help control disease and insect infestations. In some cases, biological control can be less expensive and more effective than chemicals. For example, two-spotted spider mites can be controlled by Chilean predatory mites (Hartmann et al., 2002). When using biological controls, the propagator must be knowledgeable of the life cycles of the target organisms, keep track of growing degree days, and establish a monitoring program (Rosettta, 2003). Timing is very important, as many organisms are only controllable at certain stages of their life cycles. Even under the best-managed IPM program, the use of pesticides may be warranted if populations get out of control. Most commercial propagators follow a preventative schedule for fungicides and apply pesticides when insect populations pose real or potential danger to their crop. These may be applied in granular form, as sprays, or as drenches. Although chemicals are very effective, they pose potential environmental problems, and pathogenic organisms can develop resistance to these chemicals. When using any pesticide, it is advisable to test it on a small plot before using it on an entire crop. Also, in order to be legal, chemicals must be labeled for specific crops and particular functions. For example, few herbicides are labeled for use inside of a greenhouse (Altland et al., 2003).

SAFETY

In addition to common safety procedures such as "no running with scissors," rooting hormones and pesticides are chemicals that can cause potential harm to workers and the environment. It is very important to follow the precautions listed on the label for each chemical. Personal protection equipment may include rubber gloves, boots, a spray suit, respirator, goggles, and a helmet, depending on the toxicity of the substance used. Signage specifying the chemical used and re-entry periods may need to be posted at the entrance.

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Will Some Plants Get "Green Cards"?©

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INTRODUCTION

Although the issue of invasive landscape plants emerged publically only in the mid-1990s, it has quickly become one of the foremost challenges for the nursery industry. Initially started as a concern that non-native plants were overrunning natural areas, it has evolved into a complex and challenging puzzle for all of us who produce, maintain, and market landscape plants. Depending upon which perspective we choose to take, the challenge presented by invasive plants can be a threat to our well being or an opportunity to improve our industry. In any case, this issue will not go away anytime soon, and it holds potential to become a fundamental base for building the future of our industry.

This session is intended to offer an overview of the invasive plant issue and provide specific examples and resources for additional information. The expectation is that all members of I.P.P.S., and soon the entire nursery industry, will more fully understand and appreciate the importance and complexity of the issue. From the global industry perspective, we need to come together as an industry to present a unified approach to resolving invasive plant challenges.

THE CHALLENGE

The fundamental basis of the nursery industry is horticulture — our "currency" is the wide array of plants we utilize to accomplish the results our customers want. Restrictions imposed upon what plants we use or how we use them have potential to impact us negatively, particularly if we lack control over the results. Our member businesses cannot always agree on what courses of action to take, nor can they provide the resources needed to fund extensive invasive plant research or fuel public relations initiatives. But because we tend to be personally involved in our businesses, we ally closely with our customers and can appreciate their wishes and influence their choices. Our real power to influence outcomes rests with the willingness of our people to individually advocate for sustainable consequences.

Many groups outside the nursery and landscaping industry have proposed simplistic solutions to the invasive plant problem. But history has taught us that, for the nursery industry, simple "one-size-fits-all" answers rarely produce the necessary results. We are the people who deal daily with many of the plants under scrutiny, and we depend upon a wide range of plant availability for our livelihood. Should we allow others to determine how to manage these issues; we relinquish control of the outcomes. If we can hope to be successful in our efforts, we must join together as an industry to fully understand the issues, agree upon our courses of action, and individually commit to participate in the processes to develop the solutions that will best serve us going forward.

LOOKING FORWARD

The public generally recognizes the nursery industry as the primary source of landscape plants. We are widely perceived as the most reliable source of information about plants and how to use them in landscapes. Our nursery industry leaders understand that we cannot be perceived as opposed to self-regulation for our selfish benefit. A number of major nursery players have chosen to take strong ownership of the invasive plant issue and view this as a prime opportunity to improve the industry.

To optimize our efforts in the eyes of the public, we need to agree upon our position, define it in a manner understood by all, and set policy to help coordinate our actions. Having a strong national base upon which to build will help guide our actions at local levels and help develop the most effective results. Combining a local perspective with a consistent industry framework is essential — invasiveness, even among the same plants, will vary depending upon soils, climate, environmental influences, and many other factors.

NURSERY INDUSTRY INITIATIVES

A number of industry initiatives are currently under way, nationally, regionally, and locally. Nursery representatives were influential participants in 2001 at the Missouri Botanic Garden where the Voluntary Codes of Conduct were developed. Many groups are now adopting these. In September 2006 a meeting to develop national guidelines for cultivars of invasive species took place in St. Louis with strong nursery industry participation. Some states have adopted legislation and regulation for invasive plants. Often as these were developed, nursery members have recognized the importance of playing key roles by insisting upon scientific bases for decisions and list development. But there is wide variation in the extent industry members participate from state to state.

The American Nursery and Landscape Association (ANLA) is recognized as the foremost national voice of the nursery industry. The ANLA Invasive Plant Task Force has committed to analyze the issues related to invasive plants and formulate recommendations for the industry. The Task Force will be concerned with plants that are already in commerce, as well as those plants not yet available on the market. As a start, Task Force members expect to formulate a national policy statement that can be used by the industry. This will help position us as the "good guys" in these efforts, preserving and protecting our industry image as a responsible steward of the environment. Education, communication, scientific analyses, and research are all critical components of this process. Members of the nursery industry are the ones best qualified to accomplish these results, and we have willing partners in many arenas ready to provide assistance.

In order for this to be effective, everyone in the nursery industry must become familiar with the issues, recognize the opportunities, and reach consensus on how to proceed. Once we understand the value of leveraging our expertise for the betterment of the industry, the outcomes will be improvements for everyone. Let's use this session as a starting point to ensure total industry involvement in this essential endeavor.

Will Some Plants Get "Green Cards"?: Current Thoughts on Invasive Species©

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INTRODUCTION

Invasive plants have been a topic of discussion for the past several years and will continue to be in the future. We have witnessed legislation, plant bans, and all sorts of negative information across the country targeted at "non-native" plants. The intent of this article is to review some background on the invasive species issue and highlight information that will aid in our understanding and shape the way we address the issue. Our background review will focus on: Executive Order 13112; National Invasive Species Council, Regulatory Action; the two workshops titled "Linking Ecology and Horticulture to Prevent Plant Invasions" held in St. Louis and Chicago; Assessment of Plant Invasiveness; Research Needs; Position Statements by Stakeholders; and Key Concerns impacting the horticulture and landscape professions. The invasive plant issue is extremely complex and crosses many discipline and commodity boundaries. Each has their own perspective…their own interpretation…and their own agenda when addressing concerns over the classification, use, and impact of invasive plants.

EXECUTIVE ORDER 13112, FEBRUARY 1999

Executive Order 13112 set the foundation and provided the framework from which invasive plant councils and other related groups have emerged. Executive Order 13112 states as its purpose "to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause." The Executive Order is directed at Federal Agencies and federal public lands, however it solicits cooperation and collaboration with stakeholders in public, commercial, and private sectors. As green industry members, being familiar with the stated purpose and terminology within the Executive Order will aid in our addressing the issue. For the complete executive order visit: <http://www.invasivespecies.gov>.

NATIONAL INVASIVE SPECIES COUNCIL — MANAGEMENT PLAN (2001)

As directed by the President, the National Invasive Species Council was required to develop a management plan to act as a blueprint for Federal action "to prevent the introduction of invasive species, provide for their control, and minimize their economic, environmental, and human health impacts." Importantly, it is stated that the "focus of the plan is on those non-native species that cause or may cause significant negative impacts and do not provide an equivalent benefit to society." The Management Plan defines the problem and outlines action by Federal agencies in cooperation with stakeholders. It provides a reasonable framework from which we can address the issue. However, problems have arisen with individual interpretation of the intent of the Order when addressing concerns over the classification,

use, and impact of invasive plants and the subsequent action that should be taken. Individual discipline and commodity perspectives play a significant role in the way information is developed and promoted. For the complete management plan visit: <http://www.invasivespecies.gov>.

REGULATORY ACTION

Regulatory action existed prior to the Executive Order through federal and state noxious weed acts. Since the Executive Order there has been additional legislation at the state level banning plant species. The most notable has been the prohibitive legislation of Connecticut; however, Illinois, Minnesota, New Hampshire, and Michigan have regulated several terrestrial and aquatic species. A major concern with present legislation is the apparent lack of a scientifically based process justifying the regulation of a species, risk/benefit analysis, the lack of consideration for non-invasive cultivars and hybrids, and the lack of stakeholder input in the decision process.

ST. LOUIS DECLARATION 2001

In 2001 the Missouri Botanical Garden and Royal Botanical Garden, Kew, co-sponsored a workshop entitled "Linking Ecology and Horticulture to Prevent Plant Invasions." Workshop efforts resulted in the St. Louis Declaration that included findings, principles, and the draft voluntary codes of conduct for several key parties. This landmark workshop was conducted to bring the natural resource and horticulture communities together to discuss the issue and generate a plan for workable solutions. "The St. Louis Declaration was an important first step in responding to the global invasive plants species problem. The Findings and Principles were developed by the entire group to provide a consensus statement on the severity of the problem and outline a general approach to address it." For a complete set of the proceedings visit: <http://www.centerforplantconservation.org/invasives/home.html>.

CHICAGO 2002

A second workshop was held in Chicago the following year (2002) to build upon the groundwork established in St. Louis, assess the achievements made in voluntary adoption and implementation of the codes, and further explore key components of the issue. The Chicago Meeting generated two recommendations. "(1) Non-invasive alternative plants. When horticultural plants are recognized as invasive, one positive way to address the situation is to offer producers and users alternative (or "replacement") plants that meet their requirements but that are not invasive. (2) Regionality considerations. It is commonly agreed that the potential for a particular plant to behave "invasively" depends on the region in which it exists. This situation occurs with many plants species and means that any effort to address the invasive species problem must include consideration of what is called "regionality." For a complete set of the proceedings visit: <http://www.centerforplantconservation.org/invasives/home.html>.

ASSESSMENT OF PLANT INVASIVENESS

Plant invasiveness assessment protocols have their foundation within the natural resource community. R.D. Hiebert and J. Stubbendieck (1993) prepared the *Handbook for Ranking Exotic Plants for Management and Control*. Their ranking sys-

tem was based on two sections, significance of impact and feasibility of control or management. The section on significance of impact examined the current level of impact on natural processes and the character of the natural communities. It also recorded reproductive characteristics, dispersal ability, and competitive nature of the non-native plant. Feasibility of control or management questioned abundance, presence of a seed bank, vegetative regeneration, level of effort required, and side effects of control methods.

The purpose of this system was to provide an analytical approach for prioritizing control and management efforts directed at exotic plant species on public lands. This work has contributed significantly to the subsequent generations of assessment systems currently employed today.

There are several assessment systems currently in practice in Massachusetts, Florida, Michigan, and Natureserve. Most assessment systems address the following criteria: plant characteristics, biological and economic impacts (both positive and negative), control methods and efforts, and value. These systems focus on management priorities and are employed to make informed decisions about plants already present in natural ecosystems.

Predictive Models are being developed to evaluate the probability of whether a new introduction will escape cultivation and become invasive in natural ecosystems. Reichard and Hamilton (1997) developed a hierarchical predictive tree that divides species into three categories; admit, deny admission, and delay admission for further analyses. A second-generation model has been developed by Widrlechner et al (2004). The Widrlechner model improves upon the Reichard and Hamilton model however it is still under investigation.

RESEARCH

Research is currently being conducted on biology of invasion, ecological impacts of invasive species on natural ecosystems, and the characterization of invasiveness in horticultural species, hybrids, and cultivars. Breeding and selection programs for non-invasive qualities are also under way. Research is needed to provide scientific documentation from which credible decisions can be made.

Position Statements by Stakeholders. As a plant industry where do we stand on the issue? As an association representing a plant industry where do we stand on the issue? Listed below are links to position statements from several organizations, three related to conservation, one from a plant industry, and one from the public policy arena. Visit their websites and read what they have to say.

- The Nature Conservancy, <http://www.natureserve.org/explorer/index.htm>.
- Ecological Society of America, <http://www.esa.org/pao/esaPositions/>.
- Plant Conservation Alliance, <http://www.nps.gov/plants/alien/apwgaction.htm>.
- American Seed Trade Association, <http://www.nasda.org/joint/ASTAinvasivespecies.htm>.
- National Center for Public Policy Research, <http://www.nationalcenter.org/PRNPA544InvasiveSpecies.html>.

The Invasive Plant Issue. Some of the key concerns facing the plant industries are:

- Definitions and interpretations.
- Environmental, economic, and human health negative impacts.
- Environmental, economic, and human health benefits.
- Invasive plant lists.

CONCLUSION

So, where does this bring us? The Executive Order set the foundation and provided the framework from which we can address this issue. The two workshops were instrumental in bringing the natural resource and horticulture communities together to discuss the issue and agree upon ways in which we can contribute to workable solutions. The information presented, discussed, and generated provides useful insight into identifying: how we as an industry can have a positive impact on minimizing the impact of harmful invasive plants; how we as an industry can address the issue both within and outside our boundaries; and equally important what we as an industry should expect as a set of standards in dealing with the issue from broad-based collaboration with those outside our industry.

The horticulture and landscape professions have been chastised for contributing to the invasive species problem. Contrary to points mentioned in the Executive Order, we have not always been at the table when discussing the invasive plant issue, assessing the scientific and economic credibility of the information, and contributing to what would be considered reasonable and realistic solutions. As an industry we have tended to be more reactive than proactive. The time has come for us to be proactive and be involved in the solution.

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Plants for a Livable Delaware©

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Concerned about issues associated with invasive plants, in 2002 the Delaware Invasive Species Council formed an Invasive Plants Group. The Group's overall goal was to develop a list of invasive and potentially invasive plants in Delaware. This list would form the basis of an effort to promote agreement between the green industry and public about invasive plant issues and to develop support for addressing the issues. Group members represented Delaware's Departments of Transportation, Natural Resources, and Agriculture; the Delaware Nursery and Landscape Association; and Delaware Center for Horticulture. The Group's objectives were the following: develop a list of invasive plants, make recommendations for regulatory action, describe effective control measures, recommend alternative plants, publicize the Voluntary Codes of Conduct, and develop a communication package.

After reviewing invasive plant categorization schemes developed by several states and organizations, the Invasive Plants Group agreed to use a plant invasiveness assessment tool, modeled after a Nature Conservancy environmental assessment tool. This tool utilizes current scientific knowledge about a specific plant, but also allows users to complete the assessment if information gaps exist. Starting with a comprehensive invasive plant list developed by the Delaware State Botanist, the Group developed a priority list of plants to run through the assessment tool. This list of priority plants became the Official Invasive Plant List for Delaware (Table 1). The list includes a number of plants that are currently sold in the nursery trade. The Invasive Plants Group debated the merits and consequences of using the list as an educational guide, versus drafting invasive plant legislation. The consensus was that education about invasive plants should precede any legislation. This would not only give the Nursery and Landscape industry time to adapt, but also engage the gardening public in solutions to invasive plant issues. The Official List was formally announced at a 2003 seminar, "Backyard Invaders." The seminar was targeted towards home gardeners and was held at the Delaware Center for Horticulture. It featured many vendors displaying and selling non-invasive garden choices. The Official List was also presented at the 2004 Annual Meeting of the Delaware Nursery and Landscape Association.

Inspired by an invasive plant-labeling program at Behnke's Nursery in Beltsville, Maryland, the concept of "Plants for a Livable Delaware" was developed. The program's title was chosen, in part, to reflect Governor Minner's efforts to improve Delaware's environmental quality. Plants for a Livable Delaware (PLD) targeted the Nursery and Landscape industry in an effort to position it at the center of solutions to invasive plant issues. The Delaware Nursery and Landscape Association, University of Delaware, Delaware Department of Agriculture, and Delaware Nature Society received grant funding ($25,000) from the National Fish and Wildlife Foundation for a program to promote sustainable alternatives to invasive plants. "Plants for a Livable Delaware" included promotional labeling and an informational booklet to encourage the purchase and use of sustainable landscape plants and

Table 1. Delaware's official invasive plant list.

Category	Common name	Scientific name	Plant habit*
Widespread and invasive			
	multiflora rose	*Rosa multiflora*	s
	Japanese honeysuckle	*Lonicera japonica*	v
	Oriental bittersweet	*Celastrus orbiculatus*	v
	Japanese stilt grass	*Microstegium vimineum*	h
	Japanese knotweed	*Polygonum cuspidatum*	h
	autumn olive	*Elaeagnus umbellata*	s
	Norway maple	*Acer platanoides*	t
	common reed	*Phragmites australis*	h
	hydrilla	*Hydrilla verticillata*	a
	Morrow's honeysuckle	*Lonicera morrowii*	s
	mile-a-minute	*Polygonum perfoliatum*	v
	yam-leaved clematis	*Clematis terniflora*	s
	privet	several species	s
	European sweetflag	*Acorus calamus*	h
	wineberry	*Rubus phoenicolasius*	s
Restricted and invasive			
	Japanese barberry	*Berberis thunbergii*	s
	periwinkle	*Vinca minor*	v
	garlic mustard	*Alliaria petiolata*	h
	winged euonymus	*Euonymus alatus*	s
	porcelain berry	*Ampelopsis brevipedunculata*	v
	Bradford pear	*Pyrus calleryana*	t
	marsh dewflower	*Murdannia keisak*	h
	lesser celandine	*Ranunculus ficaria*	h
	purple loosestrife	*Lythrum salicaria*	h
	reed canarygrass	*Phalaris arundinacea*	h
	Amur honeysuckle	*Lonicera maackii*	s
	Tartarian honeysuckle	*Lonicera tatarica*	s
	tree of heaven	*Ailanthus altissima*	t
	spotted knapweed	*Centaurea biebersteinii*	h
Restricted and potentially invasive			
	Butterfly bush	*Buddleja davidii*	s

*s = shrub, v = vine, h = herbaceous, t = tree, a = aquatic.

reduce sales of invasive species. The booklet was so popular that 2 printings (20,000 copies) were necessary.

The objectives of PLD are to reduce the purchase and use of invasive plants and increase the availability, purchase, and use of regionally appropriate landscape plants. In addition, PLD promoted the removal of invasive plants from privately owned natural lands. This pilot project engaged garden centers, landscape contractors, public parks, and public gardens in Delaware to create a marketing model that could be used throughout the country to promote plants for sustainable landscapes. By targeting a broad base of garden centers and landscapers, desirable alternative plants would become more prevalent in the built landscape and therefore more easily accepted into the plant palette by homeowners. As part of the program, visitors to participating garden centers were interviewed regarding the PLD publication and their knowledge of invasive plants; of those surveyed, 76% found the publication easy or very easy to understand. Twenty nine percent of the respondents indicated that they were planning to purchase an invasive plant, however the signage and PLD booklet convinced 82% to consider buying a "livable" plant instead.

A second grant for the PLD program was received from the National Urban Community Forestry Advisory Council. A new brochure entitled "Controlling Backyard Invaders" was developed. This publication detailed mechanical and chemical methods the homeowner could use to remove invasive plants from their property. It was distributed at the Delaware Horticulture Industry Expo in January 2005, as the Expo's focus was invasive plants. Links to both publications can be found at the following website: <http://www.state.de.us/planning/livedel/information/ln_native.shtml>. Delaware's Governor Minner held a press conference at a participating garden center on 20 April 2006 to announce the publication of the PLD brochures and support this initiative.

Delaware is also participating in the Nature Conservancy's "Preventing Invasion Through Horticulture" voluntary code of conduct project. This code was developed at the St. Louis Convention — Linking Ecology & Horticulture to Prevent Plant Invasions, December 2001, St. Louis, Missouri. The Code was endorsed by the American Nursery and Landscape Association and Delaware Nursery and Landscape Association Board.

In 2005, members of the Invasive Plant Group met with the Executive Director of the Delaware Home Builders Association to discuss the Plants for a Livable Delaware Program and possible incorporation into development plans. The Association published an article about PLD in their monthly newsletter and adopted the Official Invasive Plant List.

Continuing the cooperation among Delaware Nursery and Landscape Association, University of Delaware, and Delaware Center for Horticulture, in April 2006 a $25,000 grant was received from the USDA Forest Service Invasive Program. The grant will support development of a third PLD publication tentatively entitled, "Livable Plants in the Home Landscape." The guide will provide suggestions for native plant combinations as alternatives and replacements for exotic invasive species. This grant will also help to fund implementation of the Voluntary Code of Conduct pilot.

One additional collaborative project was invited for a full proposal to the National Fish and Wildlife Foundation; however it was not funded. The project is entitled, "Habitat Gardens for a Livable Delaware." The project's goal was to remove the

known invasive species *Euonymus alatus* from five locations in Delaware and replant with desirable alternatives that attract butterflies and birds. As part of this project, a fourth Livable Delaware publication was envisioned: "Butterflies and Birds: Habitat Gardens for a Livable Delaware." The project sites are highly visible, public places: the University of Delaware campus, Delaware Department of Agriculture, Brandywine Zoo, and Delaware Center for Horticulture.

Plants in Table 1 are non-native to Delaware, have the potential for widespread dispersal and establishment, can out-compete other species in the same area, and have the potential for rapid growth, high seed or propagule production, and establishment in natural areas. Plants on Delaware's Invasive Plant List were chosen by a committee of experts in environmental science and botany, as well as representatives of state agencies and the nursery and landscape industry.

- An environmental assessment was conducted on each of the plants listed, and placement on the list results from review of the scientific literature, as well as a consensus of expert opinion.
- Plants on the list are ordered from highest invasiveness.
- Plants on the list should not be planted under any circumstances and should be removed from properties where feasible.
- Listed plants that are currently in the nursery trade should be phased out of inventory and production.
- Homeowners are encouraged to ask nurseries, garden centers, and landscapers for non-invasive plants, preferably natives.
- Widespread and invasive plants are currently invasive, cause serious management concerns, or pose a serious threat to the biological diversity of Delaware.
- Restricted and invasive plants are equally problematic, however, they have a more localized distribution in Delaware.

This list has been widely distributed to nurseries, garden centers, landscapers, homeowners, students, gardeners, and land managers. A more complete list can be viewed at: <www.dnrec.state.de.us/fw/wildrehe.htm>.

Hey Joe, Can You Believe They Outsourced My Job Too?©

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During the last couple of years, top greenhouse growers have largely come to the conclusion that it doesn't pay for them to make their own cuttings. For example, one of Canadian Ornamental Plant Foundation's significant bedding plant producers in Québec, Canada, recently told me that his usual price for an unrooted geranium cutting with tag is about $0.30. His customers last season could buy the same cutting for $0.11 from Costa Rica. Cutting sales were a large part of his business, and he's now considering his options. Most of the bigger Ontario greenhouse producers have already made the change.

Is there any reason to believe it will be any different in the nursery business?

Many of you already know that Ball Seed, in the next few years, is rolling out a softwood cuttings program from Costa Rica and Guatemala. Ball has been selling perennial cuttings for a while, as has Yoder Brothers. These floral breeding programs don't take any cuttings until the stock plants have been cleaned up of viruses. So their cuttings will be superior to those coming from non-indexed stock plants. The size and distribution networks of companies like Yoder and Ball are such that the cuttings can be delivered quickly and cheaply from off-shore facilities.

I don't think outsourcing will affect seedlings much, as long as the species involved are not reproduced from cuttings. Greenhouse companies are not used to scheduling crops that take a year or more to produce.

The Use of Offshore-Produced Unrooted Cuttings at North Creek Nurseries©

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INTRODUCTION

- North Creek Nurseries began buying unrooted cuttings (URC) about 5 years ago (2001).
- We currently purchase about 500,000 annually from all the major perennial URC producers, Yoder, Florexpo (McGregor), and Maya Crops (Foremostco).
- North Creek grows over 400 different taxa of perennials. We purchase about 70 taxa as unrooted cuttings. Some of the genera we purchase are: *Achillea, Agastache, Aster, Coreopsis, Eupatorium, Gaura, Phlox, Salvia, Sedum*, and *Veronica.*
- Offshore-unrooted cuttings currently make up about 8% of our total yearly production.

HANDLING OF UNROOTED CUTTINGS AT NORTH CREEK

- Shipments of unrooted cuttings typically arrive on Wednesdays or Thursdays. The cuttings are wrapped in clear plastic bags that contain about 100 cuttings per bag. The bags are individually labeled with the item name. The bags are then packed in a cardboard box lined with Styrofoam. During the summer, cool packs are also packaged in the box to help preserve the cuttings. When a shipment arrives we immediately unpack the boxes in a cool, dry place (away from extreme heat or cold temperatures). We check for shipping damage or any signs of disease. Also, we pay close attention to the size of the cuttings. They should all be uniform in size and large enough to stick. We also look for flowers or flower buds because some taxa will not root well in this state. We report any issues to the suppliers within 24 h. Once the plants are inspected the cuttings should be stuck in a mist house as soon as possible. We recognize that some plants are more prone to "meltdown" than others, and we stick these first. Prior to sticking we immerse the cuttings in a solution of 1 ounce of Zerotol per 1 gal of water for about 5 min to kill any pathogenic microorganisms. The cuttings are then drained and immersed into a 500 ppm solution of K-IBA for about 1 min. Cuttings are then stuck into the appropriate size tray containing a media composed of peat, coir, perlite, and bark fines (12 : 3 : 2 : 3, by volume). Media pH is adjusted to 5.5, and we incorporate 1.25 lbs of Rootshield per yd^3 for control of soil-borne diseases. We also add a small starter charge and wetting agent. Depending on the taxon and time of year the cuttings will root and, with one trim, finish in 6–10 weeks. We are often able to take a secondary cutting 4–5 weeks after the initial stick. Often times this serves as our initial trim.

BENEFITS OF USING UNROOTED CUTTINGS

- Increases our production capabilities by putting all of our manpower into sticking flats. We are able to produce 25% more per manhour by not having to have a cutting crew supporting the stickers. One cutter is needed to support four stickers.
- Cuttings are generally clean and virus-free.
- Often plants have been virus indexed and arrive as clean stock.
- We are able to save space and heat by not having to carry, force, and light stock through the winter months.
- Allows us to produce some tender perennials without taking the risk or expense of overwintering stock.
- We use the initial block of cuttings purchased as nuclear stock, and we take additional cuttings from them to reduce our costs.
- Unrooted cuttings can be purchased at a lower cost than Stage III tissue culture liners.
- Allow us to spend more time producing plants that are more labor intensive such as divisions and root cuttings.

NEGATIVE IMPACT OF OFF-SHORE CUTTING PRODUCTION TO NORTH CREEK NURSERIES

- We now have to rely on someone else to supply us with true-to-name cuttings delivered in quantity and on time. Shortages and lack of availability have hurt us at times.
- We have had variety mixes shipped to us that we unknowingly pass on to our customers. This affects our credibility with our customers even though we have no control over the supply.
- Disease/pest issues (although very infrequent).
- Our customers are now able to by-pass us and produce their own plugs and not buy them from us.
- Many of our unique, nonproprietary introductions are becoming commodity items.
- Nonlicensed growers are able to pay a royalty up front and produce plants we were originally exclusively licensed to produce.
- Some proprietary plant licensors are trying to force us to pay the patent up front, resulting in administrative headaches and cash flow issues. The royalties are often double the cost of the actual cuttings, and we buy the bulk of these at the most cash-poor time of the year.

CONCLUSION

- As more plants are shipped off-shore there will a tendency to increase the use of URC.
- Off-shore URC are an economical alternative to holding and managing cutting stock
- The introduction and use of URC is making the marketplace much more competitive for propagation nurseries.

Outside The Box: Breeding of Not-So-Common Woody Landscape Plants at the United States National Arboretum

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INTRODUCTION

The woody ornamental breeding programs at the U.S. National Arboretum were started in the late 1950s and are known for the release of improved selections of such landscape staples as viburnums, crapemyrtles, maples, and elms. However, breeding and selection work is also under way on several less common flowering shrubs (*Cercis*, *Corylopsis*, and *Gaylussacia*) and trees (*Celtis*, ×*Chitalpa*, and *Halesia*). Challenges in breeding these genera can include a scarcity of available germplasm; lack of information on seed germination or propagation; unknown taxonomic and genetic information on species relationships; and marketing challenges for the new plants. However, these plants can also offer new opportunities for growers, landscape architects, and gardeners and can serve to broaden the palette and genetic diversity of cultivated landscape plants.

SHRUBS AND SMALL TREES

The primary objective of the shrub breeding program is to develop new cultivars that are disease and pest resistant, tolerant of environmental stress, can fit into today's smaller landscape, and are not invasive. Creating novel combinations of genes through interspecific hybridizations or using new sources of germplasm can result in plants with unique and valuable traits. While there will always be a demand for fundamental landscape plants such as viburnum, pyracantha, crapemyrtles, and crabapples, the industry and the gardening public are also interested in new or unusual plants that can fit into a specific landscape niche.

Cercis. Although redbuds are becoming increasingly common in the landscape, with several new cultivars emerging recently in the trade, there are few programs devoted to breeding new cultivars. The program at the U.S. National Arboretum is focused on breeding new cultivars that are easy to propagate from cuttings, show field tolerance to *Botryosphaeria* canker, and have superior ornamental traits. Efforts are currently under way to incorporate these traits from several species, including *C. canadensis*, *C. canadensis* var. *mexicana*, *C. chinensis*, *C. glabra*, and *C. racemosa*. Crosses between *C. racemosa* and *C. canadensis* have resulted in plants that show traits intermediate between the parents, and a segregating F2 population is currently under evaluation. Because hand pollinations on redbud can be tedious and time-consuming and redbuds are thought to be largely self-sterile, most of the redbud pollinations are accomplished by enclosing parent plants in a mesh cage or an isolated greenhouse with pollinator bees. In addition to traditional breeding methods, in-vitro studies indicate that some taxa are amenable to regeneration

from leaf pieces, which means that it may be possible to enhance disease resistance by genetic engineering. The breeding collection at the National Arboretum includes over 400 redbud plants, including germplasm, selections, and hybrids.

Corylopsis. The National Arboretum has had small breeding projects in the Hamamelidaceae for almost 2 decades, with a focus on interspecific hybridizations in *Hamamelis* (witchhazel) and *Corylopsis* (winterhazel). While several witchhazel selections are currently under evaluation, recent breeding objectives are to develop new hybrids of *Corylopsis* that are cold hardy to USDA Zone 6, have a compact growth habit, and have large, fragrant flowers. First-generation hybrids between *C. sinensis* and *C. himalayana* are currently under evaluation. These plants will be propagated for replicated field trials and for use as parental material for further crosses. Because of ploidy differences among the taxa, it may be possible to use interspecific hybridizations between certain taxa to generate sterile triploid selections. Species currently under investigation also include *C. glabrescens*, *C. pauciflora*, and *C. spicata*. If successful, this breeding program will result in plants that could lead to the use of *Corylopsis* as an alternative to forsythia in the landscape.

Gaylussacia brachycera. The box huckleberry (*G. brachycera*) is a slow-growing, dwarf evergreen member of the family Ericaceae and can be found growing as isolated colonies in eight states in the eastern U.S.A. Reproduction is primarily through underground runners, as the plants are thought to be self-sterile, so cannot produce seed from isolated clonal populations. What began as part of a cooperative conservation effort has grown into a germplasm collection, evaluation, and breeding project. The *G. brachycera* collection at the U.S. National Arboretum consists of 23 genotypes collected from most of its known native range. In 2006, fruit and seed production from these plants using natural pollinators was prolific due to the presence of diverse genotypes in close pollinating proximity. Studies are underway to determine parameters for optimal seed germination and will be followed by evaluation of the resulting seedlings for traits of interest, including commercial production potential and landscape use as an evergreen groundcover.

URBAN TREES

The continued urbanization of the United States requires countering the loss of genetic diversity of the natural forest with increased diversity of the urban forest. The U.S. National Arboretum has a long tradition of breeding urban-tolerant and pest-tolerant shade trees (e.g., *Platanus* ×*hispanica* 'Columbia' and 'Liberty'; *Ulmus americana* 'New Harmony' and 'Valley Forge'). The arboretum will continue its efforts in breeding large shade trees but has instituted a new program breeding trees specifically for street and utility line applications. Trees in urban environments are subjected to additional stresses beyond that of the general landscape and increasingly are being planted in more restricted spaces. The available palette of urban-tolerant, small trees with compact habit for planting under utility lines is extremely limited. Those species of trees that are of suitable height (e.g., flowering dogwood, *Cornus florida*) are often intolerant of urban edaphic conditions (e.g., soils compacted and anoxic, high soluble salts, fluctuating moisture and temperature), while traditional tree species utilized in urban tree plantings are either too large (e.g., London plane, *P.* ×*hispanica*) or too invasive (e.g., Norway maple, *Acer platanoides*) for modern cityscapes.

Celtis. The genus *Celtis* (hackberry) is composed of approximately 60 species in the north temperate and tropical regions. Several species, including those in North America, are adaptable species that could function as tough, urban-tolerant trees. However, problems with witch's broom, nipple gall, and viruses currently limit their widespread use in the landscape. Studies are currently under way at the arboretum to examine the taxonomy, pollination, and reproductive biology of this genus to determine the feasibility of developing a breeding program.

×Chitalpa. The intergeneric hybrid between *Catalpa* and *Chilopsis* has potential as an urban tree, combining the urban and cold tolerance of *Catalpa* and the drought tolerance, smaller stature, and remontant flowering of *Chilopsis*. Work begun at North Carolina State University by Richard Olsen is continuing at the National Arboretum. The arboretum now holds the largest collection of *Catalpa* in the United States, including taxa with powdery mildew resistance, greater cold hardiness, and unique ornamental foliage and flower traits. New hybridizations are currently underway to breed a new generation of *×Chitalpa* resistant to powdery mildew, leaf spot, and the catalpa sphinx moth larvae; are remontant flowering; and are fruitless (triploid).

Halesia. The silver bells [*Halesia carolina* (syn. *H. tetraptera*) and *H. diptera*] and their relatives, have potential as small- to medium-sized flowering trees for increasing diversity of urban and suburban landscapes. A long-term evaluation of wild-collected *H. carolina* germplasm has revealed variation in plant habit, growth rate, flowering time, and flower size and color. These selections are being propagated for replicated field trials and for use as parents for breeding. Future efforts will focus on collecting diverse germplasm from other *Halesia* species and sister genera, identifying useful traits, and creating hybrids to enhance ornamental traits, including reduced fruit set.

OTHER PLANTS

In addition to breeding and selection programs on these less common woody landscape genera, the National Arboretum continues to work with more popular and well-known ornamental plants, including *Acer* (maple), *Clethra* (summersweet), *Hydrangea*, *Lagerstroemia* (crapemyrtle), *Prunus* (flowering cherry), *Syringa* (lilac), *Tsuga* (hemlock), and *Viburnum*. For information on cultivars from the research program, please visit the National Arboretum's web site <http://www.usna.usda.gov/Research/index.html>.

Heuchera and Its Allies©

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The Saxifragaceae contains 80 genera and 1200 species. These include the popular genera of:

- *Astilbe* — Many flowers and colored leaf forms including a new yellow-foliaged form.
- *Bergenia* — Fleshy leaves, earliest spring bloomers, some repeat like *Bergenia* 'Herbstblüte'.
- *Darmera* — Large-leafed northwest native, hardy in Vermont.
- *Francoa* — Chilean relative of *Heuchera* with full rosettes of foliage and wand-like flowers from pink to blue to white.
- *Heuchera* — Evergreen groundcovers in myriad foliage colors.
- ×*Heucherella* — Bigeneric hybrids of *Heuchera* and *Tiarella.*
- *Mitella*— Quiet woodlander. Asian species have larger leaves and better color and texture.
- *Mukdenia* — Perfect woodland plants that prefer acidic soils. *Mukdenia* prefer cooler evening temperatures although they are grown in hot/humid areas of Japan in an all-mineral mix.
- *Rodgersia* — Large leaves in different shapes (palmate, pinnate) Flowers from buff-white to strong pink. Must have moisture and acidity.
- *Saxifraga* — Woodlanders and montane species that are adapted to limey conditions; many have attractive spikes of flowers.
- *Tellima* — Northwest woodlander tolerant of drought and shade
- *Tiarella* — Native to much of the U.S.A. and Canada. One species is native to Asia.
- *Tolmiea* — The piggyback plant. Shad-tolerant woodlander with adventitious plantlets on their leaves.

Heucheras (coral bells) have risen in the perennial ranks from anonymous border gems to one of the hottest genera obtainable today. From the rather drab green and purple forms of the wild, these plants have exploded a paint pot of foliage colors from ambers to reds to metallic sheens. In 12 years of existence, Terra Nova has grown hundreds of thousands of seedlings of such varied genera as *Heuchera, Tiarella,* ×*Heucherella, Campanula, Pulmonaria, Verbascum,* and *Echinacea.* In total, over 500 new selections have been offered for the first time in wholesale quantities by Terra Nova. In the trial gardens of the Royal Horticultural Society (RHS) and such renowned events as Plantarium in Holland, Terra Nova's plants have gone on to win an impressive 70 international awards of merit. Terra Nova's founder and president, Dan Heims, was honored to receive the prestigious Reginald Cory Cup from the Royal Horticulture Society to recognize the advancement he has brought to the genus *Heuchera.* There is a "breeder's view" of the different *Heuchera* species used and what each has added to the perennial palette available today. *Heuchera* make excellent cut flowers (and cut foliage!). The foamy bells (×*Heucherella*) are the bigeneric hybrids of *Heuchera* and *Tiarella.* Come explore!

Heuchera Species and Their Attributes

- *Heuchera americana* — Tough, shade tolerant, no mildew problems, good variation in coloring, long petioles, tolerance of high heat and humidity combined.
- *Heuchera cylindrica* — Some mildew susceptibility.
- *Heuchera sanguinea* — Much mildew susceptibility, intolerance of high heat and humidity combined.
- *Heuchera micrantha* — Intolerant of high heat and humidity combined, good mildew resistance.
- *Heuchera maxima* — Intolerant of high heat and humidity combined, less hardy than most.
- *Heuchera richardsonii* — Extreme hardiness and scope.
- *Heuchera villosa* — Tolerant of high heat and humidity combined, very late bloomer.
- *Heuchera hallii, H. merriamii, H. rubescens* (montane forms) — Intolerant of high heat and humidity combined, extreme hardiness, early bloom.

From their first introduction, a million-selling variegated *Heuchera sanguinea* named 'Snowstorm'; enough profits allowed the building of a small laboratory and the rental of a windowless basement of a bookstore in the early 1990s. Here Dan teamed up with Ken Brown, a food microbiologist, and became 50/50 partners. From transitional greenhouses in Wilsonville, Oregon, Terra Nova moved to its current headquarters on 15 acres of rich Oregon farmland, near Canby, Oregon in 1995. Here the labs and 5 acres are dedicated to research and development. The rest of the property is covered with production greenhouses, offices, a laboratory, and display gardens. At this time, Terra Nova employs 55 people with 65% of our payroll dedicated to R&D. Once plants are selected by the breeding and sales teams, they are placed into tissue culture. Test tubes of these new plants are sent with extensive documentation and protocols to labs in New Zealand, Germany, Costa Rica, Indonesia, and other countries for continued propagation because the Terra Nova pilot lab is working at full capacity. Plants are brought into the U.S.A. and weaned into soil. These are then shipped around the U.S.A., Canada, and the rest of the world.

Breakthroughs in *Heuchera* breeding occurred on a yearly basis in the mid 1990s. Tiny flowered forms of the common coral bell were supplanted by large-flowered plants with prodigious displays. Cut flower varieties with meter-tall blooms were not unheard of in the trial fields. By using different species, Terra Nova's breeders transformed a generally "quiet" genus to one with the highest demand in today's marketplace. The current craze for container plants and the "strategic partnership" with Proven Winners™ has caused exponential leaps in orders.

Many selections are patented in the U.S.A. and protected under E.U. breeder's rights. Unscrupulous labs around the world are very quick to snap up the unprotected forms and diminish the payback of tremendous time and labor required to produce a new introduction.

The foliage taxa soon followed, but were plagued by tall, inconsequential flowers. Here's where the breeding team stepped in and brought the two worlds of flower and foliage together in many of the newest forms. Further additions like ruffling and a whole new color palette of foliage (including 'Amber Waves' and 'Peach Flambé')

were introduced in the early 2000s. This fusion of color, ruffling, and bloom is where we begin our story of the 'Dancer Series'. This series began as a controlled breeding project to produce dark-foliaged *Heuchera* with good flowers. In 2001, the existing Terra Nova *Heuchera* were evaluated and the 30 best dark-foliaged types, flowering types, and those with a combination of dark foliage and good flowers were put together and hand crosses were made. *Heuchera* seed is very fine, and seed flats can hold a thousand plants. At the three-leaf stage, when plants are barely half an inch across, early selections can be made. We grew out the darkest 200 plants per cross (of 156 crosses) and selected only the darkest seedlings to grow on to 4 inch. These we gave a winter chill and let them flower before selecting for the best. Of these, 100 plants were selected to be used for further breeding.

The Terra Nova Breeding team walks through the greenhouses weekly and evaluates the crops. At the *Heuchera* breeding table, one plant continuously stood out with its compact habit, dark, well-veiled foliage, prolific light pink flowers, and continuous bloom (till frost!). Dan thought it looked like the flowers were dancing over the leaves. The colorful undulating leaves were like a Gypsy's skirt. 'Gypsy Dancer' was selected by the breeding team for introduction to the trade.

'Fandango' and 'Tango' were selected in 2003 from the 60 plants selected from 250 crosses sown. There were many great plants that year with more colorful flowers and outstanding, prolific bloom.

'Fandango' stood out with its tight habit, cut and veiled leaves, numerous medium pink flowers, and its free-flowering nature.

'Tango' glowed with its dark foliage, compact habit, bright fuchsia pink flowers on short stalks, and reblooming habit.

Heuchera perform and bloom best if given 12 weeks of vernalization at below 40 °F. They like to be planted high in their pots, and they prefer mineral rich soils with good drainage. Fertilizer needs are low, with most plants happy with 75 to 100 ppm feeding. Hardiness of most taxa is Zone 4, and a replanting every 2 to 3 years is recommended to keep the clumps vigorous. The most serious pests are strawberry or vine weevils whose "C-shaped," beige larvae consume the fleshy parts below ground.

What's a *Tiarella*? The name is derived from the Greek word "Tiara" — meaning "turban."

It's also called: foam flower, false miterwort (after *Mitella*), sugar scoop (in Pacific North West), and lace flower.

What makes them great?

- Nice evergreen foliage.
- Blooms in the shade (but takes morning sun).
- Many forms to choose from.
- Great fall color.
- Splendid spring (and longer) floral display.
- Deer resistant.
- Excellent ground cover.
- Easy to ship (flexible leaves and flowers).
- Adapt well to garden conditions.

Ranges from Nova Scotia through the Piedmonts all the way to Mississippi. Several species are found from Alaska to the Pacific Northwest to central California and east to Montana. Only one species is known in Asia.

What can go wrong?

- Mildew on some forms (mostly species).
- A favorite of vine or root weevil.
- Do not take well to drying out completely.
- Over fertilization.

Fix it by providing:

- A pH 5.0 to 6.3.
- Well-draining, fertile soil.
- 55% shade.
- Even moisture.
- Fertilizer rate at 75–100 ppm (drop to 50 ppm after flowering)
- Watch for symptoms of *Rhizoctonia* and *Pythium* (Banrot® for control, preplant)

The breeders and their progeny:

- **Sinclair Adam** – Dunvegan Nsy. – The "Pharoah" of foamflowers; 'Oakleaf', 'Brandywine', 'Dunvegan', 'Laird of Skye' '1993, 'Winter Glow' 1993, 'Slick Rock'
- **Don Jacobs –** "Eco Man", 'Running Tapestry', 'Eco Red Heart', 'Eco Rambling Silhouette', 'Eco Eyed Glossy', 'Eco Blotched Velvet', 'Eco-Rambling Tapestry'
- **Charles Oliver** – Primrose Path – The "Godfather", 'Pink Brushes', 'Pink Pearls', 'Butterfly Wings', 'Elizabeth Oliver', 'Arpeggio', 'Running Tiger', 'Tiger Stripe', 'Filigree Lace'
- **Dan Heims** –Terra Nova Nurseries, Inc. 'Black Snowflake' 2001, 'Black Velvet' 1998, 'Candy Striper' 2004, 'Crow Feather' 1998, 'Cygnet' 1998, 'Dark Eyes', 1996 'Dark Star', 'Freckles' 1996, 'Heronswood Mist' 1998, 'Inkblot' 1997, 'Iron Butterfly' 1999, 'Jeepers Creepers' 2000, 'Lacquer Leaf' 1998, 'Mint Chocolate' 1998,'Neon Lights' 2000, 'Ninja' 1998, 'Pink Bouquet' 1998, 'Pink Skyrocket' 01, 'Pinwheel' 1996, 'Pirate's Patch' 2004, 'Sea Foam' 2001, 'Skeleton Key' 1995, 'Snowflake' 1996, 'Spanish Cross' 1997, 'Spring Symphony' 1997, 'Starfish' 2000, 'Sugar and Spice' 2004, 'Stargazer Mercury' 2004, 'Stargazer Venus' 2004

As a whole, the Saxifragaceae has given the horticultural community a wealth of genera and species and promises even more excitement as new selections are introduced.

Using Traditional and Biotechnological Breeding for New Plant Development©

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INTRODUCTION

The constant search for new forms and colors of plants for the horticultural industry is making the development of new cultivars a permanent endeavor. There exists a tremendous potential to introduce noncultivated species from nature and to breed new ornamentals from these native species (Bridgen, 2001). There are several native Chilean geophytes that have potential as commercial and ornamental plants. Species such as *Leucocoryne, Conanthera, Rhodophiala, Alstroemeria,* and *Zephyra* could be bred and used as cut flower crops, potted plant crops, and garden flowers.

The Chilean territory is an "ecological island" with geographical barriers that have isolated the biological communities from the rest of the continent and produced a high percentage of endemism. The Atacama Desert to the north, the Pacific Ocean to the west and south, and the Andes Mountains to the east have made Chile one of the world's few biodiversity hotspots. Continental Chile is home to some 5,100 species, of which about 2,630 are endemic (Marticorena and Rodriguez, 1995). Such a proportion of endemism is one of the highest found in any region on Earth.

Traditional breeding is still the most important source for releasing new cultivars to the market. However, there are several in vitro techniques that can be used to make traditional breeding quicker and more successful.

IN VITRO BREEDING TECHNIQUES

Plant tissue culture is the art and science of aseptically growing plant cells, tissues, organs, and plants on a nutrient medium under controlled environmental conditions. Biotechnological techniques such as embryo culture, somaclonal variation, in vitro mutation techniques, and micropropagation are incorporated into breeding programs to circumvent incompatibilities and to elicit novel changes.

Embryo Culture. Embryo culture is the sterile isolation and growth of an immature or mature zygotic embryo under aseptic conditions on a nutrient medium with the goal of obtaining a viable plant. It is most often used to rescue embryos from interspecific and intergeneric crosses that do not fully develop naturally or where the embryo aborts. This method can also be used to rescue seedless triploid embryos, produce haploids, or overcome seed dormancy. The embryo culture technique depends upon the isolation of the embryo without injury, formulation of a suitable nutrient medium, and the induction of continued embryogenic growth and seedling formation. The basic premise for this technique is that the integrity of the hybrid genome is retained in a stalled or abortive embryo and that its potential to resume normal growth may be realized if it is supplied with nutrient substances in vitro.

Plant embryos are located in the sterile environment of the ovule, and thus surface sterilization of embryos is not necessary. Instead, entire ovules or ovaries are surface sterilized, and subsequently embryos are removed aseptically from the sur-

rounding tissues. The procedure makes it relatively easy to obtain pathogen-free embryos because harsh surface disinfection procedures can be used to the ovaries or ovules.

Large embryos are not very difficult to excise. However, small embryos are easily damaged and require the use of microdissecting tools and a dissecting microscope to excise them without injury. It is important that the excised embryo does not become desiccated during dissection. Embryos from the Chilean geophytes that we are breeding are removed aseptically at different time periods (7, 10, 14 days) post-fertilization. They are then usually cultured on a Murashige and Skoog medium with dilute (50%) nutrient concentrations (Murashige and Skoog, 1962). These geophyte cultures are often placed in dark conditions and cultured under a cool temperature (18 °C).

Somaclonal Variation and In Vitro Mutation. Somaclonal variation is genetic alteration generated by the use of a tissue culture cycle and is a tool that is used for crop improvement. Somaclonal variation can be a heritable variation that is sexually transmitted to the progeny. Some in vitro techniques such as adventitious shoot formation, callus culture, cell suspension culture, and protoplast culture increase the chance that genetic mutations may occur. Somaclonal variation can result from two sources. It can arise from preexisting genetic variation that is expressed in regenerated plants and it can be induced by the culture process (Lu and Bridgen, 1997).

Genotype is an important variable to consider when trying to induce somaclonal variation and can influence the frequency of regeneration. With the large germplasm source that is available from Chile, several genotypes have been tested for their ability to mutate in vitro. Different explant sources from *Leucocoryne, Conanthera, Rhodophiala, Alstroemeria,* and *Zephyra* have been tested because genotype is a critical variable for success. Meristems and other organized growing points produce fewer mutations than unorganized growing points. Indirect organogenesis (via callus), somatic embryos, and shoots via direct organogenesis have been compared for their ability to produce mutations. Long-term cultures have been shown to induce more mutations than short-term cultures.

It is known that the growth regulator composition of the medium can influence the frequency of somaclonal variation. Different auxins and cytokinins can be used at high concentrations to induce mutations. Some herbicides and chemicals such as colchicines can also be used to mutate plants in vitro. Gross chromosomal changes such as polyploidy and aneuploidy can be induced. If tetraploids form, they can be crossed with the normal diploids to produce sterile triploids.

Micropropagation. Micropropagation is the aseptic propagation of plants in vitro. This is a clonal technique that is often used once a new plant is developed because the procedure can hasten the introduction of new plants. When new plants are developed by using the previous protocols, the following five stages of micropropagation are used for each of the new plants.

Stage 0 involves the preparation of the stock or mother plant from which the primary explant is to be excised. Careful selection is made at this stage to be certain that these plants are disease-free and healthy. The time of year in which the explant is removed from the mother plant may affect the results of the micropropagation program. Changes in temperature, water availability, light intensity, and photoperiod will affect the levels of carbohydrates, proteins, and phytohormones in the stock

plant and may affect the response of the explant in vitro. Best results in vitro are generally achieved when the explant is taken during the active phase of growth.

Stage I is the establishment phase in which the explant is disinfected and cultured aseptically on a nutrient medium. The main objective of Stage I is to obtain explants free from surface pathogens such as bacteria and fungi. The selection of a suitable explant source is essential at this stage. Almost any plant tissue or organ can be used, but the degree of success will depend upon the species, the removal of surface contaminants from the explant, and the culture system that is used. Disinfecting the surface of an explant generally involves washing the tissue, followed by sterilization with one or more disinfectants. Washing the explant under running tap water greatly reduces the amount of contamination. Washing the explant with soapy water before placing it under running tap water may further reduce the number of pathogens present on the explant or make them more accessible to sterilants. After washing, the explant is immersed in an antiseptic solution to kill contaminants present on the surface. A 0.5%–5.25% solution of sodium hypochlorite is the most commonly used sterilant with plant tissue cultures. Ethanol, calcium hypochlorite, and hydrogen peroxide are other common disinfectants. Various sterilants may be used alone, in sequence or in combination to obtain the most effective sterilization procedure. The explant must then be rinsed one to several times in sterile distilled water to remove any remaining traces of the disinfectant. Damaged tissues of the explant are then removed and the explant is subdivided into appropriate sizes for culture. The explant is then placed on a nutrient medium designed for maximum growth of that particular species. If contaminants are present after disinfection, they will become apparent within 3 to 5 days after culturing.

Stage II is the multiplication phase and is used to rapidly increase the number of propagules. The clean plant material from Stage I is repeatedly subcultured in Stage II until the desired number of propagules are obtained. Propagules may be from terminal buds, axillary branching, or from adventitious bud formation. As the new shoots develop, they in turn produce buds along their axis. Through repeated subculture, this process can be repeated indefinitely. Cytokinin concentrations of 1–20 $mg \cdot L^{-1}$ are used to enhance axillary bud proliferation. Optimum concentrations are determined for each species. Adventitious shoots originate in tissues located in areas other than leaf axils or shoot tips. Adventitious shoots, roots, bulblets, and other specialized structures may originate from stems, leaves, tubers, corms, bulbs or rhizomes. The number of propagules is increased by subdividing and reculturing the in vitro-derived organs.

Stage III is the rooting stage. In vitro-derived plants may be induced during this phase to produce roots in vitro or in vivo. If rooting occurs in vivo, Stage IV, the acclimation phase, is combined with Stage III. In the past, the majority of all shoots were rooted in vitro. Although this procedure is still used, it is quicker and more economical to combine rooting and in vivo acclimation. In some species, in vitro rooting techniques are the only practical methods of rooting plantlets. A separate root-inducing medium is used during Stage III because the presence of cytokinins in Stage II inhibits root formation. Other factors that may influence rooting include other growth regulators, support substances, nutrients, organic substances, light, and temperature. With some species, all that is required to induce rooting is to transfer shoots to a cytokinin-free medium. However, in many species, the initia-

tion of roots occurs only in the presence of auxin. The response of shoots to auxins is dependent upon the species, the type of auxin, and the concentration of auxin.

Stage IV is the acclimation or "hardening-off" phase. This is the process by which the tissue cultured plant adapts to the new environment. Acclimation is necessary for in vitro-derived plants because they are produced under very high relative humidity, very low air movements, optimum nutrition, and ideal light and temperature conditions. A suitable environment can be created by placing plantlets in a clear plastic bag or box or under intermittent water mist/fogging. Plants are acclimated by gradually reducing the relative humidity in their surroundings. The application of antitranspirants and the treatment with fungicides are often beneficial and may increase the survival of plants outside of the culture vessel.

The diverse and colorful genera of Chilean geophytes create a tremendous potential for the breeding of new hybrids. Our breeding work since 1985 has demonstrated that interspecific hybridization of these plants can be successful. In 2007, the winter-hardy *Alstroemeria* cultivar, 'Mauve Majesty' is being released.

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The New Faces of Hellebores©

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INTRODUCTION

Hellebores have proven to be one of the ultimate perennials for shade: long lived, long blooming, evergreen, and virtually disease free. It is certainly no wonder they were selected "The 2005 Perennial Plant Association plant of the year."

Still, improvements in this genus are occurring at a rapid pace. Colors have been much improved on in the past decades. New colors, richer color saturations, and superior flower forms are the hallmarks of the new generation of hellebores. Recent improved leaf color … and shapes only hint at future possibilities.

SEED PROPAGATION

Parent Plants. Good seedlings begin with strong parent plants. The genetic heritage of a superior clone is passed on through controlled crosses and rigorous editing of stock beds. Careful monitoring of the percentage of successes in breeding ensures flower quality.

The "mother" plant has historically been selected for shape, the pollen parent for color. Pollen is placed on the stigma of the "mother" before the anthers on that flower start dehiscing. This avoids self pollination and, when done at the proper time, can avoid the necessity of emasculating the flower.

Seed Collection. Constant vigilance is the name of the game as you watch seed pods ripen. Seed dispersal happens rapidly (ants will carry seed away). Many a good cross has been lost due to failure to collect seed at the proper time.

I usually collect my seed over a 2-week period. I then allow them to dry in paper bags before cleaning. A note of caution: prolonged handling of seed pods when cleaning and extended exposure to leaf scratches on hand and arms while collecting may cause dermatological reactions.

Seed Sowing. Seed is best sown fresh. Old seed does not germinate well or even at all in some cases though cold storage helps extend viability. Seeds should be sown in flats and barely covered with compost or Turface. Cold stratification is also necessary for germination. This usually takes place naturally out of doors in late winter/early spring. For faster germination keep seed warm for 6 weeks then place in a cooler for 4 to 6 weeks. It is now possible to seed in June, transplant in January, and have shippable plugs in May. Seedlings are pricked out after a second set of leaves appears directly into a 3-inch pot or a 50-unit-cell seed tray. It is important to note that hellebores put on their growth in the cooler seasons — spring and fall.

Hybrid vigor, heterosis, is vital. Plants that are selfed too frequently are unhealthy and rapidly decline. Growth of seedlings can be further enhanced by constant fertilization at 100 to 150 ppm. Potting soil is a peat, coir, perlite, and bark finds (12 : 3 : 2 : 3, by volume) mixture. For optimal growth, soils are best adjusted to a pH of 5.5. Root rot can be inhibited by application of root shield $1^{1}/_{4}$ lbs/yd^{3}.

In the garden, in my acidic Pennsylvania soils, hellebores can be left undisturbed for years and years. However, for finishing off plants for retail, adjusting potting soil pH and a comprehensive feeding program is necessary. Deeper pots are preferred; hellebores tend to resent cramped roots. Checking of growth can be expected if grown too long in shallow containers.

ASEXUAL PROPAGATION

Asexual propagation is necessary when attempting to reproduce a particular clone. This is vital for maintaining superior forms. Asexual propagation is achieved by divisions, or more recently, progress has been made with tissue culture. With this latter process transitioning the plants from lab to garden soil is still a challenge.

Color seed strains may provide a similar product to asexually reproduced clones for the gardener. It is my opinion that a high percentage rate of true-to-color type should be documented (80%–90% true) before release of a color strain.

Division. Divisions are best made in late summer. Ensure that there are old and new roots on each division and at least two sets of leaves. This will keep the plant better balanced and avoid the pulling out of young roots. I usually place divisions in containers and watch watering for at least 8 weeks before placing in the open garden.

Tissue Culture. Tissue culture breakthroughs are beginning to happen. This is especially true with straight species of the caulescent group and their crosses. *Helleborus* ×*nigercors* seems to have the highest success rate, with cultivars 'Valentine Green', 'Ivory Prince', and 'Pink Beauty' to name a few. *Helleborus niger* also seems to be responding well. As a "pure," uncomplicated species — and one of the parents of *H.* ×*nigercors* — the protocol is more easily established with these plants. *Helleborus* ×*hybridus* is the complex hybrid of many species, thus presenting a greater challenge. Success in reproducing a variety of superior selections — each with a differing genetic heritage — remains a goal to be achieved. To date the replication turnover for *H.* ×*hybridus* during Stage 2 — a 12-week period — is an average of 1–1.3 or 1–1.8 plants. Stages 3–4, when the plants are introduced to soil are also problematic, which is why *H.* ×*hybridus* are so expensive at sale. And just because a selection *does* respond does not necessarily mean it is worthy of reproduction. We should always be rigorous in our selection of the best possible forms. This is not pessimism, but quite the opposite — there are many opportunities for us in the future. And the future remains bright indeed for this beloved genus.

Large-Scale Propagation and Production of Native Woodland Perennials©

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Native woodland perennials are a source of frustration for propagators, because issues concerning seed viability, extended germination times, and slow and seasonal growth of seedlings discourage large-scale propagation and production. However, with proper seed handling and pretreatments as well as a "liner" approach to production, I believe that large-scale production is possible and profitable.

INTRODUCTION

The demand for native plants grows greater every year. Access to improved cultivars, increasing sophistication on the part of the gardening public, and increased interest from government and the commercial sector have all contributed to this phenomenon. Many species can be easily and quickly produced from cuttings or seed (i.e., Asteraceae, Scrophulariaceae, etc.), but others — especially the woodland wildflowers commonly known as spring ephemerals — have proved especially difficult to accommodate in large-scale perennial production. Genera such as *Trillium, Cypripedium, Polygonatum*, and *Hepatica*, while outstanding garden subjects that command premium prices, have developed a reputation for recalcitrance that is only partly deserved. Woodland wildflowers and bulbs are still supplied primarily as bare root, wild-collected stock. Thankfully, this questionable practice is now looked down upon by most of the perennial industry and consumers alike. Although collected plants are extremely cheap, we have found through experience that consumers will pay premium prices for genuinely nursery-raised material if it is available as an alternative. Besides being environmentally and ethically sound, nursery propagation also helps ensure a more consistently labeled and sized, well-established product.

WILDFLOWER PROPAGATION

Overview. Because they cannot be rooted from stem cuttings, many woodland species have traditionally been multiplied by division of rhizome, tubers, corms, or bulbs. This is a very labor- and space-intensive method, often prohibitively so. Furthermore, as in all types of nonsterile, asexual production, systemic diseases, especially debilitating viruses and bacterial infections, can be passed on from plant to plant. Other pests, such as nematodes, can also be a problem. I believe that seed propagation is a viable and cost-effective alternative for many of these woodland species. Seedlings are usually free of systemic diseases and pests, and allow us to take advantage of genetic variability to select individuals for vigor, color, disease resistance, etc. But to be successful, it is important to have some understanding of their physiology and development.

Hydrophilic and Hypogeal Seed. Many of the spring ephemerals have a reputation for being difficult to grow from seed. Much of this reputation stems from a lack of understanding that usually leads to germination failures or poor growth. The biggest problem is that the seed dies quickly under conventional dry storage. The list of plants with what has been termed ephemeral seeds (meaning short-lived or transitory) includes most of the stars of our spring wildflower displays. Included are: *Asarum* sp., *Hepatica*, *Sanguinaria*, *Trillium* sp., *Phlox divaricata*, *Iris cristata*, *Chrysogonum virginianum*, *Stylophorum diphyllum*, *Jeffersonia*, *Claytonia* sp., *Podophyllum peltatum*, *Shortia*, *Uvularia*, and *Dicentra* sp. (see Table 1 for a more complete list).

The term ephemeral is not entirely accurate, however, and I think leads to misconceptions about handling the seeds correctly. Many of these species have seeds that are very long-lived if stored under moist conditions (trilliums for example can remain viable in the soil for at least 3–4 years). I think a more accurate term is "hydrophilic," meaning needing or requiring the presence of water. In general, hydrophilic seeds are associated with stable temperate forest communities, and especially with species whose seeds ripen in the spring and early summer.

Immature Embryos and *Hepatica*. Many of the woodland wildflowers produce seed with embryos that are immature at the time of senescence. These are indicated in Table 1 as Type D and some Type C. If seed is sown immediately when ripe, many will germinate the following year. *Hepatica* species (also classified as *Anemone*) are Type D germinators. Seed ripens 4–6 weeks after pollination, and the clusters of seeds are green when ripe. They typically fall from the plant and are taken away by ants. We collect the seeds in mid spring when they fall from the peduncle with slight pressure. The seed is sown immediately and kept outdoors in the shade (Remay cover) through the summer (average temperature range 55–85 °F) and overwintered in an unheated greenhouse under winter blankets (temperature 25–35 °F). Seedlings emerge early the following spring. In the wild, only the cotyledons or sometimes these plus one small true leaf will be produced the first year. However, if we germinate them in the greenhouse in March, by June they have produced 2 or 3 true leaves and can be transplanted into individual 2½-inch pots (Landmark Plastics). They are kept in the covered greenhouse under ambient temperatures and fertilized weekly with Peters Pear Lite Special (150 ppm N). By fall, the seedlings have filled the liner pots. These are stepped up into 1 qt pots (Kordloc) using a variation of Fafard #52 growing mix [pine bark, perlite, and peat moss (12 : 5 : 3, by volume)] with incorporated Nutricoat 100-day fertilizer. The plants are ready for sale the following spring with a 2-year production time once seed has emerged. The main disease of *Hepatica* and many Ranunculaceae is ascochyta leaf blight (*Ascochyta actaeae* or related species). It produces lesions on the petioles and leaf, causing premature leaf drop and weakening or killing the plants. The disease is most prevalent in cool, wet weather, but can be a serious problem under irrigation in the nursery. Good sanitation, protection from rain, and good watering control plus a weekly application of Millstop fungicide has controlled the disease.

***Trillium*.** *Trillium* species are one of the most cherished and most challenging woodland wildflowers to produce commercially. In the wild, it is estimated that seedlings take 7–10 years to reach maturity, and 5–6 years is the standard in

Table 1. Representative species with hydrophyllic seed (intolerant of dry storage).

Dry storage will kill seed or greatly delay germination. Ideally, cleaned seed should be sown as soon as ripe in an outdoors cold frame. Alternatively, seed can be stored in a self-sealing plastic bag for 6–12 months at 40 °F, but this will not always substitute for outdoor stratification. I recommend including some damp (not wet) vermiculite in the bag for those species followed by an asterisk(*).

Germination patterns:

A — seed germinates upon sowing at 70 °F.

B — seed germinates after 90-day moist stratification at 40 °F.

C — seed has a double dormancy (immature embryo, impermeable seed coat, or a combination) or is hypogeal, showing above ground the second spring.

D — immature embryo – seed requires 90 days moist stratification at 70 °F followed by 90 days at 40 °F.

H — seed requires light to germinate.

Achlys triphylla (vanilla leaf) B*

Aconitum sp. (wild monkshood) B

Actaea sp. (doll's eyes, baneberry) B or C*

Anemone quinquefolia (windflower) B

Anemonella thalictroides (rue anemone) D

Asarum sp. (wild ginger) D**

Athyrium (syn. *Diplazium*) *pycnocarpon* (glade fern) A, H

Caltha palustris (marsh marigold) B*

Cardamine (syn. *Dentaria*) sp. (toothwort) D

Carex plantaginea (plaintain sedge) B

Carex platyphylla (silver sedge) B

Caulophyllum thalictroides (blue cohosh) C*

Claytonia virginica, *C. caroliniana* (spring beauty) D*

Clintonia sp. (wood lily) C*

Clematis sp. (clematis) C* (or long A*)

Coptis sp. (goldthread) B or C

Corydalis sp. (corydalis) D

Dicentra canadensis (squirrel corn) B*

Dicentra cucullaria (Dutchman's breeches) B*

Dicentra eximia (wild bleeding heart) B*

Dicentra formosa subsp. *oregana* (western bleeding heart) B*

Diphylleia cymosa (umbrella leaf) B

Disporum sp. (fairy bells, Mandarin) C*

Erythronium americanum (trout lily) C*

Galax urceolata (galax) A, H,

Hepatica sp. (hepatica) D*

Hydrastis canadensis (goldenseal) B*

Hydrophyllum sp. (waterleaf) B*

Iris cristata (dwarf crested iris) B or C*

Iris verna (dwarf iris) B*

Jeffersonia diphylla (twinleaf) D*

Lysichiton americanus (western skunk cabbage) A*

Maianthemum (syn. *Smilacina*) sp. (false Solomon's seal) C*

Maianthemum canadense (Canada mayflower C*

Medeola virginiana (Indian cucumber) C*

Mertensia virginica (Virginia bluebells) B*

Orontium aquaticum (golden club) A*

Osmunda sp. (osmunda ferns) A, H

Pachysandra procumbens (Allegheny spurge) B

Panax quinquefolius (American ginseng) B or C*

Podophyllum peltatum (mayapple) B*

Polygonatum sp. (Solomon's seal) C*

Pyxidanthera barbulata (pixie moss) A, H

Sanguinaria canadensis (bloodroot) D*

Scirpus sp. (rush) B, H

Shortia galacifolia (Oconee bells) A, H

Stylophorum diphyllum (celandine poppy) B*

Symplocarpus foetidus (skunk cabbage) B*

Trillium sp. (trillium) C*

Trollius laxus (spreading globeflower) B

Uvularia sp. (large-flowered bellwort) C*

Viola sp. (violet) B

Xerophyllum asphodeloides (turkeybeard) B

cultivation. We grow *Trillium grandiflorum, erectum, sulcatum, simile, flexipes, cuneatum,* and *luteum* from seed and have been working to speed up the process as much as possible. The seed ripens in mid summer, 10–12 weeks after pollination. Each capsule contains 15–30 seeds. The embryo within a mature seed is somewhat immature and dormant as a result of desiccation at the time of seed-coat maturation. If fresh seed is sown immediately, it will germinate after the first winter, producing a root and rhizome the first summer and a cotyledon the second summer. However if seed is collected before the seed coat matures ("green"), which is typically 2–3 weeks early, and kept in controlled, moist, warm conditions for 4–8 weeks, many seeds will produce the root and rhizome that season, which cuts a year off the production time (Solt, 2002). I call this a "long summer" treatment, and it has worked to overcome embryo dormancy on other species such as *Clematis*, *Actaea*, and *Caulophyllum*.

Trilliums are very temperature sensitive and possibly also daylength sensitive. Air temperatures above 85 °F will trigger dormancy. We have had promising results when we give trillium seedlings "long springs," placing the seed flats in a cool greenhouse that is run 5–15 °F above outdoor temperature in spring. The seedlings emerge a month earlier than they would outdoors, and so have extra growing time during the cool, short-day months. *Trillium* seedlings are very succeptable to lily grey mold, *Botrytis elliptica.* Affected seedlings develop watery then necrotic blotches and spots and usually the whole leaf is quickly affected. Fungicides labeled for *B. elliptica* are effective controls. We use a weekly application of Millstop from April through June as a prophylactic. Trillium seedlings grown with a combination of long summers and long springs with good botrytis control can reach saleable size (1 year from flowering) in 4 years, which is still a long production time, but I think it does make specialist production more feasible.

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Grafting: A Review of Basics as Well as Special Problems Associated With Conifer Grafting©

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INTRODUCTION

The role of grafting in contemporary plant propagation has declined with advancements in conventional cutting propagation and subsequent micropropagation. However, grafting is sometimes still the method of choice when dealing with certain rare and unusual woody plants and is therefore currently employed by a handful of specialty nurseries and a few larger firms that still market specialty crops.

The purposes of this brief paper are twofold: (1) To enumerate the advantages and liabilities of grafting with the implicit question: Is grafting a viable method for a given nursery to adopt and use in its production? (2) To describe the basic steps in grafting while examining a few unique requirements of grafting evergreen conifers relative to deciduous plants.

REVIEW — DIFFERENCES BETWEEN GRAFTING CONIFERS AND DECIDUOUS PLANTS

- Timing is critical when grafting conifers versus deciduous plants. Temperatures should be cool to avoid premature shoot flushes on the scions, and late December through February is best.
- Humidity is essential, and conifers require closed frames and high humidity.
- Understock must be in active growth before grafting, and rootstock must be warmed up 2–3 weeks before grafting ensues.
- Conifers require a side-veneer or modified-side-veneer graft.
- Fungal contamination is always a major concern and must be closely monitored. Sanitation is therefore critical, and removal of yellowing or blackened needles is essential. Routine applications of broad spectrum-fungicides or sterilants will be necessary.
- Acclimation to outside conditions is far more problematical than with deciduous grafts.

ADVANTAGES OF GRAFTING

1) Grafting may be the only method to efficiently propagate a given species or variety. This is very much the case with the majority of dwarf conifers, which cannot be successfully cloned by means of cutting propagation. Selections of Japanese maple (*Acer palmatum*), arboreal dogwoods (*Cornus*), European beech (*Fagus sylvatica*), hybrid witch-hazels (*Hamamelis*), and oak cultivars (*Quercus*) are additional examples of woody plants that are still largely grafted.

2) Grafting is often the most reliable way to rescue plants that are in advanced stages of decline or those that exhibit anomalous growths such as witches' brooms. Witches' brooms usually possess thickened and compressed stem tissue. By the same token, trees or shrubs in advanced maturity offer the propagator little in the way of good cutting material. Once grafted and placed under an improved cultural regime, it's possible to effect their rejuvenation so they can be more easily multiplied through cuttings.
3) Grafting may produce a larger plant in a given period of time. Grafters often describe the "jump start" effect that the rootstock's vigor and energy supply to the scion. Cultivars of Nootka falsecypress [*Callitropsis* (syns. *Chamaecyparis* and *Xanthocyparis*) *nootkatensis*] represent one such example because they can be propagated through cuttings or by grafts. Grafted plants, however, are known to reach saleable size 2–3 times faster than those on their own roots.
4) Grafting may employ a selected rootstock which, when compared to growing a given taxon on its own root system, represents improved tolerance of heat and drought, resistance to disease, and a more fibrous root system allowing for improved anchorage, transplanting, and reestablishment.
5) Grafting employs rootstocks that are historically valued for their dwarfing effects on plants. It is likely that this dwarfing may be related to incompatibility between stock and scion.

LIABILITIES OF GRAFTING

1) Grafting is by far the most labor-intensive form of clonal propagation. Aside from the actual process of joining plants together, the grafting process requires considerable time in rootstock preparation as they must be carefully potted, trimmed of unwanted needles and stems, and weeded. Then, too, scions must be cleaned prior to grafting, taking great care to avoid wounding cambial tissue. When grafting conifers, the labor involved in the aftercare is significant; constant monitoring for disease, gradual trimming back of the understock, and the loosening of grafting rubbers all are time-consuming activities.
2) Grafting is a costly process requiring the purchase of rootstock, coolers, or refrigerators for the storage of scions, heated greenhouses, and the essential tools of grafting such as grafting knives, rubber ties, and wax.
3) Success in grafting is inherently unpredictable, and the percentage of "takes" can vary widely from year to year and is often weather dependent. Scions from parent plants that are weakened or stressed due to drought or cold temperature injury will limit success as will the exposure of rootstock to an adverse environment.
4) The relationship between stock and scion may yield undesirable growth responses and unsightly graft unions; this relates to the concept of latent incompatibility.

GRAFTING: A REVIEW OF THE BASICS AND THE SPECIAL REQUIREMENTS OF CONIFERS

All successful grafting can be broken down into three major factors: (1) The condition of the rootstock, (2) proper grafting technique, and (3) the aftercare process. Of these three factors, the condition of the rootstock is, by far, the greatest determinant in the success or failure of grafts. The aftercare of grafts is also exceedingly important especially as it concerns traditional winter-grafting (bench grafting) procedures, and this includes needle-bearing evergreens. Nontraditional strategies, such as the current use of hot-callus-tube systems whereby heat is applied directly to the graft union to promote faster callusing and healing, simplify aftercare considerably. Under this protocol, grafts can be performed anytime on dormant stock, and once healing has commenced (20–25 days), grafts are removed from the greenhouse and placed in minimally heated cold frames, thus avoiding the trickiness of acclimating them to outside conditions. However, many grafters complain that hot-callus-tube systems promote too much warmth and too little humidity to efficiently graft evergreen conifers, and most conifers are still grafted traditionally onto actively growing rootstocks (as indicated by the presence of white root tips). Consequently, conifer grafts are best left in the greenhouse until the danger of hard freezing is over.

Rootstocks. Rootstocks must be potted and well rooted, of vigorous growth, and appropriately sized. Most grafters buy or grow their rootstock several months ahead of the grafting season to ensure they are properly "seasoned." Grafters generally acquire more rootstocks than they intend to use so they may best select a rootstock whose diameter most closely matches the diameter of the scion, which varies considerably between cultivars.

The choice of the rootstock is likewise critical, and in general, the rootstock and scions must share a strong botanical affinity. Exceptions are noted in the rose family (*Rosaceae*) and the olive family (*Oleaceae*) where grafting between genera is possible. But trial and error as well as cost and availability often determine the selection of rootstock when more than one species is possible. In a few cases, the rootstock selection may relate to climate and soil types of the area. A good example is the use of Momi fir (*Abies firma*), a species noted for tolerance to heat and heavy soils, as the rootstock of choice for southern areas.

Grafting Technique. The following materials should be acquired before grafting.

- A good-quality, grafting knife of German or Swiss make, composed of soft steel that can be sharpened to a fine edge. Razor blades or box cutters work well for tiny, thin scions. Never use a grafting knife for any other purpose than grafting!
- A honing stone for sharpening — an Arkansas oilstone or ceramic stones work well.
- Grafting rubbers — lighter grades for small scions and heavier grades for larger wood.
- Sealants such as sheet parafilm to wrap graft unions or paraffin (candle wax) heated to a liquid state and brushed on the unions. Note: melted wax should be cooled to 140 °F before applying.

While a range of grafting techniques can be employed on deciduous plants, evergreen conifers are exclusively grafted using a side-veneer or modified-side-veneer

graft. This is necessary because conifer grafts are generally much slower to heal and flush growth than deciduous grafts, and retaining the shoot portion of the rootstock functions to provide nutrients and photosynthates to young growing scions. Therefore the rootstock nurses the scions through the healing process and during its acclimation to outside conditions.

The reader may consult the literature for illustrations depicting this technique but, for new grafters, the best way is to gather copious amounts of practice wood and sit down with an experienced grafter until one acquires a "feel" for the knife and cuts can be made with a one-stroke motion. First-time grafters tend to whittle or turn the knife while cutting, causing uneven cuts or bevels that prevent a close knit between the scion and stock.

Scions should be collected no sooner than 10–14 days before grafting. Scions should match as closely as possible the diameter of the rootstock and, with few exceptions, the goal is to graft as close to the crown (root-shoot interface) of the rootstock as possible while matching the cambial layers on both sides. If the rootstock is thin or light, scions composed of 1-year wood may work best; larger scions of 2-year-old wood can be used on thicker stock. Ideally, the temperature should be above freezing when collecting scions since the wood may be brittle and crack at lower temperatures. Scions collected at below-freezing temperatures should be warmed up gradually in cold water before grafting.

There are excellent propagation manuals that summarize the most efficacious rootstock and scion combinations. For conifers, grafters have historically used the following combinations:

- Eastern white pine (*Pinus strobus*) for all five-needled and some three-needled pines.
- Scotch pine (*P. sylvestris*) for all two-needled and some three-needled pines.
- Norway spruce (*Picea abies*) for all spruces.
- White fir (*Abies concolor*), Fraser fir (*A. fraseri*), or Cannan fir (*A. balsamea* var. *phanerolepis*), Veitch fir (*A. veitchii*) popular in Europe, and Momi fir for southern regions for all firs.
- For other genera, grafting scions onto species rootstock generally works out well.

Aftercare. The acclimation of grafts from a greenhouse environment to outdoor conditions, where temperatures fluctuate widely and humidity levels are lower, is most often the greatest single source of failure in grafting. This is especially true of conifer grafts where the soft flushes of new growth are prone to desiccation and dieback. Consider the following steps as a useful guideline in the aftercare of conifer grafts:

January Through February.

- Fresh grafts require a high degree of humidity, and conifer grafts are traditionally held in a plastic-covered grafting case or frame and plunged into a moistened medium consisting of perlite or a combination of perlite and peat moss deep enough to cover the graft union.

- Grafts should be periodically misted lightly to maintain high humidity and to cool scions during sunny days. Misting grafts every 7–10 days is usually sufficient in early winter but misting more frequently will be necessary as greenhouse temperatures rise in late winter and early spring.
- Monitoring fungal disease is critical, and broad spectrum fungicides or sterilants should be applied every 10–14 days.

March Through May.

- Check periodically to ensure that rootstocks are well watered.
- On easy-to-graft species, such as five-needled pines, callusing and healing will occur within 2–3 weeks. By the end of the winter, it is advisable to check grafting rubbers and loosen them to allow for cambial expansion. Grafting rubbers should remain on, however, until the following fall.
- Rootstock should be lightly headed back to remove succulent shoots, which are most prone to fungal infection; otherwise, rootstock should remain intact to nurse young scions.
- Closely monitor for fungal infection [gray mold (*Botrytis*)], paying special attention to young candle growth on scions.
- Remove plastic coverings in the morning hours to gradually acclimate grafts to lower humidity and higher temperatures.
- Discard dead or dying grafts. Separate strongly growing, well-flushed grafts from weaker, nonflushed grafts.
- When removing grafts from cases, shade them under benches, shade cloth, or moistened burlap before setting them outside.
- Place grafts outside under shade cloth or lath.

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Efficiency Tools for Field Growers©

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THE HEALTHY FARMERS, HEALTHY PROFITS PROJECT

INTRODUCTION

The Healthy Farmers, Healthy Profits Project is being funded by the Centers for Disease Control and Prevention's National Institute of Occupational Safety and Health to find and share work efficiency tools that maintain health and safety and increase profits for nursery growers in the upper Midwest (NIOSH award No.U01OHO8100).

Nursery work is associated with relatively high rates of musculoskeletal problems (i.e., 400 per 10,000 for California nursery workers) (Faucett et al., 2001; Hildebrandt, 1995). The two types of injury risk that we are concerned about are cumulative injury and traumatic injury. Cumulative injury refers to pain that builds up over time. This is often musculoskeletal pain such as back pain, knee pain, and repetitive stress on hands, wrists, and joints. Traumatic injury refers to pain caused from a particular event such as crushed fingers from improper hitching or internal injuries from a worker being pinned between tractor and wagon.

Three tools in particular offer potential improvements over commonly used methods in plant propagation: field stools, pot filling machines, and container stabilization methods. The Healthy Farmers, Healthy Profits Project <http://bse.wisc.edu/hfhp> has "work efficiency tip sheets" with detailed information and lists of suppliers for each of these tools as well as five additional tools (tarp draping systems, electronic pruners, a one-person hitch, a long-handled diamond hoe, and a tree guard zipper). All of these tools help nursery managers increase profits and reduce health risks to nursery workers.

FIELD STOOL

The field stool is a one legged stool that straps to the worker's waist, providing a hands-free seat for tending to plants. The height of the stool is adjustable as are the waist belt straps. The lightweight stool features a steel leg, a plastic seat, and nylon webbing straps. The leg ends in a wide spring-type foot. Workers who normally stoop or kneel to weed containers or collect seed or shape plants can sit, kneel, or lean in different postures while wearing the field stool. Stooping and kneeling hurts worker's backs and knees and strains the hamstrings and torso. Videotape analysis of nursery workers weeding containers shows that workers are in physically stressful "unacceptable" postures 56%–77% of the time. Analysis methods followed OWAS, the Ovako Working Posture Analysis System (Karhu et al., 1981). Using the stool puts workers in less stressful postures and reduces the amount of time spent in "unacceptable" postures by 40%–66%. There is less strain on the body and less risk of injury. The field stool with waist belt is preferable to using a standard garden stool or a pail since the field stool goes where the worker goes and leaves

both hands free for work. The field stool is sold as a "milking stool" for less than $40 at dairy supply stores.

POT FILLING MACHINES

Often pot filling is done by hand by workers who stand around a wagonload of growing medium and scoop it into pots. This process is slow and repetitive and can cause overstrain injuries to workers. These injuries can occur in fingers, hands, wrists, arms, shoulders, and neck. They are slow to heal and cause pain that can become chronic and lead to lower productivity and time off work. Using a pot filling machine is faster and prevents these risks of overstrain injury. A pot filling machine drops growing media into a pot that the worker places under a chute. Pot filling machines do not move pots or help plant them. Workers manually remove the pot from the machine and place the plant or cutting into it. Usually pot-filling machines become cost effective for nurseries that fill at least 20,000 pots per year. Our studies have shown that nurseries that use pot filling machines to fill 20,000 pots save 250 labor hours a year. If labor is calculated at a cost of $15.00/h, the nursery saves $3,750 per year. Therefore a $16,000 machine will pay for itself in 4.3 years compared to filling those 20,000 pots by hand. When the potential savings from reduced time off work due to chronic overstrain injury is considered, pot-filling machines become even more cost effective. There are many types of pot filling machines on the market.

CONTAINER STABILIZATION METHODS

A third task that can cause repetitive motion injuries is righting containers after they have blown over in a wind gust. Workers who stoop and bend to perform this task hurt their back and knees, and their repeated gripping of the lip of the container causes hand and finger fatigue. Plant quality suffers as branches and stems break, at first from tipping over and then later from workers who climb between the pots to right them. Survey results from 687 Midwest nursery growers revealed that nurseries spend an average of 50 h per year righting containers, or $750 per year with labor costs at $15/h. There are several different types of container stabilization methods on the market. Some hold down the pot with a stake that hooks on the outer lip. This method works well for pots that sit on soft soil. Others are wire or plastic baskets that make a wider, more stable footprint for each pot. The basket system works well in container yards where it would be hard to pound in a stake. Connector systems use a method that joins rows of pots into heavier units less likely to tip. Another method is a heavy plastic unit with inserts for several pots. Some stabilizer systems also help maintain proper plant spacing in the container yard, making inventory organization easier and maintaining room for plant growth.

FIVE ADDITIONAL TOOLS

Other tools that can help reduce injuries and increase labor savings for nursery growers include tarp draping systems, electronic pruners, a one-person hitch, a long-handled diamond hoe, and a tree guard zipper. Nursery managers who adopt any of the tools mentioned above can save labor costs, increase profit, and reduce risk of injury to workers. Further information and ordering sources are available on the Healthy Farmers, Healthy Profits Project website (<http://bse.wisc.edu/hfhp>). Following are brief descriptions of each.

Tarp Draping Systems. Tarp draping systems allow workers to safely cover a loaded truck with a tarp. Often workers climb the load to haul the tarp or are hoisted in the air on a forklift to help position the tarp. Climbing a truck or wagon puts workers at risk of knee and ankle injuries, and a worker hoisted in the air risks falling. Safer tarp draping systems include a 2-pole method where workers hook the corners of the tarp on two long poles and walk alongside the truck, a roller permanently attached to the truck, a unit that mounts onto a skid loader, or the flagpole method where the tarp is hoisted onto 4 flagpoles and then dropped onto a loaded truck or wagon which has been driven underneath. These "no-climb" tarp draping systems range in price from $60 to $2,000. Reductions in labor and improved product quality can help recover the cost of the system. Factoring in the potential for reducing medical or workman's compensation costs, the payback period is even shorter.

Electronic Pruners. Nurseries with workers who prune at least 75 h a year and typically cut large branches to shape trees should consider investing in a portable, battery operated electronic pruner that can save time and reduce risks for serious injury. Using manual pruners requires strong grip and force and strains hands, arms, and fingers. Tired workers tend to make slower, more ragged cuts that don't heal quickly and invite disease organisms. Pruning for days and weeks at a time can sometimes cause carpal tunnel syndrome in the wrist. Fixing carpal tunnel syndrome with surgery costs on average $10,000 in medical costs. Several researchers have found that workers who use electronic pruners can prevent hand and arm pain compared to those who use manual pruners (Walula et al., 2000; Oude Vrieling et al., 2004). Electronic pruners are safer than pneumatic pruners because the blade does not immediately close upon contact but is squeezed closed by the trigger finger. Electronic pruners are more efficient than manual pruners and can cut pruning time by 20%. If a worker spends 150 h pruning annually and saves 20% of that time after switching to electronic pruners they will save 30 h per year and $450 in labor costs (at $15/h). A $1500 electronic pruner would then pay for itself in 3.3 years.

One-Person Hitch. A one-person hitch is a coupling device that facilitates hitching and unhitching wagons to tractors or trucks without the operator ever leaving the driver's seat. As the driver backs the tractor towards the wagon tongue the hitch attaches the two, and a release cable from hitch to tractor seat lets the driver unhook safely. This eliminates the risk of injury from crushed fingers or workers getting caught between tractor and wagon. Hitching with a one-person hitch is 91% faster than without, and it requires less precise tractor driving. The hitch comes with two units: one that mounts onto the tractor and another that goes on the wagon tongue. An $800 expenditure to outfit one tractor and three wagons would take 53 h of time saved at $15/h labor to recoup. This calculation does not take into consideration the potential for eliminating the risk of traumatic injury and its accompanying medical or workman's compensation costs.

Long-Handled Diamond Hoe. Using a common hoe can strain workers' backs, necks, shoulders, and arms because they are forced to adopt a stooped position while chopping weeds. Consider a sharp, long-handled hoe that encourages workers to stand upright and slice weeds instead. Two styles of slicing hoes (the long-handled diamond hoe and the collinear hoe) promote a more upright posture and keep wrists in a neutral position. The long-handled diamond hoe has a 2 inch × 8 inch

diamond-shaped blade sharpened on all 4 edges. The handle is 6 inches long and ends in a modified "T" shape. While standing upright, workers loosely grip the "T" with one hand and place the other along the handle, weeding with a push-pull motion similar to running a household vacuum. This works well for slicing off weeds under a mulch layer. The collinear hoe has a rectangular blade parallel to the ground. While standing upright, workers grip the handle with thumbs up and make short sweeping motions.

Repeated measurements of a worker's spine angle during an hour's hoeing with a stirrup hoe showed 15 degrees of forward lean. With the long-handled diamond hoe the worker worked in a more upright position, with a forward lean of 8 degrees from vertical. Changes in work position alleviate muscle stress and prevent pain. The "T" handle on the long-handled diamond hoe gives workers an alternative hoeing position. The long-handled diamond hoe is fast and precise; removing 2- to 4-inch weeds 21% faster than a stirrup hoe in our field trials. It costs $35–$40 and can pay for itself by saving time and preventing injury.

Tree Guard Zipper. Installing and removing corrugated plastic tree guards is hard on the fingers, hands, and wrists. Pulling the edges open requires hand force, and the plastic edge can cut workers' fingers and scar tree bark. Installing guard after guard can lead to carpal tunnel symptoms. A tree guard zipper is a cast aluminum hand tool that spreads the edges of the guard and holds them open while workers pull the plastic tubes on or off. Growers who have used the zipper claim they can install and remove tree guards faster than by hand, and in our field studies workers were 37% faster at installing and 27% faster at removing tree guards with the zipper. Using the zipper puts workers in a more upright posture. According to OWAS categories of work postures (Karhu et al., 1981), workers spent 59% less time in unacceptable postures during installation and 24% less time in unacceptable postures during removal. Using a tree guard zipper prevents bark scarring. The zipper costs $45–$50 and can pay for itself with just a few hours in saved labor.

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DNA Nultiscan®: A New Tool for Rapid Detection of Pathogens in Water, Soil, and Plant Tissue©

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The main limitation in plant disease management is the ease of plant pathogen identification. Standard procedures' limitations include:

- Time-consuming and often laborious.
- Require extensive knowledge in both classical taxonomy and culture methods.
- Exclude culture-independent organisms.
- Detect few organism at a time.

Molecular and serological identification methods, on the other hand, generate accurate results rapidly but detect few organisms at a time. The solution is DNA-array technology:

- Originally developed to screen for human genetic disorders in 1989.
- Successfully applied to detect and identify different microorganisms in clinical laboratories in 1992.
- Successfully applied to discriminate and identify DNA samples isolated from specific oomycete (1998), nematode (1999), and bacterial cultures in plant pathology (2003).

The advantages of DNA Multiscan include:

- Multiplex detection.
- Rapid, accurate, simple, and sensitive.
- Semi-quantification.
- Analysis of samples from different biological sources (plants, seeds, soils, composts, potting mixes, rockwool, water, nutrient solution, etc…).
- New microorganisms added regularly.
- Bundling of organisms to meet needs.

Currently detectable organisms are shown in Table 1.

During the analysis, the sample's total DNA is extracted. This includes any plant DNA, bacterial DNA, fungi DNA, yeasts DNA, algae DNA, and nematode DNA. Amplification of pathogens DNA is then carried out. This is followed by hybridization, which is a key step of the DNA Multiscan process. Keys to the success of the process are:

- The specific labeled amplified DNA sequence hybridizes with its correspondent oligo on the macro-array.
- The oligo is specific to the disease causal agent and can be developed in-house for specific needs.

Table 1. Currently detectable organisms by DNA Multiscan®.

FUNGI AND OOMYCETES:

Athelia (*Sclerotium*) *rolfsii*
Botrytis cinerea
Colletotrichum sp.
Colletotrichum acutatum
Colletotrichum coccodes
Colletotrichum fragariae
Colletotrichum gloeosporioides
Colletotrichum graminicola
Cylindrocarpon destructans
Cylindrocladium sp.
Didymella sp.
Fusarium sp.
Fusarium oxysporum
Fusarium solani
Gnomonia comari (*Zythia fragariae*)
Penicillium sp.
Phytophthora sp.
Phytophthora cactorum
Phytophthora capsici
Phytophthora cinnamomi
Phytophthora citricola
Phytophthora cryptogea
Phytophthora drechsleri
Phytophthora fragariae
Phytophthora infestans
Phytophthora nicotianae
Phytophthora ramorum
Phoma destructiva
Plectosphaerella cucumerina
Pyrenochaeta lycopersici
Pythium sp.
Pythium aphanidermatum
Pythium dissotocum
Pythium irregulare
Pythium polymastum
Pythium sylvaticum
Pythium ultimum
Rhizoctonia solani
Sclerotinia sp.
Sclerotinia minor
Sclerotinia sclerotiorum
Sclerotinia trifoliorum
Thielaviopsis basicola
Verticillium sp.
Verticillium albo-atrum
Verticillium dahliae

BENEFICIALS:

Trichoderma asperellum
Trichoderma harzianum
Trichoderma hamatum

BACTERIA:

Erwinia carotovora subsp. *atrospetica*
Erwinia carotovora subsp. *carotovora*
Erwinia chrysantemi
Pseudomonas cichorii
Pseudomonas marginalis
Pseudomonas viridiflava
Pseudomonas syringae pv. *porri*
Ralstonia solanacearum
Rhizobium radiobacter (syn. *Agrobacterium tumefaciens*)
Xanthomonas fragariae

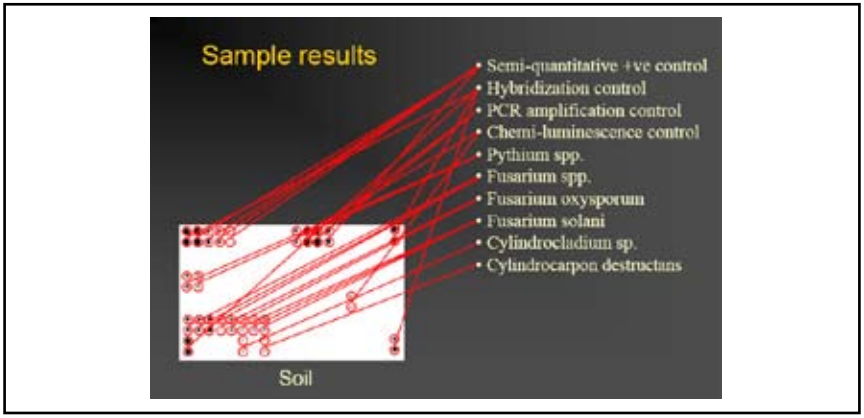

Figure 1. Example of sample results.

An example of sample results is shown in Fig. 1.
Current applications include the following:

- Disease diagnosis.
- Continuous monitoring recirculating greenhouse fertilizer solutions or pond water.
- Detection of organisms in soil, peat, compost, and other growing media.
- Regulatory requirement to justify the use of certain restricted chemical pesticides.

Growing Insect-Free Plants with New Technology©

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DEALING A BLOW TO PESTS AT THE PROPAGATION STAGE

Can very warm water kills pests and make a nursery plant propagator happy and rich? Yes to the warm water killing pests and yes to the part about making nursery professionals happy. Whether you can get rich using this method is up to you. We think that multiple potential benefits can be found using a hot water immersion system to decimate insects, or should we say cook insects, at the propagation stage. This method was developed through University-based research in Hawaii and at the University of Maryland.

Many nursery plant propagators are anxious to adopt effective, cost-efficient methods of nonchemically controlling pests. Concerns over worker's unnecessary exposure to chemicals has prompted many owners to look for alternative methods to deal with insect and mite control that places less reliance on pesticides. Greater regulation on the use of chemical pesticides has created an opportunity to look to other methods of dealing with pests. The idea of using hot water treatments to control pests on nursery cuttings is relatively simple but effective. Most pests of ornamental plants can survive at high temperatures, but there is a temperature window at which insect pests die but which plant material tolerates.

Funding from Maryland Nursery and Landscape Association (MNLA) and the Northeast IPM Group (NEIPM) enabled us to build a portable hot water immersion system that is economical and relatively easy to construct and operate by plant propagators. The system involves an instant hot water heater that rapidly heats

water to the proper temperature and recirculates the water around plant cuttings. Propagation plant material is placed in treatment mesh baskets and placed in a recirculating hot-water system. Growers are likely to adopt methods that are practical and easy to use — criteria that this system meets.

We tested multiple temperatures and treatment times for 13 species of woody plant and herbaceous plant material and a couple of greenhouse species. We established threshold temperatures at which cuttings of these species can be treated without suffering injury. We also evaluated the impact of hot water treatment on four different insect and mite populations on plant cuttings taken.

INTRODUCTION

Nursery managers will propagate many species of nursery plant material by taking cuttings from stock plants and rooting them in mist chambers before moving them to production growing areas. A stock plant can have a small infestation of insects or mites that are difficult to detect such as scale, mealybug, thrips, aphids, or spider and broad mites. Growers strive to propagate from clean plant material, but sometimes the pests are so small or the pest is found in cryptic parts on the plant that they go undetected.

In a mist chamber it is nearly impossible to apply insecticides since the foliage is being constantly syringed off by the frequent mist cycle needed to keep plants moist during the rooting stages. A systemic insecticide applied to the substrate is not practical since the plants do not have roots to pull up the soil-drench-applied insecticides. Some nursery managers have resorted to dipping cuttings in dip tanks with pesticides in the hope of killing pest before they are moved into mist greenhouses for rooting. The problems with this approach are multi-fold: (1) Most pesticides are not labeled for this usage, and therefore, there are no labeled rates and directions. (2) Exposure risk to pesticides by employees dipping the plants is very high. (3) There is not a good way for owners to dispose of the remaining pesticide dip when the process is completed.

The idea of using hot water treatments to control pests is relatively simple but effective. Most pests of ornamental plants can survive at high temperatures, but there is a small temperature window at which insect pests die but which plant material tolerates. Dr. Hara at Hawaii University has tested the hot water bath method on a number of plant species and found that 49 °C (120.3 °F) for 1–10 min gave effective control of several species insects including aphids, scale, mealybug, and mites on nursery plant cuttings. Hara tested hot water treatments on tropical plant material.

In our trials we established the threshold temperatures that temperate zone plant material can be safely treated with hot water and not damage the plant material. We need to also establish whether these hot water treatment temperatures and length of treatments that are safe on plants also kill the pests.

For this project we worked with several Maryland nurseries in evaluating temperature ranges and length of treatments that are safe. We let the nursery managers select plant material that had damage from known pests that are commonly found on stock plants. Special thanks to the following nurseries for working closely with us in this project: Chesapeake Nursery, Woodland Nursery, Marshy Point Nursery, Ivy Farm and Hillcrest Nursery, the Perennial Farm, Bluemel Nursery, and Greenstreet Growers Greenhouses.

HOT WATER AS A SOIL DRENCH TO CONTROL SOIL PESTS

In Ohio, Bob McMahon of Ohio State University has been working on controlling greenhouse pests using hot water drenches. In his studies he found that treating soils using hot water drenches and taking the soil up to 110 °F kills larvae of fungus gnat very effectively. He also tested the tolerance of poinsettia and New Guinea impatiens to hot water drenches. McMahon found that poinsettia could tolerate soil temperatures up to 135 °F without damage. New Guinea impatiens tolerated even higher temperatures up to 150 °F without damage. McMahon has applied 24 ounces of water to 6-inch pots, waited 3 min and applied a cooling drench of water at 20 ounces per pot.

Our approach at the University of Maryland Cooperative Extension has been a little different. We are looking at treating plant cuttings taken from infested stock plants and cleaning them up so they are relatively pest free. In our system whole plant cuttings are submersed in water held at a constant temperature for a set amount of time with the water being recirculated around the plant cuttings. The treated cuttings are then cooled using water at 50–60 °F, for 60–120 sec.

The cuttings are then stuck as in normal propagating methods.

OBJECTIVE: DEVELOP AN EFFECTIVE IPM TOOL FOR NURSERY MANAGERS

Our lofty goal was to build a device that is affordable (under $4,000), portable, and practical for treating large numbers of cuttings. The system we chose was based on a modified model developed by Dr. Arnold Hara of Hawaii University. The system uses an instant hot-water heater and propane gas for the energy source. Hot water is circulated through a 100-gal stock tank and plant material is lowered into the water in PVC netted cages. Temperatures are monitored as the water moves to the tank and a thermostat records the temperature of the recirculating water to make sure the temperature is constant and even.

Circulation and temperature uniformity in the treatment tank is achieved though a circulation grid consisting of a centrifugal pump and plumbing system. The pump outlet is split to both sides of the tank, causing the water to follow the oval-shaped perimeter of the tank. Our Extension agricultural engineers designed the piping, placement of thermocouplers, and control values. We used temperature gauges to measure the temperature in various parts of the stock tank to determine if the temperature was uniform. The first pump placed on the system did not give adequate circulation, and we had variation in the temperature in the stock tank. We requested that our agricultural engineer increase the horsepower to move the water around the plant cuttings. This large pump greatly helped in making the temperatures in the treatment tank much more uniform. A circulation control value was placed on the system so we could increase or lower the recirculation rate as desired. It would be increased when the tank was completely filled with treatment cages and we needed maximum flow around the cuttings.

Design of the System. The hot water immersion system has two main systems. The first is the water heating system with the instantaneous water heater and its water and gas supplies that provide the hot water for the immersion tank. Thermometers, control valves, and pressure gauges are part of the system to monitor and to help achieve the hot water necessary. The second system centers on a pump that circulates the water in the immersion tank through pipes and risers with nozzles to mix the water and push it into the plant material. Using control valves the

discharge from the pump can be directed into the tank to mix the water or the water can be directed away from the tank to dispose of it. Cooled water might be recycled to the heater.

Certain considerations for the design are important in order to make a good functioning system. The water heater has a given capacity for heating water, and that defines the water flow rate and water pressure required for the system. It sets the limitation on the amount of hot water that will be available to initially fill the immersion tank and the amount of hot water available to maintain a given temperature. Since the water temperature is critical to the success of the immersion process, insulation was placed around the immersion tank to reduce heat loss, thus temperature change is reduced. The ability to monitor the water temperature going into the immersion tank and the temperature of the water being circulated is essential. A good water circulation system to stir the water is desired to maintain temperature uniformity.

Water Heating System. An instantaneous water heater was selected for the portable hot-water immersion system. For a stationary system a regular commercial or residential-type water heater with a fairly fast recovery rate should work. For the purpose of clarity, the brand name, and model numbers of the actual equipment used to build the system will be given; this does not mean that other equipment could not be used nor is it an endorsement for any specific equipment.

For the University of Maryland unit, a Paloma Automatic Gas Water Heater Model PH-24M-DP for propane gas was used. The unit has a rated input of 178,500 Btu/h on high and a 37,700 Btu/h rate at half way on. This translates into a 90 °F rise in water temperature at a water flow rate of 3.17 gpm on high burner rate and a 100 °F rise in water temperature at a water flow rate of 2.85 gpm on high burner rate. This is important design information because this is the maximum water heating rate for the system. Other data to note is that a water pressure of 12.9 psi is required to push the water through at the high rate of heating. This pressure differential is required for the flow control valve of the heater to work properly. The section on operating the system will illustrate this.

The instantaneous heater turns on as the hot water tap is opened and cold water flows through the heat exchanger. A pressure differential switch controls flow. A water temperature knob can be adjusted to set the water temperature at a given flow rate. For this application the "HOT" setting is used.

System Operation.

- Determine the high temperature intended for the process. We found that most plants can tolerate 120–125 °F for varying amounts of time. Some more sensitive plant material will need lower temperatures. It is much more efficient to start at the high temperature and work down to a lower temperature than to try to increase the temperature after starting at a low temperature.
- Allow the water to flow into the tank to a point that will cover the baskets used to hold plant material and be above the blue suction line for the circulation pump. Temperature stabilization is important. The lid will help hold water temperature and should be used whenever possible.

- Allow at least 15 min for tank temperature to stabilize before starting the process of putting plants in the tank. Tank temperature can be monitored using the circulation pump system and temperature gauge located to the right of the pump motor. Pump motor control is located below pump motor.

Establishing Killing Temperatures for Insects and Mites. Hara, in his research work on hot water immersion, placed plant cuttings into a netted cage. He preconditioned the plant material by holding the cuttings at 40 °C (104 °F) for up to 15 min. The plant cuttings and net holding chamber is removed and the temperature is then raised to 49 °C (120 °F) for 8–12 min. After the disinfecting treatments at 49 °C the plants are then cooled to ambient air temperatures, which was approx. 24 °C (74 °F) for 5–6 min. The cuttings are then stuck into a mist chamber.

Table 1. Hara noted that hot water treatment at 49 °C (120 °F) kills the following pests:

Insect (treated with hot water)	Temperature (°C)	Time to obtained > 99% mortality (min)
Ants	49	0.5
Aphids (banana and cotton)	49	1.0
Taro root aphid (on roots)	49	5.5
Cockerell scale	49	8.0
Green scale	49	10.0
Mealybug (obscure and citrus)	49	12.0
Spiraling whitefly	49	12.0
Root mealybugs (potted)	46	Variable due to density of root ball

Testing out the System Performance. We set up tests to evaluate the hot water recirculation system when under a working load of cuttings. We quickly found out that if we brought the temperatures up to the desired temperature and then inserted cages holding the cuttings, the water temperature dropped. We experimented with heating up the water in the stock tank to higher temperatures then slowly lowering the temperatures. Through repeated trials we found that it is best to run the temperatures up to 145–150 °F for at least 30 min to heat up the stock tank and the surrounding insulation. In the colder weather of the winter it may require up to 45–60 min to adequately heat up the tank. We also raised the temperature 1 °F warmer than the target temperature to compensate for the lowering of the temperature when the cutting baskets were lowered into the treatment tank.

Another modification was the addition of an insulated lid with a 1-inch polystyrene layer that covered the treatment stock tank. The insulated lid combined with pre-heating the tank to 145–150 °F for 30 min worked well. Slowly introducing water from a hose to bring the temperature down to the desired temperature worked well. The preconditioning of the stock tank allowed us to maintain a constant temperature of the water for 20–30 min.

Temperature Adjustment and Treatment Cages. To improve the ease of placing and removing the cuttings into the tank we constructed large cages of 18 inches × 18 inches. We found these cages were too large and cumbersome for treating a small number of cuttings at a time. These larger cages might work if a grower were treating large numbers of cuttings of the same plant species. For our trials smaller was better. We modified our experimental cages by making them a compact 12 inches × 12 inches. Since the cages were made of PVC plastic pipe they tend to float up in the tank. We drilled holes into the PVC pipe so the cages sank into the water in the tank. These smaller cages appeared to fit the cuttings better with fewer floating out in the main body of treatment tank.

We were able to fit up to six cages into the stock tank during a treatment. The plastic mesh used to cover the cages had a $^3/_4$-inch opening to allow the water to flow through the cage. This $^3/_4$-inch opening worked well for most of the woody cuttings with very few cuttings escaping. When testing the herbs we had to place the cuttings into finer silk mesh bags and place them in the cages to keep them from escaping from the cage into the stock tank.

Plant Material Tested in 2004–2006. Each treatment temperature and time interval had 5 replications. Immediately after being taken out of the hot water treatments the cuttings were moved into water at 65–70 °F for a cool down period of 5 min. Cuttings were then immediately stuck into substrate and placed under a timed interval mist system. Cuttings were observed over a 6- to 8-week period. We noted if the treatments caused scorching of foliage, dieback of the cutting, or lack of rooting. If any damage was recorded at temperature or time interval it was determined to be unacceptable.

In Table 2 we report the lowest temperature and time interval that did not cause burning, dieback or lack of rooting of the cuttings. Hara noted in his work in Hawaii that 49 °C (120 °F) was the temperature that gave effective kill of mealybug, armored scale, aphids, whitefly, and ants. He noted that 46 °F (117 °F) also killed pest but required longer treatment times of 30 min which often caused injury on plants he tested in Hawaii.

A temperature of 120 °F appears to be the threshold above which injury is incurred on several species of plants in our trial. We found that 120 °F at 10- to 20-min treatment times appears to be safe on azalea (*Rhododendron*), ivy (*Hedera* sp.), boxwood (*Buxus* sp.), Leyland cypress, and arborvitae (*Thuja*) 'Green Giant '.

Treatment of Insects and Mites.

Boxwood Mite Control. Boxwoods were obtained that had heavy population of boxwood mite (*Eurytetrancychus buxi*) eggs present and damage to 90%–100% of the foliage from last season. Cuttings were taken from the plants and twenty 6-inch branch tips, taken randomly, were examined and the number of eggs recorded to establish a precount average number of eggs. Only eggs were present at this time of year since the boxwood mite overwinters. Growers take cuttings during the winter months for rooting cuttings. We felt this was appropriate to evaluate whether the hot water treatment would kill the eggs. On 7 April 2005, 6-inch cuttings were treated at 120 °F for 15 min. This temperature and length of treatment was chosen since this was determined to be the highest temperature and greatest

Table 2. Plants treated in 2004 to 2006.

Nursery supplying plant material	Plants used in trail and month tested	Highest temperature (°F) plants will tolerant	Greatest length of treatment time (min) without damage to plant material	Additional comments
Marshy Point Nursery	*Rhododendron* 'Rosebud', plants treated 13 August	120	10	120 °F for 15 min caused 50% treated plant foliage to scorch
Ivy Farm, Eastern Shore of Virginia	*Hedera helix* 'Wingertsburg'	120	15	At 20 min 75% of plants were scorched
	Hedera helix 'Marginata of Hibbard'	120	20	125 °F at 10 min or more resulted in foliage scorching
	Hedera colchica plant treated in April	120	15	At 20 min 25% of foliage was scorched. Treatment at 125 °F for 10 min caused 20% foliar injury. At 125 °F for 15 min or more caused over 50% foliar scorching.
Chesapeake Nursery	*Cotoneaster* ·×suecicus (syn. *dammeri*) 'Coral Beauty' Treated 6 June 2004	120	10	At 115 °F the plants can stand up to 20 min with no foliage damage
	Viburnum plicatum f. *tomentosa* 'Shasta' treated June 6	120	10 min with 30% of plant showing leaf scorch	Plants treated at 155 °F can tolerate 20 min with no injury
	Ilex crenata 'Convexa' treated 6 June	115	10 min with 40% of plants damaged	Not very tolerant of treatments

	Pieris japonica	120	20	Less than 20% foliar injury, all cutting survived.
Woodland Nursery	*Buxus sempervirens* 'Rotundifolia' treated in August	120	15	At 125 °F for 10 min 70% of plants dead
Hillcrest Nursery	*Salvia officinalis* (sage)	112	20	At 115 °F for 15 min 10% of plants dead, at 20 min 50% dead
	Artemisia dracunculus (tarragon)	110	0	At 110 °F all plants, tarragon appears very heat sensitive
	Rosmarinus officinalis (rosemary)	115	10	At 115 °F for 20 min plant ok
Bluemel Nursery of Harford County and Perennial Farm of Baltimore County	*Miscanthus sinensis*			
CMREC Nursery plants	×*Cupressocyparis leylandii* (Leyland cypress)	120	15	120 °F for 20 min suffered > 40% damage. Higher temperature caused 100% death
	Thuja 'Green Giant'	120	10	Plant looks good for 2 weeks then browning and dieback occurred on anything above 120 °F or times treatment times of 15 min or longer
Greenstreet Growers of Lothian, Annapolis	New Guinea impatiens	120	20	Plant cuttings appears very tolerant of 120 °F treatment

length of time we could treat without causing damage to the cuttings in previous temperature phytotoxicity trials. The level of control of boxwood mite at 120 °F for 15 min gave 100% control on the treated plants (Table 3). Plants treated at 115 °F for 15 min only had a little over 60% control.

Fern Scale Control. Liriope plants infested with fern scale, *Pinnaspis aspidistrae,* were used in the trial. Soil was removed from the root system before treatment in the hot-water immersion system. Twenty liriope plants were examined and recorded the number of 3rd-instar females present. This established an average number of scales per plant for the pre-treatment count.

Plants were then treated at 120 °F for 15 min and 115 °F for 15 min. Plants were then potted and placed under a mist system. Untreated control plants were also placed under mist. A treatment of 115 °F was not sufficient to kill the scale but 120 °F for 15 min gave 99% control (Table 3).

Miscanthus mealybug. Container-grown miscanthus plants infested with miscanthus mealybug, *Miscanthicoccus miscanthi,* were obtained from a local grower. A pre-count was taken on 20 plants to establish an average number of overwintering mealybugs per plant. Plants were then taken out of the pots and the soil was removed and whole plants were treated at 120 °F for 15 min and 125 °F for 15 min on 4 April 2005. The plants were then potted and placed under mist. Plants were examined one time on 14 May and number of mealybugs counts. The mealybug hide between the leaf roles and since this was destructive sampling only one sampling could be taken. The treatments of 120 °F for 15 min gave above 99% level of control of miscanthus mealybug. The 125 °F also worked with no damage to the plants but a grower really only needs to reach the 120 °F temperature to control this pest (Table 3).

Chinese Holly: Cottony Taxus/Camellia Scale, *Pulvinaria floccifera,* Control. Ten branch samples were treated at 120 °F for 15 min and 10 untreated controls were compared. Post counts of hot water treated plants gave 99% or above level of control of this scale (Table 3).

Table 3. Summary of trials results conducted by University of Maryland.

Insect (treated with hot water)	Temperature	Time (min) to obtained > 99% mortality
Boxwood mites	49 °C (120 °F)	15
Miscanthus mealybug	49 °C (120 °F) * can tolerant 51 °C (125 °F)	15
Cottony taxus/camellia scale	49 °C (120 °F)	15
Fern scale	49 °C (120 °F)	15

WHERE DO WE GO FROM HERE?

We believe the potential for using hot water treatments for reducing certain ornamental pests is strong. It may not control all pests, and some plants may be sensitive to the temperatures needed to kill a particular pest but this can be established by continued research on temperature tolerance of additional species of plants. We con-

ducted trials on a couple of herb species and found that plants such as tarragon could not withstand temperatures above 110 °F and basically cooked the cuttings at this temperature. Sage only tolerated temperatures up to 112 °F, and rosemary could take 120 °F but for just 10 min. Growers are not likely to kill many pests at this lower temperature and shorter treatment intervals. This is too bad since there are only a very limited number of labeled chemical options for growers to use on herb crops. On the bright side we found that New Guinea impatiens cuttings are very tolerant of 120 °F treatments for up to 20 min. A major pest group that damages New Guinea impatiens is broad and cyclamen mites. Other researchers have reported that treatment with hot water at 112 °F for 10–12 min kill cyclamen mites.

We plan to continue our work at the University of Maryland and expand the list of species of plants tested to establish whether they can tolerate 120 °F temperature treatments and for what length of time. We believe we have a machine that is fairly economical to build and fairly user friendly with a little practice.

We will be publishing a two-part fact sheet in early 2007 that explains how to build and operate the hot water immersion system.

Until then we will try to keep the heat up on the pest, at least at the propagation stage.

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Just When I Thought I Had the Right Recipe©

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The horticulture industry, indeed the world, is all about change today. There are constantly new ideas surfacing, different technologies emerging, and new plants being introduced. In this evolutionary world, when is the last time you took a look at your media recipe? Are you still using what dear old dad concocted back in '72? Are new plants problem crops or does the price of your mix give you the shudders? This article tackles some of the reasons to make changes and hopefully some guidance in implementing those changes successfully.

Let us begin by looking at the reasons we would change recipes in the first place. Ingredients offered over the years have changed. We are witnessing peat moss shortages from the East and bark shortages from the South, and we all know with shortages come price increases. In our generation of recycling, more compost is being produced, and the quality continues to increase whereas cost remains stable or decreases. While we seldom experience completely new ingredients to the market, recycling material from other industries offers that potential. A foam waste product from the auto sector has been successfully used as a lightweight ingredient for rooftop plantings. Aged bark piles formerly thought to be unusable due to the high percentage of stone contamination can now be successfully cleaned of stone debris by innovative new technology. Plant breeders are introducing new plants that are wonderful to the eye but need special care in the growth stages. These plants are also moving through our production at high speed, and being first to the market is a key for profitability. There are many other reasons that you may want to change the media recipe that is specific to your nursery.

Specific to your nursery! Your nursery is as individual as you are yourself, and "one size fits all" seldom works in the entirety. When preparing to modify your media recipe; list the benefits / drawbacks that the existing media offer. It is not uncommon to find that groups of plants do well or not so well in your existing blend. The next step is to list which criteria need to be addressed and for which groups of plants. Cost is always a consideration; however, cost should seldom be the limiting factor in plant growth or health. Nor is cost easily determined between two separate potting mixes. The easy example is a poinsettia crop grown in a low cost mix that is of marketable size December 26 — not a viable solution. The true value of the mix can only be ascertained when the crop is sold. Perhaps this is one of the reasons recipes don't change very often: fear of the unknown.

The list is complete and which criteria to change and for what crops are set. The next step is to gather information. Existing suppliers are a great place to start. They know your individual nursery, nurseries in the area that are similar and available ingredients, and they should have a vested interest in working with you to make the best recipe choices happen. Competitive suppliers will also provide a great source of information, but may not possess the same knowledge of your nursery's individuality. Don't be afraid to ask for information. If the main goal is to increase air porosity for your Japanese maples then you need to start with analyzing your

current mix and comparing subsequent mixes against that standard. Physical tests are time-consuming, but in most instances, the supplier will be able to complete the tests. Chemical tests can be performed at independent labs at reasonable costs. Visiting other nursery operations, near or far, and talking with liner suppliers can also provide valuable information, especially about new selections. Industry conferences and tours are great networking opportunities. Use every chance to learn and then go learn again!

Once you have decided what to change and for what crops, monitor and evaluate until the crop is sold. Mixes that begin cheap can become expensive due to higher crop loss and delayed maturity. Make a lot of notes and include key personnel. Crop evaluations should also cover top to bottom inspections. Root growth, especially during crop establishment, should be routinely monitored. Look for healthy roots to the bottom of the pot. Wet layers at the bottom will cause rooting issues and are disease prone. Root stress may show damage in the spring and cause crop loss. Does the canopy fill the pot as quickly; are plants saleable when needed? Did the change in recipe result in the change you were aiming for? Remember to only make final decisions when the crop is sold.

There are no magic ingredients, nor will one recipe be best for all crops. There are many trade-offs when designing your media recipe, and finding balance takes effort and will be different for each individual nursery. As a final thought — always keep in mind that the plant gains most of its nutrient and water needs from the media. Starting with the right media will lessen plant stress and be more profitable.

Selectrocide™ Chlorine Dioxide as a New Product for the Control of Algae and Other Microbial Pests in Greenhouse Irrigation Systems©

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THE ALGAE PROBLEM

Algae cause a number of problems relating to greenhouse management. It forms on sidewalls of the greenhouse, particularly when plants are grown close enough for fertilizer solution to splash, drip, or drain onto the glazing material (Fig. 1). The advanced stage of development reduces light transmission through the sidewall and growth of plants in the immediate vicinity. It is viewed by many as a nuisance and can lead customers to form a negative impression of the operation by suggesting that cleanliness and good sanitation practices are not priorities.

Its presence is known to provide feeding and breeding areas for insects such as fungus gnats and shore flies (Fig. 2). Populations of these insects are known to vector plant diseases, particularly those that occur in the growing medium. A shore fly population, if present in a retail area, can be quite distracting and cause shoppers to question whether the "bugs" are going to harm the plants they purchase. Until recently we responded by saying shore flies were only nuisance pests and would not harm plants. Research has shown otherwise, and shore flies are now known to spread diseases in the same way that fungus gnats do.

Algae cause direct crop loss when present on the growing medium surface of seedling plugs (Fig. 3). Young, tender seedlings are negatively affected as advanced algae development results in loss of crop uniformity and forces compromised growing decisions. If the larger seedlings are dry yet the smaller seedlings are not, should the plug tray be watered? If a chemical growth regulator application is scheduled, when should the tray be treated? Regardless of the decisions, some plants will either be over-watered or under-watered and receive too much plant growth regulator or not enough. At some point, the additional expense of hand labor becomes necessary to grade the plants prior to use.

Advanced stages of algae develop mats that repel water, making it difficult to keep the growing medium moist. As the mat matures, it creates a slimy surface that presents further impediments to seedling growth. This thick layer can attack the base of the stem of tender seedlings causing collapse and death.

Dark green to black patches of algae on floors and walkways, in addition to providing breeding areas for insects and diseases, can become slippery and cause safety concerns for employees and customers.

Algae can clog drip emitters (Fig. 4), mist nozzles and water breakers, solenoid valves, and other parts of irrigation systems. Discussions with growers repeatedly touch on the following cost associated with algae. Clogged drip tubes, particularly those used for hanging baskets, cause significant concern and crop loss. Not only do drip emitters need to be replaced after failing, but more often than not, the

Figure 1. Algae forming on greenhouse sidewalls.

Figure 2. Algae provides feeding and breeding areas for insects.

Figure 3. Algae on growing medium surface causes crop problems.

Figure 4. Algae and biofilm cause clogging of drip emitters. New emitter on left, clogged on right.

Figure 5. Schedule 80 PVC will not prevent algae growth inside irrigation lines.

clogged emitter is only identified after the hanging basket is damaged or killed from lack of water.

Several growers have reported to me that they replace thousands of drip emitters after every spring production season. Stories are also told of growers who remove the filter cartridges from their in-line filters because they become clogged too often. Think about that!

Understanding the Enemy. I have heard the following advice regularly in conversations about irrigation systems. Don't use Schedule 40 PVC in the greenhouse because its white construction allows sunlight to penetrate, which allows algae to grow inside the pipe. Use schedule 80 PVC instead (Fig. 5), because it's thicker, gray construction prevents sunlight penetration, which prevents algae from growing. For growers who have followed this advice; Schedule 80 PVC pipe and fittings cost between two to three times as much as schedule 40. Other growers have told me that they used to paint their irrigation lines black for a similar reason. While the logic seems sound, read on to learn why adopting either of these practices amounts to nothing more than throwing money and time down the drain.

Two years ago I was in a 5-ft deep ditch (Fig. 6) cutting into 2-inch water and fertilizer mains to service a new greenhouse. Upon cutting through the fertilizer line I was left scratching my head in bewilderment. That fertilizer main was lined with the greenest layer of algae imaginable, 5-ft underground in complete darkness.

I had been under the impression for many years that algae require light to survive. How could I have algae 5-ft underground? I next cut through the clear water

Figure 6. Underground clear water and fertilizer mains, which were cut to show algae and biofilm growth in the absence of sunlight.

Figure 7. Longitudinally cut PVC mains; top section is new, middles section carries clear water, bottom section carries fertilizer. Note discolored biofilm layer in clear section and algae dominated layer in bottom section.

Figure 8. Experimental irrigation matrix for researching biofilm and algae in irrigation lines.

line and, while it was not lined with green algae, it was lined with a distinctive brown deposit. I saved samples of each pipe and cut them longitudinally to document my finding in a picture. In Fig. 7, the top section of pipe is new, the middle section is the clear water line, and the bottom section is the fertilizer line.

A NEW WORD: BIOFILM

The research team I am working with on the chlorine dioxide project includes both chemical and physical engineers and a microbiologist. It was the microbiologist who raised my knowledge of algae to a new level. The brown lining inside my clear water line is a network of living organisms called biofilm (also called bioslime, slime). Biofilm is a complex of bacteria and both organic and inorganic components that form a persistent, living layer inside irrigation lines. The continual flow of water through the pipe replenishes nutrients, which allows the biofilm layer to sustain itself. When fertilizer is injected into this environment the biofilm flourishes and is able to form a symbiotic relationship with algae. What one needs the other provides. The result: biofilm becomes capable of replacing algae's need for sunlight.

This is why the schedule 80 recommendation and painting irrigation lines are doomed to fail.

The Research. An experimental irrigation system was designed to allow us to research a new product, Selectrocide™ brand chlorine dioxide. The accompanying pictures on the right show the manifold system (Fig. 8). Four independent zones each included a dedicated Dosatron injector. A fifth zone was installed without an injector to serve as a control. Sections of clear PVC pipe in each zone allowed us to see algae as it grew in the pipes. It also allowed us to take pictures of how well various treatments killed the algae lining the pipes.

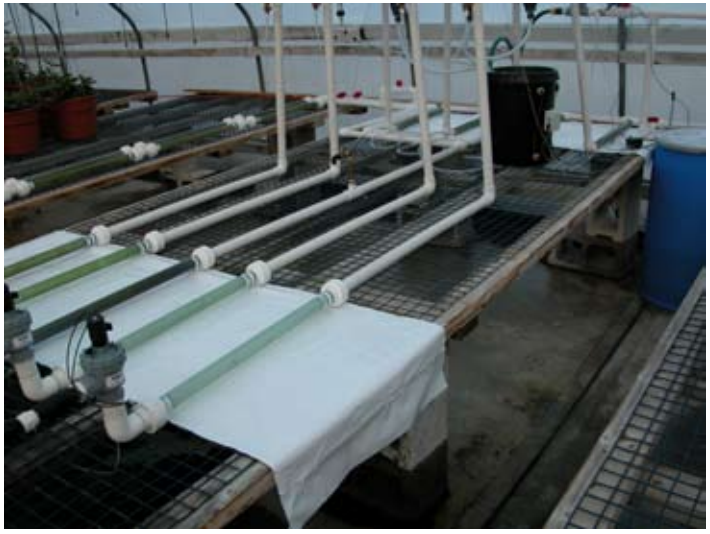

Figure 9. Clear sections of PVC installed to view algae and biofilm development.

Clear sections of pipe were also installed before the injectors to confirm that the lines were contaminated with algae during the time that the various chlorine dioxide treatments were occurring. These sections are visible in Figure 9. Our strategy was simple: if the water before the injector was green and the water after the injector was clean…we had a winning treatment. A common, constant fertilizer solution of 200 ppm nitrogen was used during the experiments.

Shock Treatment. Within weeks after installation a dark green layer of algae formed inside the clear sections of the manifold (Fig. 9). The first series of experiments was designed to determine how a contaminated irrigation line could be shocked to kill and strip algae and slime from the line.

Figure 10A shows our first results. The clear section of pipe in the foreground received an overnight shock treatment of 50 ppm chlorine dioxide. The pipe was filled or "charged" at the end of the day and left that way overnight. The line was flushed the following morning prior to taking the picture. The green pipes in the upper portion of Fig. 10B were not treated. The treated pipe was just as green as these before the chlorine dioxide shock treatment was made. Needless to say, we were quite pleased with the results.

In the next step we repeated the overnight shock treatment to determine if additional shock treatments would be beneficial. Figure 10B shows one such experiment where different concentrations and number of overnight exposures were studied. The untreated control line is the dark green line in the center. Two consecutive, overnight shock treatments of 50 ppm provided excellent removal of algae and slime inside the lines. Shocking for more than two nights did not provide additional benefit.

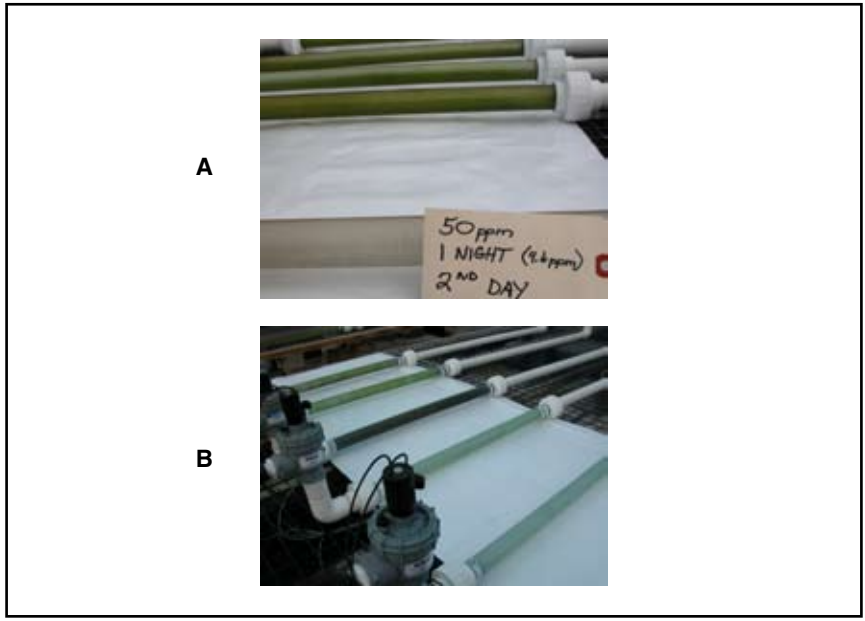

Figure 10A & 10B. Top image showing clear section of line following shock treatment with Selectrocide. Bottom image showing various treatments with untreated control line in center. Note algae contamination in center line.

Our recommendation will call for one's entire irrigation system to be shocked for two consecutive nights, twice a year. The timing of these two shock treatments could be in January and July, between major crop cycles.

Continuous Treatment. Shocking the experimental system gave us 4 to 6 weeks of residual effect before we noticed visible signs of algae reforming in the clear sections of pipe. The next step was to investigate how an ultra low concentration of chlorine dioxide, injected continuously into the irrigation system, would prevent algae and other microbial organisms from establishing their presence.

Figure 11 shows results of an experiment, which began with two consecutive overnight shocks of 50 ppm to ensure that all lines, including the center control line, were clean. Following the shock treatments ultra-low, continuous injection of chlorine dioxide started. Concentrations included, from top to bottom: 0.1, 0.25, control, 1.0, and 2.0 ppm, respectively. The picture was taken 12 weeks into treatment. Notice that the control line became dark green with re-established algae. Note also that the lowest concentration of 0.1 ppm (top line), while not nearly as green as the control, shows visible signs of the return of algae. Concentrations of 0.25 and higher all prevented re-establishment of algae. Based on these and other results, our recommended continuous concentration will be as little as 0.25 ppm following periodic shock treatments to keep the irrigation system and water algae free.

FROM RESEARCH TO THE COMMERCIAL GREENHOUSE

One of the most enjoyable and valuable aspects of my research is being able to take scientific results and apply them in my commercial greenhouse before making

Figure 11. Clear sections of lines following continuous injection of Selectrocide with untreated control in center.

general recommendations to fellow growers. I love this part of the process. My early research with Florel generated results that were so encouraging I actually considered questioning their accuracy. As soon as I saw the same results on my commercial crops I knew I had something significant to report.

The chlorine dioxide research that we've conducted to date is following the same path as Florel. The research manifold results presented above were so dramatic that we repeated them to make sure what we were seeing was real. Then, we developed a commercial recommendation that we tested on the rest of my greenhouse range.

With the cooperation of Hal Blakeslee from Anderson injectors and both Lela and Eddy Kelly from Dosatron International, we have developed a protocol that will allow growers with either type of injection equipment to perform both the shock and continuous treatments to obtain terrific results in traditional, nonrecirculating irrigation systems.

Anderson provided a 50-gpm unit to the project that I installed at the closest point to where municipal water enters my range. The injector was installed after the town water meter and an updated backflow preventor. I installed one access valve before the injector to be able to sample water off the street before treatment. It's the only valve on my range from which untreated water can be drawn.

The new Anderson unit began operation on 21 Jan. 2005. Half of my range was open and heated at that time, and the irrigation lines in these houses were given two overnight shock treatments at 50 ppm. On 23 Jan. I began injecting the continuous dose to treat every drop of water entering my range.

The Recommendation. Summarizing, the recommendation for using Selectrocide™ chlorine dioxide to prevent algae, slime, and other microbial growth from contaminating traditional nonrecirculating greenhouse irrigation systems is:

- Twice a year shock treatment consisting of two consecutive overnight charges of 50 ppm.
- Continuous injection to maintain residual level of 0.25 ppm for remainder of year.

Details of Injection. The EPA label for Selectrocide™ chlorine dioxide is based on a stock solution concentration of 500 ppm. Based on this concentration, in order to deliver the shock treatment an injection ratio of 1:10 is required. This will inject one part of 500 ppm stock solution into nine parts of water to achieve a diluted concentration of 50 ppm.

Once the shock treatment was mastered, the continuous dose was considerably easier to deliver. Our target concentration was 0.25 ppm. We began injecting this concentration on 23 Jan and immediately found that none of it was making it out the end of the hoses further downstream in the system. We realized that the 0.25 ppm of chlorine dioxide was being consumed by something in my water. The concentration was gradually increased until we could detect 0.25 ppm coming out of the hoses and mist nozzles. We settled on injecting 0.5 ppm to achieve the desired 0.25 ppm residual level downstream. At the time of writing, this injection strategy was into its 3rd month and working beautifully. To achieve the continuous injection of 0.5 ppm the stock concentration was lowered to 300 ppm. This allowed the injector to run within its usual range of injection ratios.

What About My Water? A major turning point in this project occurred when the microbiologist, upon sampling my town water as it entered my range, documented algae in the supply repeatedly. Learning that I have been paying to receive algae in my water all these years has been an eye-opening experience.

Immediately after learning this fact my treatment strategy changed. I saw no alternative but to do what was necessary to treat the water as soon as it reached my side of the meter. Before this realization, our strategy was to inject chlorine dioxide through my central fertilizer injector. The reason? The injector was already in place. The problem? Injecting at this point only treated half of my irrigation system. My range is designed with independent clear water and fertilizer lines in every house.

It makes sense that, once we documented algae in my water, the continuous injection needed to be high enough to kill the algae and still end up at the residual level of 0.25 ppm. I have been injecting 0.5 ppm continuously ever since. Occasional minor adjustments to the Anderson injection ratio have allowed me to maintain the desired target range using a stock solution concentration of 300 ppm.

Another aspect of the logic to treating every drop of water at its source is that, if the water is free of algae, then injecting fertilizer further downstream doesn't create the problem it once did. Without algae in the first place, the nutrients can't add fuel to a fire.

Continuous Treatment…Wow! A week after we began the continuous injection we began sampling my water to document the effects of this injection strategy into the entire irrigation system. Samples were taken immediately before the injector (untreated water from street), immediately after the injector, and directly from mist nozzles in my propagation house several hundred feet downstream. Sampling continued throughout the spring production season from January to June.

Water samples are taken directly to a laboratory for analysis. After culturing the water samples on agar in Petri dishes, colonies of bacteria, algae, and fungi are seen as small spots. One criterion used in water testing is the number of colonies per unit of water. The higher the microbial count, the higher the level of contamination of the sample. A second step in the analysis is sampling, culturing, and identifying the individual colonies.

Samples were taken several days after continuous injection of Selectrocide™ chlorine dioxide in January. The three samples were untreated water immediately before the injector (municipal), treated water immediately after the injector, and treated water from propagation house mist nozzles further downstream. The results have been stunning. A high concentration of microbial colonies, some of which were identified as algae, was found throughout the sample labeled "municipal." However, colony free samples resulted from the "post injection" samples immediately after the injector and "propagation house clear water" representing the sample from the mist nozzles.

A Picture and a Thousand Words. The treatment recommendation that we have developed is sound, and it works. The lab samples pictured above speak volumes…even water from highly treated municipal supplies contain levels of algae that can cause problems in our greenhouses. Pond, stream, and well water have all been shown to have the capability to contain algae.

I'm hoping that these research results and the knowledge we've acquired to date help convince growers who are having problems with algae and other, nonvisible microbial contamination that treatment as close to the water source as possible is the best strategy for achieving success. If our irrigation systems can be treated and maintained algae free, there will be one less avenue for this problem organism to enter the greenhouse. Keep reading, we haven't finished the story yet.

Anywhere Else that Algae Comes From? There is another piece of the algae puzzle we've been able to put into place during this project. Our microbiologist, after learning how crops are grown in a commercial greenhouse, told me that algae are capable of living in acidic peat bogs where our peat is harvested. During processing the peat is dried, which triggers the algae to go dormant. Once in a warm, moist, and fertilized container in the greenhouse the algae become active again and able to grow. In this environment, light is required and the accompanying pictures of draceana spikes below tell a familiar tale.

The curling mat of algae on this long-term crop speaks loudly about its water-repelling characteristic (Fig. 12). When developed sufficiently, it can be peeled off the growing surface in one piece. Notice also, just below the algae mat, that the growing mix is clean and fresh. In this environment, no sun…no algae.

Commercial Growing Media. Back in January we sampled several growing mixes and components that I had in my warehouse. We still blend our own growing mix using some topsoil, peat, coir, and rock wool and steam pasteurize it before use.

The picture to the right shows three cultures, clockwise from top: my freshly steamed mix, a commercial plug mix, and the raw peat/coir component used in my mix. Some of the microbial colonies in the plates represent beneficial nitrifying bacteria.

Figure 12. Crusted, water repelling algae mat on growing medium surface.

Unlike the goal of irrigation water, we do not want a microbe-free environment in the growing mix. With that said, we identified algae in all three samples. Wow! We are currently sampling from a larger number of commercial mixes to document the widespread presence of algae. Some of these mixes are being used in simulated growing conditions to determine if surface algae can be grown using sterile water. If we show this to be the case, it will add to our knowledge base and help identify another point of entry for algae in the greenhouse.

Before ending this issue, take a look at the two drip emitters pictured in Fig. 4. On the right is an emitter I removed from a hanging basket drip line after finding it had failed. Note the accumulation of biofilm at the tip, which has plugged the emitter. We analyzed the plug and have confirmed that it is not particulate matter that passed through my filter but, rather, biofilm and algae that have become established inside the line. On the left is a new emitter for comparison.

For now, I'll leave you with the following message regarding this exciting research. **To Be Continued…**

Recent Advances in Cutting Propagation©

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INTRODUCTION

Staying abreast of research developments is a challenge in any area of science and, perhaps, even more so in the relatively obscure area of fundamental and applied research of adventitious root formation on cuttings. There are not a large number of scientists doing plant propagation research, certainly fewer than there were even a few decades ago. As well, there are several journals that publish propagation findings, so there is not just one place to turn for timely information. Traditionally, more applied work was found in the *Combined Proceedings of the International Plant Propagators' Society* (CPIPPS), and more fundamental research was published in the *Journal of the American Society for Horticultural Science* (JASHS) or *HortScience* (HS). In the last 15 to 20 years, however, several other publishing venues have gained in popularity, including the *Journal of Environmental Horticulture* (JEH), the *Proceedings of the Southern Nursery Association* (SNA), and *HortTechnology*. Add to that the ease of using the Internet to find published and anecdotal information on propagation, and it is more apparent why so much less is being published in JASHS, HS, and CPIPPS.

Many industry professionals turn first to articles published in the popular literature — *American Nurseryman, NMPro, Grower Talks*, etc. Articles in these publications typically are written by one of the magazine editors or a respected horticultural scientist or extension faculty. The information usually is very basic, along the lines of an introductory textbook, and review years of work or industry practice, so are less up-to-date than the scientific literature. On the other hand the work is described in language that can be taken straight to the propagation house and put into practice by the average plant propagator.

Growers who are more technologically oriented, or who have an advanced degree in horticulture or a related science, may feel they can tackle the refereed scientific literature. This information is written by the scientists who did the work and, hopefully, is published no more than a few years after the work was completed. As well, the work often was done through a grant funded by a horticulture granting agency like the Horticulture Research Institute (HRI) or the U.S.D.A. and so has already passed a degree of scientific muster. However, many propagators may not feel they are qualified to read this level of scientific literature. My advice to these folks is to identify someone on your staff, or hire someone, to do this reading for you — as you will see in the examples below, there may be research results that will apply directly to your production system, and save you lots of money!

Of course, this disconnect between what the industry reads and what horticulture scientists publish is why the International Plant Propagators' Society (I.P.P.S.) was founded, as a venue for the interaction of all persons interested in plant propagation. Many I.P.P.S. members cite as a major attraction of I.P.P.S. and the annual meetings the opportunity to network with others with a range of training, from

practical propagation-bench, to public garden, to large-scale industry, to university laboratory. To this I would add that I.P.P.S. attendees on tours should pay attention — since the propagator doing a dog-and-pony show at the nursery, but not attending the talks, may have some valuable information to share.

As I browsed scientific literature from 2003 to 2006 in the preparation of this paper I was surprised and a little disappointed to find that, despite the importance of plant propagation to the nursery industry, there is relatively little research information making its way into the literature. As mentioned above there are fewer nursery-production-oriented research faculty in our Land-Grant universities than ever before, and there remain few significant grant opportunities for research on plant propagation issues. On top of that there is unprecedented competition for faculty positions and funding from all those areas of research that fall under the umbrella of "biotechnology," which hold great promise for all aspects of plant production, but which also are expensive to develop and maintain — leaving little behind for applied horticultural science. So, these days, most propagation research is undertaken by those faculty and individuals who are passionate about the subject — indeed, passionate enough to carry on with limited or no funding.

Given the paucity of propagation research being published, one might reach the conclusion that all the important work was done in the 20th century — the heyday of horticultural research — but this is far from the truth. Now more than ever there is a need to maximize propagation and production efficiencies, in light of ever-rising fuel, materials, and labor costs. There are so many new plant species that are not described in past literature, and the differential behavior of cultivars is evident in all aspects of plant production.

Surprisingly there have not been the advances in the biotechnology or chemistry of adventitious root formation that we anticipated just 20 years ago. While we have more genetic mutations associated with adventitious rooting at our disposal than ever before, we have yet to learn anything we didn't know decades ago — and unless a significant economic incentive develops we may remain in the dark, well into the future, about many aspects of root formation and growth. A partial solution to this dilemma may rest in using cutting-edge genetic tools to re-evaluate stock plant and cutting pretreatments to rooting that were reported in the past and not followed up. Again and again a particular method, e.g., the etiolation of stock plants, will be studied intensively during the careers of a few horticulture scientists, then fade into obscurity. This, of course, is why we are so fortunate to have resources like the textbook *Plant Propagation: Principles and Practices*, and the CPIPPS to serve as a record of propagation methods only partially developed. Biological Science is now in a position to expose the underlying genetic and physiochemical controls that facilitate some of these novel propagation techniques — if only someone will take up the mantle!

Given the many sources of information available to us, and the many forms this information may take, there is always a need to look around at that research that is being published in the literature today — to see what is new or being given new importance. I am pleased to have this opportunity to review new advances in cutting propagation for the Eastern Region, North America, and quite surprised by some of the things I found. To maintain some semblance of organization I have grouped the research I chose to share into three broad categories, presented from more fundamental to more applied: cutting physiology, plant growth regulators,

and propagation/production efficiencies. One area of research I have omitted is that of new plant propagation research. While this is important to the industry, there is not much "new" in cutting propagation that takes place when a researcher evaluates the rooting potential of a previously undocumented plant species, though the work, or course, stands on its own merits as original research.

CUTTING PHYSIOLOGY

In the area of the physiology of cutting propagation papers came out in the last few years in two basic areas that seem applicable to I.P.P.S. readers. A series of excellent papers by Anthony LeBude of NCSU describe the relationship between mist irrigation and cutting water potential, with the goal of being able to use computer-controlled mist irrigation in the most effective way to maximize rooting and root growth. The studies were presented over 2 years at research meetings of the Southern Nurserymen's Association (2003 and 2004) and were published in *Tree Physiology* (2004) and *HortScience* (2005). The impetus for this work was the observation that cuttings of loblolly pine, *Pinus taeda*, rooted better when they experienced moderate water stress (on the order of -0.5 to -1.2 MPa) during the initial 4–5 weeks in the rooting bench. Cuttings that were too wet or too dry did not root well. Using a mist research system based on a computer controlled irrigation boom, LeBude first linked cutting water potential (Ψ_w, which requires a destructive measurement) and rooting percentage. He then worked to link Ψ_w with vapor pressure deficit (VPD), which is essentially the evaporative potential of the cutting and is easily measured with a thermocouple and relative humidity sensors. LeBude showed that Ψ_w and VPD were both good predictors of the rooting potential of loblolly pine cuttings, opening up the prospect of dynamic environmental control of cutting irrigation. It is easy to envision mist levels being controlled by computers sensing VPD and giving the propagator unprecedented control over cutting water status. It is not known if the stem cuttings of all plants benefit from mild water stress during rooting — that research still needs to be done.

One researcher who has worked steadily on cutting physiology is Dan Struve of Ohio State University. Professor Struve has been trying for many years to solve the problem of poor overwinter survival of cuttings of certain species rooted in the summer that fail to produce new growth before winter sets in. Work in the past has focused on forcing new growth on rooted cuttings — with mixed success. Sometimes it is almost impossible to get cuttings to break bud again in the fall. Struve and a visiting scientist, Phillip Wilson, sheared stock plants of *Viburnum dentatum* to induce new axillary shoot growth before taking the cuttings. The idea was that if new shoot growth is pushing before the cuttings are taken, the shoots are more likely to continue growth after rooting. They also looked at incorporating controlled-release fertilizer (CRF) in the rooting medium as a means of increasing the new shoot growth. Wilson and Stuve found that cutting with actively growing axillary shoots grew more in the same year, and overwintered better, than cuttings from unsheared stock plants. Using CRF also increased growth both before and after overwintering. These results, found in the Spring 2006 issue of the *Journal of Environmental Horticulture*, should be applicable to other species that are notoriously difficult to overwinter, such as *Stewartia* and red maple. Cutting survival was influenced by the amount of axillary shoot growth in the present study, and the best time and degree of shearing would need to be determined for each species.

PLANT GROWTH REGULATORS

A number of papers have come out in the literature recently on novel methods of applying auxin to cuttings. The majority of this work has come from Dr. Jeff Sibley's group at Auburn University in Alabama, in collaboration with Dr. Ken Tilt of Auburn and Dr. John Ruter, a researcher for the University of Georgia who is based in Tifton. I had a number of papers to draw on — all authored by Gene Blythe, a graduate student with Dr. Sibley — from the I.P.P.S. proceedings (Southern and Western regions), the proceeding of the Southern Nurserymen's Association, and *Scientia Horticulturae*, an international horticultural science journal based in Great Britain. Because the synthetic forms of auxin used in plant propagation are potentially carcinogenic and more restrictions in the use of auxin for commercial plant propagation are likely, there is a need for research into novel methods of applying auxins that reduce worker exposure and the amount of auxin used in the industry. Despite the obvious need for more research in this area there has been remarkably little work reported in the literature.

Sibley's group has taken the lead in investigating two methods of applying auxins: through the rooting medium or via the cutting foliage. The foliar auxin work is based on research done in the 1960s by Professor John McGuire of the University of Rhode Island (my predecessor) and reported in early I.P.P.S. Proceedings. McGuire showed that isotopes of indole-3-butyric acid (IBA) applied to the base of cuttings were rapidly redistributed throughout the stem and leaves of the cutting. Blythe and coworkers took this as support for their hypothesis that auxins applied to the foliage should move to the cutting base and stimulate adventitious root formation. The present research used a range of plants in controlled comparisons of foliar sprays with conventional quick dips. The auxin formulations varies, but were based for the most part on dilutions of Dip 'N Grow® (Dip 'N Grow, Inc., Clackamas, Oregon). Foliar-applied auxin did not work as well as might have been hoped. The rooting response of cuttings treated with foliar auxin generally was equal to or less than those treated with a quick dip. One drawback with the species chosen for these studies was that for the most part they rooted fine without any auxin, so benefits of even the quick dip treatment were not always obvious. On the other hand, in certain species, shoot growth was inhibited, suggesting that auxin levels were too high in the shoots and not high enough at the base of the cuttings. The authors concluded that the foliar-applied auxin was not moving to the base of the cuttings in sufficient amounts to affect adventitious root formation.

In a similar vein, Sam Drahn of Bailey's Nursery reported, in the 2003 Western Region CPIPPS, on using Hortus water soluble IBA salts with a backpack or boom sprayer to treat cuttings of 30 plant taxa on a commercial scale. The goal of his studies was clearly to reduce to costs associated with sticking the millions of cuttings that Bailey's processes each year. Drahn experimented with much higher rates of foliar auxin than used by Sibley's group, in the range of 750 to 2,500 ppm, and again compared these treatments to a conventional quick dip. Though the optimal rate varied with the species, the foliar sprays worked well, and only in a few cases was any auxin toxicity apparent. Drahn went on in his paper to analyze the costs of each treatment and concluded that foliar sprays are an economical alterative to treating individual cuttings before sticking. I followed up with Sam, who reported that his trials are continuing with great success. He has been very impressed with

the savings in labor and overall production costs and looks forward to switching the majority of his cutting propagation over to foliar auxin treatments.

In contrast to their results with foliar sprays, Blythe and coworkers' studies using auxin-pretreated rooting plugs (Q Plug™, International Horticulture Technology, Inc., Hollister, California, USA) worked quite well, with very low auxin concentrations (< 45 ppm) working as well as a quick dip auxin treatment for a range of species. At higher concentrations (> 45 ppm) a number of species began to exhibit symptoms of auxin toxicity, such as stunted roots, rooting higher up on the cutting, and delayed shoot growth. I contacted the authors about the longer-term effects of the auxin-laden plugs on subsequent plant growth. They reported back that the rooted plugs continued to grow well (presumably when using lower auxin rates). This is a promising technology that clearly deserves further research and commercial development. Using pre-treated plugs could dramatically reduce worker exposure to auxin as cuttings are being prepared and could also reduce the waste and environmental concerns associated with discarding unused dips or powders that have been contaminated during use.

PROPAGATION/PRODUCTION EFFICIENCY

Finally, I ran across a rather unlikely paper by a German scientist in the pages of the 2003 CPIPPS of the Great Britain and Ireland region. This paper, by Professor Wolfgang Spethmann of the University of Hannover, described a number of experiments with a wide range of woody plants using long cuttings to reduce production time and produce standards for grafting. Spethmann's strategy was to use cuttings in the range of 24 to 100 inches long that are then rooted in high humidity. He employs a peat-sand rooting medium and a plastic greenhouse with high-pressure fog. Spethmann has done a lot of work with the dog rose, *Rosa* 'Pfänders Canina', for use in rose standards. But what really caught my eye was a table of rooting results for what are traditionally thought of as difficult-to-root trees: *A. platanoides*, *Carpinus betulus*, *Pyrus* sp., *Quercus robur*, *Tilia cordata*, and *Ulmus* 'Regal', as well as apple, cherry, and pear. Cutting lengths for these taxa varied from 39 to 93 cm (15 to 36 inches), and stock plant ages up to 30 years old, and yet rooting ranged from 57% (*Pyrus* cv.) to 80+% for *Tilia*, *Carpinus*, *Quercus*, and 97% for *A. platanoides*. As my mother used to say, "Who would've thunk it?!" These can only be termed phenomenal results — certainly worthy of our scrutiny and follow-up research.

Spethmann's method presents a striking contrast to the normal practice of taking cuttings in the range of 5–20 cm (2 to 8 inches) — and getting weaker rooting responses! I can image that this technology could draw upon a coppiced stock block — taking advantage of the rejuvenation that comes with repeatedly cutting back the stock plant — maintained to produce long cuttings. Though I am sure this technique will not work for everything, it struck a chord with me because of my recent efforts to propagate Canadian hemlock, *Tsuga canadensis*, from mature adelgid-resistant forest trees. Last winter (February) I grafted putative resistant hemlock wood onto seedling Canadian hemlocks and had a number of branches left over from which all the suitable small cutting wood had been removed. On a whim, we treated the branches — ranging from 6 to 12 inches (15 to 30 cm) in length, and including some 2-, 3-, and perhaps even 4-year-old wood, with Hormex 45 (4.5% IBA in talc) and stuck them under mist in perlite and peat (4 : 1, v/v) with 70 °F

bottom heat in a poly greenhouse set to 65 °F. Contrary to our expectation, the grafted plants failed completely, while the long cuttings rooted better than 60%. These cuttings also formed good root systems and grew on well the following growing season, while a group of shorter cuttings, which had rooted only 10%–25%, suffered high mortality or grew poorly.

In a series of follow-up communications, Professor Spethmann emphasized the use of high-pressure fog, the benefit of cutting back the stock to promote long shoot growth, the use of current year shoot growth, and taking cuttings (of sycamore maple, *A. pseudoplatanus*) from low on the stock plant. He continues an active research program with long cuttings — stay tuned for more exciting results from this effort.

In conclusion, my review of cutting propagation literature from 2003 to early 2006 revealed that in certain areas the science and art of propagation by cuttage does move forward, albeit at a slower pace than in decades past. While there is some work in molecular biology of rooting taking place, the majority of applied nursery propagation literature is still found in relatively few journals and proceedings, and it is obvious that there are fewer nursery-oriented horticulture scientists and faculty than there used to be. It was also very apparent to me that though it may be time consuming and a difficulty for propagators to keep up on the literature, there are important developments being reported that should not be missed — the professional can not afford to get behind on the literature if he wants to remain competitive. I am pleased to represent the International Plant Propagator's Society in my efforts to keep you informed — Seek and Share!

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Flowering Shrubs: Shaking Up the Market©

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Spring Meadow has a long reputation for seeking out and introducing new and interesting shrubs. About 25 years ago we decided to make a concerted effort to work directly with plant breeders to protect and introduce new shrubs and to sell them under an umbrella brand. We currently represent breeders in Japan, Korea, Canada, Netherlands, Germany, England, Poland, France, Belgium, and the United States. Initially we sold plants under the name ColorChoice®, and 3 years ago we partnered with the marketing co-op Proven Winners® and now sell our new shrubs under the Proven Winners ColorChoice™ brand. From the beginning our intention was to change the way people view flowering shrubs. If you look at the plants that we've introduced and the way we market them you can see that in many ways we are emulating the perennial market.

In determining which plants to introduce under the Proven Winners brand we developed a selection criteria that is based heavily on a criteria list developed by J.C. Raulston. Past experience in producing and selling perennials also influenced the criteria. The criteria we utilize keep us focused and help us to define what makes the Proven Winners ColorChoice program unique and different from other branded programs. While no plant meets all the criteria, we seek to obtain as many characteristics as possible.

PROVEN WINNERS COLORCHOICE PLANT SELECTION CRITERIA

1) The plant must root from cuttings. We have passed on some really good plants that are propagated by budding or grafting, but we are a propagation nursery by trade so it only makes sense to choose plants that root from cuttings.
2) The plant has to perform in production. We have to be concerned that the plant grows well for our customers as well as for us. We work with about 80 licensed growers and sell to about 3,000 customers so we have to be concerned with production.
3) A plant must look good in a container. After all this is how the majority of our plants are produced and sold.
4) The plant has to have retail appeal, or better said "impulse appeal." Garden centers don't have many salespeople so the plant needs to sell itself.
5) We look for plants that are colorful during the spring selling season. The vast majority of plants are sold from April to mid-June. If a plant is in bloom or is at its best during this time it will sell at a much great level than if it blooms in August when no one is in the store.
6) We want plants that have attractive or colorful foliage. Plants with beautiful foliage sell regardless of bloom. It's a bonus if they also bloom in spring but if they have red foliage they'll sell even when they're done flowering. This extends the selling period, and it offers the end-consumer a plant that is attractive all season long in their garden.

7) We look for plants that grow over a wide geographic area. When you are promoting a plant on a national level you want it to perform on a national level. A plant like Limelight hydrangea grows from Manitoba to Orlando, which makes doing a national marketing campaign possible.
8) We look for plants that have multiple seasons on interest. The more interest the longer selling period, and it provides more pleasure to the end-consumer.
9) We want plants that have a unique new look or use. New forms offer new landscape and garden uses and broadens the number of applications in which a plant can be used.
10) We actively seek out plants that are dwarf or compact. My Monet® weigela is the perfect example of this. Typically a large shrub is used as a specimen; the dwarf My Monet weigela can be used as a ground cover and hence in much greater quantities. People don't have the knowledge or the time to prune, and these plants solve that problem.
11) Last but not least, the plant has to perform in the landscape or garden. It has to be more than just new; it has to perform, because for better or worse, people will have an experience with your brand and they will remember it is a good experience or a bad experience.

The end result of our selection criteria is to: (1) Provide growers with value in that they are easy to grow and easy to sell; (2) Provide retailers value in plants that sell faster and over a longer period of time; and (3) Provide the consumer with plants that are easy to grow and incredibly colorful. To be commercially successful a new plant must provide value to everyone down the line a plant.

Now let's look at some of the plants Spring Meadow has introduced. All of them are easy to grow and root, and most grow over a wide geographic area and look good in a container so I will just concentrate on just a few of the other criteria. Many of these plants have multiple selling characteristics but for the sake of time I've placed the plants in the most applicable heading.

SELLING CHARACTERISTICS

Colorful or Attractive Foliage.
Golden Anniversary™ abelia (*Abelia* ×*grandiflora* 'Minipan')
Silver Anniversary™ abelia (*A.* ×*grandiflora* 'Panache')
Sunshine Blue® bluebeard (*Caryopteris incana* 'Jason')
Golden Shadows® pagoda dogwood (*Cornus alternifolia* 'W. Stackman')
Blondy® euonymus (*Euonymus fortunei* 'Interbolwi')
Dream Catcher™ beautybush (*Kolkwitzia amabilis* 'Maradco')
Golden Lanterns® pheasant berry (*Leycesteria formosa* 'Notbruce')
Coppertina™ ninebark (*Physocarpus opulifolius* 'Mindai')
Black Lace™ elderberry (*Sambucus nigra* 'Eva')
Snow Storm™ spirea (*Spiraea media* 'Darsnorm')
'Eyecatcher' (*Weigela florida*)
Wine & Roses® weigela (*W. florida* 'Alexandra')

Colorful Foliage and Compact.
Summer Wine® ninebark (*P. opulifolius* 'Seward')
Fine Wine® weigela (*W. florida* 'Bramwell')
Midnight Wine® weigela (*W.* 'Elvera')
My Monet® weigela (*W. florida* 'Verweig')

Dwarf or Compact.
English Butterlies™ Series (*Buddleia davidii*): 'Adokeep', Adonis Blue™ butterfly bush; 'Peakeep', Peacock™ butterfly bush; 'Pyrkeep', Purple Emperor™ butterfly bush
Petit Bleu™ bluebeard (*C.* ×*clandonensis* 'Minbleu')
Arctic Fire™ redosier dogwood (*C. sericea* 'Farrow')
Arctic Sun™ bloodtwig dogwood (*C. sanguinea* 'Cato')
Lil' Kim™ rose of Sharon (*Hibiscus syriacus* 'Antong')
Cityline™ Series (*Hydrangea macrophylla*): 'Venice Raven', Cityline® Venice; 'Berlin Rapa', Cityline® Berlin; 'Paris Rapa' Cityline® Paris; 'Vienna Rawi', Cityline® Vienna
'Little Lamb' (*H. paniculata*)
Little Henry® virginia sweetspire (*Itea virginica* 'Sprich')

Impulse Appeal.
Chiffon Series™ rose of Sharon (*H. syriacus*)
Satin Series™ rose of Sharon (*H. syriacus*)
Hydrangea macrophylla 'Claude'
Hydrangea macrophylla 'Shamrock'
Pinky Winky™ panicle hydrangea (*H. paniculata* 'DVPinky')

Unique Use or Look.
Castle Wall® holly (*Ilex* ×*meserveae* 'Heckenfee')
Castle Spire® holly (*I.* ×*meserveae* 'Heckenstar')
Fine Line® buckthorn (*Frangula alnus* 'Ron Williams')
Pink Parasols™ spirea (*S.* 'Wilma')

Multiple Seasons of Interest.
White Dome® smooth hydrangea (*H. arborescens* 'Dardom')
Quick Fire™ panicled hydrangea (*H. paniculata* 'Bulk')
Cardinal Candy™ linden viburnum (*Viburnum dilatatum* 'Henneke')
Brandywine™ smooth withered viburnum (*V. nudum* 'Bulk')

Blooms During the Spring Selling Season.
Chardonnay Pearls® deutzia (*Deutzia gracilis* 'Duncan')
Show Off™ forsythia (*Forsythia* × *intermedia* 'Mindor')
Bangle™ woadaxen (*Gensita lydia* 'Select')

Outstanding Performance in Production / Garden.
Fire Ball® winged euonymus (*E. alatus* 'Select')
Gold Splash® wintercreeper euonymus (*E. fortunei* 'Roemertwo')
Pink Shira™ bigleaf hydrangea (*H. macrophylla* 'Sonmarie')
Hydrangea paniculata 'Limelight'

Oso Easy™ Roses
- Fragrant Spreader rose (*Rosa* 'Chewground')
- Paprika rose (*R.* 'ChewMayTime')
- Peachy Cream rose (*R.* 'Horcoherent ')

Techny Gold™ arborvitae (*Thuja* ×media 'Walter Brown')
Spring Grove® western arborvitae (*T. plicata* 'Grovpli')

The Early History of the International Plant Propagators' Society©

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Creation of the International Plant Propagators' Society can be credited to the vision and commitment of numerous people, especially Edward H. Scanlon (1903–1976), and to Scanlon's *Trees Magazine*, which routinely announced happenings about the Society and its members. Summarized here are some of the events and personalities that led to the Society we know today.

Edward H. Scanlon started several professional organizations devoted to trees and especially to people who worked with trees. He capitalized upon his position as editor/publisher of *Trees Magazine* to promote the need for the new organizations and their various events. Unfortunately, this widely read magazine was no longer published after his death in 1976.

"It is the belief of *Trees Magazine*," Scanlon wrote, "that a new organization is badly needed and would be enthusiastically supported by progressive nurserymen, scientists, and arborists" (Scanlon, 1951a). He proposed to name the new group the Plant Propagators Society and invited all persons interested in this new organization to contact him. (Many years later an apostrophe was added to "Propagators" in the Society's name, hence it is used accordingly throughout this article.)

"Arrangements are proceeding," he later wrote, "for the organizational meeting of the Plant Propagators Society to be held in Cleveland, Ohio, Nov. 8th and 9th, 1951" (Scanlon, 1951b). He thought such an organization would provide critically needed information on plant propagation "about which so little is known and is beset with so many vagaries." Nonetheless, Scanlon must have worried about the success of this first meeting, because he also announced it on two other pages in the same September-October, 1951, issue of *Trees Magazine* (Scanlon, 1951c, 1951d).

As it turned out, this organizational meeting in 1951 was successful beyond hope. Spirited discussion set the tone for very healthy and protracted questioning by a large majority of the 75 nurserymen, scientists, arborists, and public officials who attended the meeting. An Organizational Committee was set up, with Scanlon as temporary chairman (Anonymous, 1951a). At its continued deliberations the following July, this Committee and others in attendance, all functioning as charter members, adopted a constitution and elected the following officers: James S. Wells, president; Dr. L. C. Chadwick, vice president; and Edward H. Scanlon, secretary-treasurer (Anonymous, 1952a; Scanlon, 1952).

Both Wells and Chadwick continued in their offices a second year (Anonymous, 1952b). Chadwick was president the third year (Anonymous, 1953), and member of the executive committee the fourth year (Anonymous, 1954).

Scanlon was Secretary-Treasurer of the Society during its first 3 years (Anonymous, 1951b, 1952b, 1953), and vice president and president in the fourth and fifth years, respectively (Anonymous, 1954, 1956). He might have edited the Proceedings of the first and possibly the second annual meetings, neither of which has an editor identified.

This inference is supported by two observations. He is the author in the first Proceedings of promising tree species and selections. As Commissioner, Division of Shade Trees, Cleveland, Ohio, at the time, he knew the need for trees of consistent form instead of the usual variability among seedling trees. He also hoped propagators would produce more of such trees. Thus, the article features twelve full-page photographs of tree species and selections of globular, pyramidal, and fastigiate forms, including the pyramidal *Acer rubrum* 'Bowhall' red maple and the fastigiate *A. rubrum* 'Armstrong' maple (Scanlon, 1951e).

Another reason to infer that Scanlon had been the first editor is the core of the Society's logo (Fig. 1), which is "two hands cutting a bud from a stem with a budding knife." It is featured on the front cover of all of the Proceedings, beginning with the first one. Scanlon had found this logo in a 1920 edition of *The Nursery Manual*, authored by the eminent horticulturist, Liberty Hyde Bailey (Scanlon, 1976). Predating this publication was an earlier edition, titled, *The Nursery Book*, by the same author, published as early as 1906 (Keen, 1954), which suggests the logo alone may be at least 100 years old. It was first associated with the Plant Propagators Society in *Trees Magazine* with an announcement that the Proceedings of the Society's initial meeting had been published (Anonymous, 1952c).

Annual meetings and events of the Plant Propagators Society were regularly publicized in *Trees Magazine*. New officers elected at the fourth annual meeting, for instance, were shown in a group photograph (Fig. 2) in *Trees Magazine*. Dr. L.C. Chadwick was the retiring president, Scanlon, the new vice president, and Dr. William Snyder, the new secretary-treasurer. Richard H. Fillmore, the new president, could not attend the meeting due to illness (Fig. 3) (Anonymous, 1956).

Figure 1. This core of the IPPS logo first appeared in the March-April 1952 issue of *Trees Magazine* in an announcement of the availability of the Proceedings of the first annual meeting of what is now the International Plant Propagators' Society. The logo had first been published in various editions of The *Nursery Manual* and its predecessor, The *Nursery Book*, by Liberty Hyde Bailey, prolific author of numerous books on horticulture and related subjects.

Figure 2. "New and retiring officers of the Plant Propagators Society are shown at the Society's fourth annual meeting in Cleveland, Ohio, in December 1954. Left to right: Edward H. Scanlon, newly elected vice president and retiring secretary-treasurer; Dr. William E. Snyder, Cornell University, new secretary-treasurer; and retiring president, Dr. L. C. Chadwick, Ohio State University. New president, Richard H. Fillmore, was unable to be present." [Anonymous, 1955a]

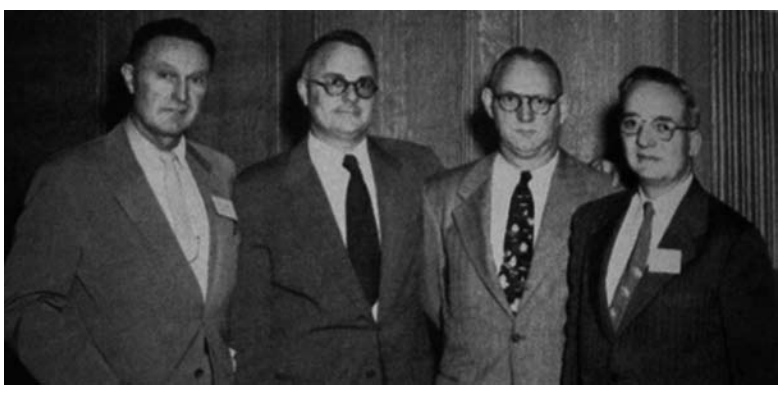

Figure 3. First four presidents of the Plant Propagators Society, left to right: Edward H. Scanlon, 1955-56; James S. Wells, 2 years, 1951-53; Dr. L. C. Chadwick, 1953-54; Richard H. Fillmore, 1954-55. (Photo, exclusive of caption, from Trees Magazine 14(2):12, 1954)

When I was a graduate student at Ohio State University and research fellow of the Ohio Nurserymen's Association, I was fortunate to attend the fifth annual meeting (Anonymous, 1955b) with my major professor, Dr. L.C. Chadwick, to report results of my research on growing woody landscape plants in containers under Ohio climatic conditions (Barker, 1955).

Two years later, when I was a lecturer in the Department of Landscape Management at the University of California, Davis, I helped promote the Plant Propagators Society in western North America. One day I called on Dr. Hudson T. Hartmann, who taught plant propagation at the University of California, Davis. Dr. Hartmann and his colleague, Dr. Dale Kester, had just published the first edition (now in the seventh edition) of their universally popular textbook on plant propagation (Hartmann and Kester, 1959).

I told Hartmann about the enthusiasm among plant propagators at the December 1955 meeting of the Plant Propagators Society in Cleveland. "Many of them," I said, "vigorously expressed bold opinions." In the membership roster in the Society's latest proceedings, I had noted that very few members lived west of the Mississippi River. I told Hartmann that the lively discussion on plant propagation topics I had witnessed in Cleveland, Ohio, likely would prevail at a similar meeting of plant propagators on the West Coast. Hartmann concurred (Fig. 4).

In 1960, after receiving very positive responses from our widespread survey of plant propagators and other interested parties in western North America, we held an exploratory meeting in Davis, California. Twenty-two people attended. Two nurserymen from the San Francisco bay area in California were elected to lead the group: Don Hartman as chairman, and Herman Sandkuhle, Jr. as vice chairman (Fig. 5). (Note the slightly different spelling of the surnames of Don Hartman and Dr. Hudson Hartmann.) Don's father, Ray D. Hartman, of San Jose, California, had participated in the Society's organizational activities about a decade earlier (Anonymous, 1952d;Scanlon, 1952).

Several organizational meetings were held in Davis, California, throughout the summer of 1960, primarily focusing on developing a program for an initial western

Figure 4. Phil Barker (left) and Dr. Hudson Hartmann initiated a meeting of western plant propagators in 1960, leading to the Plant Propagators Society (PPS) becoming the International Plant Propagators' Society (IPPS), with autonomous regions.

Figure 5. Herman Sandkuhle, Jr. (left) and Don Hartman represented the western plant propagators at the Tenth Annual Meeting of the Plant Propagators Society in Cleveland, Ohio, in 1960. By acclamation of the Society officers at this meeting, they became charter vice president and charter president, respectively, of the new Western Region, International Plant Propagators' Society (Anonymous, 1960).

meeting of plant propagators. The meeting was held 14–17 October 1960 at the Asilomar Conference Grounds, beside the sandy beach of the Pacific Coast, approximately 80 miles south of San Francisco, California.

The meeting was a pinnacle of success, both in terms of hoped-for attendance and the cogent topics presented by knowledgeable and interesting speakers. The fall weather was perfect, and the waves of the Pacific Ocean applauded our camaraderie. Especially noteworthy was the presence of six members of the Plant Propagators Society who lived east of the Mississippi and their optimistic speeches about the inevitable benefits of membership in the Plant Propagators Society. These members were Richard H. Fillmore, John Mahlstede, Ph.D.; Kenneth Reisch, Ph.D.; Hugh Steavenson, Harvey Templeton, and James S. Wells.

In his provocative keynote address, Wells (1960a) reiterated what he had said in his keynote address at the initial meeting of the Society 10 years earlier, citing the critical value of plant propagators. In his summary statements, he avowed, "the plant propagator is one of the strongholds of the real craftsman."

Fillmore's (1960) delivered comments were philosophical and convincing: "The Plant Propagators Society has meant a great lessening of professional loneliness. We all need each other, and the place to find each other is in the Plant Propagators Society."

The tone of the entire meeting was upbeat, with obvious recognition by everyone of its historic significance. Hartman and Sandkuhle were designated to attend the forthcoming tenth annual meeting of the Plant Propagators Society in Cleveland, about 6 weeks later, from 1 to 3 Dec. 1960 (Fig. 5). Their "marching orders" were

Figure 6. Don Hartman, 85 (left), and Dr. Phil Barker, 81, reminisced about the formation in 1960 of the Western Region in North America of the International Plant Propagators' Society during their visit together in Davis, California, May 31, 2006. Don lives in Murphys, California, which is in the western foothills of the Sierra Nevada Mountains, and Phil lives in Davis, California, in the San Joaquin Valley, 100 miles (160 km) east of San Francisco.

for this western group to become part of the Plant Propagators Society, but with distinct autonomy (politically independent and self-governing) and to publish a combined proceeding with the original group.

Despite the favorable outlook of the six eastern emissaries who had attended the California meeting about 6 weeks earlier, Hartman and Sandkuhle sensed that many attendees at this December meeting in Cleveland were skeptical about reorganizing the Society. Both of them worried that reorganization of the Society as proposed by the western group might not become a reality.

On the last night of the meeting in Cleveland, Hartman awoke Sandkuhle; together, they roused leaders of the Society out of their sleep. In the wee hours of the night, they hammered out details of a logical reorganization plan (personal communication with Don Hartman (Fig. 6). Reorganization of the Society was approved the next morning, following eloquent commentary and an affirmative motion by Wells (1960b). [Recollections of this historic event as well as current photos of many of the early participants were published four decades later in the Pacific Coast Nurseryman (Anonymous, 2000)].

Consequently, the Plant Propagators Society, with membership primarily in eastern North America, became the International Plant Propagators' Society (IPPS), with autonomous Eastern and Western Regions within North America. A combined proceedings of their annual meetings would henceforth be published under the auspices of International officers. Growth of the organization since then has been remarkable. Presently, there are nine regions throughout the world, with current membership exceeding 2,200.

Two selected articles from the 2004 Proceedings demonstrate the truly international nature of this organization. For example, du Toit traveled from Pretoria, South Africa, to attend the Eleventh Annual Meeting of the IPPS Japan Region in Hamamatsu, Japan. At this meeting, du Toit (2004) reported on leading-edge propagation research on an indigenous shrub used for medicinal purposes in South Africa. Mike Evans from San Juan Capistrano, California, greeted attendees at this same meeting. As incoming president of the International officers of the Society, Evans (2004) invited them to the meeting the following year of the IPPS Western Region in North America, where the International officers, who rotate annually among the various Regions, would be meeting.

The benefits of plant propagators having a mutual professional organization are profound. The meetings and the Combined Proceedings are exemplary vehicles of technology transfer. They foster international dialogue among plant propagators and plant scientists, and have promoted cross-cultural visits and unlimited exchange of information on plant propagation principles and practices. Plant propagators and plant scientists alike share their practices and research results with each other on a myriad of topics. Moreover, information from these sources is routinely used to update plant propagation texts of worldwide distribution.

Through timely intuition, Edward H. Scanlon tossed a pebble in the water, making ripples that have radiated worldwide, resulting in what is now the esteemed International Plant Propagators' Society.

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Breeding, Propagation, and Production of Clematis©

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INTRODUCTION

The Guernsey Clematis Nursery Ltd. and Raymond J Evison Ltd. are two companies based on the small island of Guernsey situated just 50 miles north of the coast of France and 100 miles south of the coast of England (in the English Channel). The island itself is just 24 sq. miles. Its size and location gives it a very mild and moderate climate with a maximum summer temperature that seldom reaches 30 °C (85 °F) and winter temperatures that rarely drop much below freezing and never for prolonged periods. With the history of horticulture on the island and infrastructure in place, plus the beneficial climate, Guernsey became an excellent location for glasshouse production. The main disadvantage of growing on Guernsey is that of export, with an ever-increasing cost to transport goods from the island to mainland Europe.

The Guernsey Clematis Nursery Ltd. began in 1985, set up by its founder, Raymond Evison, for the production of young clematis. This has developed over the last 20 years to the nursery that now has 9 acres of glass (3.6 ha) with the majority of production carried out on Ebb & Flow benches with much automation and computer-controlled climate zones. The nursery now produces 3 to 4 million young plants annually, of about 200 species and cultivars, and exports to 18 countries worldwide.

His love for the genus has taken Raymond Evison around the world on plant hunting expeditions and prompted him to write a number of books dedicated to the promotion of clematis and their extensive diversity as a genus and their many uses in the garden. He has been responsible for the introduction of many species and cultivars and has a passion for clematis old and new that has earned him many awards and medals of recognition for his contribution to the horticultural industry including: The Victoria Medal of Honour by the RHS for his Outstanding Service to British Horticulture, Exporter of the Year Award by Nurserymen and Garden Centre Awards in London, The Lawrence medal for his exhibits at the Chelsea Flower Show, and an OBE by Her Majesty Queen Elizabeth II for his services to horticulture on Guernsey.

The company of Raymond J. Evison Ltd. was formed to carry out Public Relation activities including the sale of books that Raymond has written (and is writing) and to handle new introductions to the clematis market. Also in 1995 a joint venture between Raymond J. Evison Ltd. and Poulsen Roser A/S (a highly regarded rose breeder in Denmark) was formed with the purpose of breeding new clematis cultivars with a targeted programme to provide clematis to fit the desires and demands of a modern market.

Overall, it is the purpose of Guernsey Clematis Nursery Ltd and Raymond J. Evison Ltd. to use the advantages of climate and expertise of glasshouse production on Guernsey along with the extensive knowledge of the genus of clematis from Raymond Evison and the extensive experience of breeding from Poulsen Roser to

produce and provide a high quality clematis product consisting of new and improved cultivars designed for the modern home and garden.

BREEDING

Parent plants are selected according to pre-set criteria of characteristics including colour, compactness, flowering ability, disease resistance, and others. "Father" (pollen donor) plants are set out in a grid opposite the mother (pollen receiver) plants as programmed. As a "mother" plant's flower bud matures and swells but before it opens, the sepals (modified leaf/petals) are removed and the flower is carefully emasculated to ensure that it couldn't self-pollinate. A bag is placed over the emasculated flower head to prevent the stigma from being pollinated accidentally by stray pollen or insects. A period of time is allowed for the stigma and ovary to continue to mature until such time that it is ready to receive pollen from the "father" plant. In autumn (fall) the seed heads are collected and stored until the time of sowing. Approximately 25–35,000 seed are sown from this programme every winter of which about 30% germinate, leading to 7–10,000 brand new cultivars of clematis for evaluation every year.

From Pollination to Production in Eight Years. The evaluation process is very time consuming. All new cultivars are grown under conditions that closely mimic commercial practices to ensure that the clematis are assessed under uniform conditions and in ways that will fit a commercial production programme. The plants are assessed at three stages, firstly focused on the flower and flowering ability, secondly grown on to a stage where they can be assessed on overall habit (compactness, time to flowering, foliage : flower balance), and thirdly at a more commercial level of propagation and pest and disease resistance. The joint venture partnership also allows for hardiness to be tested in a Danish climate. At each stage, less than 10% of the plants are selected and the remaining seedlings discarded so that at the end of an extremely extensive testing and trialling period of about 8 years, only about five cultivars may ever reach commercial release. It is important that thorough evaluation is part of the breeding programme so that new cultivars are released with confidence that they will perform reliably as expected and will supersede existing cultivars in appearance, successful both commercially for the grower and in the garden for the consumer.

Some of the aims of the programme have been to produce clematis with exceptional colour that are extremely floriferous, have the ability for continuous flowering, and with very compact growth suitable for production as a pot plant for the home or container for the patio. It is considered that the modern market for plants, including clematis, is demanding a product with instant impact for little input (growing skills) suitable for the conservatory or patio, with people having less time for gardening in the larger part of the garden.

This has led to the recent introduction of the following cultivars:

- Rosemoor™ clematis 'Evipo002': Exceptional red flower, very high impact plant.
- Wisley™ clematis 'Evipo001': A mass of flower ideal for growing with roses in the smaller garden.
- Cezanne™ clematis 'Evipo023': Flowering and re-flowering to provide a container plant in flower from May to September, impressive on the patio.

- The Boulevard Collection®, including Parisienne™ clematis 'Evipo019': Compact, free flowering, and high impact pot plant.
- The Garland Collection®, including Viennetta™ clematis 'Evipo006': Free flowering, long shelf life clematis that can be produced in flower virtually year round (excellent at Christmas), flowering in the house for 6–8 weeks continuously.

PROPAGATION

The Guernsey Clematis Nursery Ltd. produces two key products (in the main), the first of which is a rooted cutting of about 13 weeks pruned at least once. The second is a 7-cm (3-inch) liner product potted on from the rooted cutting and grown for a further 5 months and pruned at least twice more. Most of the material for propagation is generated from the regular pruning of the commercial crop. The nursery endeavours to maintain the highest standards of production from beginning to end; therefore, from this very first stage of production, damaged or weak and nutritionally poor material is discarded and not used for propagation.

Internodal cuttings are then made with the use of razor blades taking uniform material from just 1–2 nodes of each stem. The made cuttings are dipped into a preventative fungicide and cold stored to ensure that they are turgid prior to sticking. They then are dipped into a rooting hormone powder and stuck into pre-prepared trays. The trays are filled with a 17 peat and 3 perlite (v/v, for aeration) mix and capped with a thin layer of sand to keep the moisture away from the foliage. These trays are mechanically filled with the peat mix to ensure uniform density throughout the whole tray and the whole batch. They are then automatically watered up to provide the correct amount of water to each tray. These are then check weighed to ensure the correct amount of moisture has been added. Attention to detail and uniformity at this stage determines the quality of product achieved and uniformity of crop throughout the growing cycle.

The completed cutting trays are enclosed in a polythene tent, and the Ebb & Flow table moved into the rooting zone of the glasshouse. The tent itself helps to maintain the high humidity, the zone is controlled to a temperature of 21 °C (70 °F), shade screens are used to protect from direct sun, and thermal screens used to conserve night time heat. Overhead lights can also help to extend the propagation season so that cuttings can be made from late February until early October. Black-out screens prevent light pollution from the glasshouses to the surrounding neighbourhood.

After 4-weeks, the clematis generally have initiated roots and begin the weaning process by being transferred to the next zone, held at a lower temperature, and with holes cut in the polythene to reduce the humidity. After a further 4 weeks the rooted clematis are then transferred to the final weaning zone where the covers are completely removed and only a minimum-heating regime is maintained. A programme of feed and nutrition is applied with the watering from week 8 onwards.

The final 12- to 13-week product is then either knocked out of the trays and prepared for dispatch or potted on into the 7-cm liner for further production, again on Ebb & Flow tables, in controlled climate zones. Guernsey Clematis customers would take 7-cm liners to finish for next season's sales, generally grown over a 9- to 12-month growing cycle.

The mobile bench (Ebb & Flow) system allows for the plants to be moved into optimal growing conditions and moved to work areas for production processes such as potting, pruning, and dispatch. All the tables are subirrigated by flooding, and all the water (run-off) is collected, cleaned with UV sterilisation, re-dosed with nutrients, and reused for up to 6 months. With this re-cycling system and a recent investment in a reservoir to collect the glasshouse roof rainwater run-off, the main Guernsey Clematis production nursery has become virtually self sufficient in its water use.

By keeping the plants off of the ground, and by subirrigating, the tops of the pots remain dry, helping in the prevention of disease. Guernsey Clematis operates an integrated pest management system throughout the whole nursery. With the use of bio-control agents and applications of beneficial nematodes in the propagation zones, the use of insecticides has been significantly reduced.

Environmentally, the nursery has reduced its oil consumption with the use of better glasshouse facilities and heat conservation techniques. Water is almost self-sufficient, and the use of pesticides significantly reduced. It is a continued aim to maintain good environmental standards.

With the uniformity gained from mechanisation and by focusing on the production procedures, Guernsey Clematis Nursery Ltd has been accredited with the certificate of ISO9001 (2000).

CONCLUSIONS

The investment in the breeding programme and thorough evaluation of new cultivars is helping to maintain a leading edge in the market for clematis with new products and greater product standards addressing the needs of a demanding and difficult market. The investment in facilities and attention to detail in production is maintaining the high quality standard that Guernsey Clematis is building into its reputation. It is important that the nursery is recognised for both of these attributes, otherwise how will the product from Guernsey be differentiated from clematis from any other country? Guernsey is still a small island in the middle of the English Channel; it is important that the nursery maintains a good reason to be recognised on the world stage for the quality production of new and improved clematis cultivars.

While They Were Asleep: Do Seeds After-Ripen in Cold Storage? Experiences With *Calendula*

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INTRODUCTION

Methods to break seed dormancy are of great interest to plant propagators, with many papers on this topic presented at past I.P.P.S. meetings. For example, in Vol. 54 of our Combined Proceedings of the International Plant Propagators' Society, there were reports on embryo culture to avoid dormancy (Douglas, 2004) and recommendations on dormancy-breaking techniques for *Helleborus* (Bush, 2004), *Salvia* (Navarez, 2004), and many wildflowers and grasses native to the North Central U.S.A. (Diboll, 2004). As propagators, we typically want quick methods that consistently result in high germination rates without large labor inputs. But if we can afford to be more patient, some seeds may eliminate their primary dormancy mechanisms during storage. This progressive loss of dormancy after maturity in "air-dry" seeds is known as after-ripening (Murdoch and Ellis, 2000). Typically, after-ripening is thought to occur under warm, dry conditions (Foley, 2000; Probert, 2000), but the literature of after-ripening is somewhat confusing. Simpson (1990) defined after-ripening in a more general way as "loss of the dormant state over some period of time through exposure of the seeds to a set of environmental conditions after maturation and separation from the parent plant." The term has even been used to describe combinations of warm storage and the effects of stratification (Baskin and Baskin, 1988).

Murdoch and Ellis (2000) and Probert (2000) noted that the rate of after-ripening increases with temperature in a predictable manner, and many studies on after-ripening focus on storage conditions at or above room temperature in order to get the most rapid loss of dormancy (Ellis et al., 1983; Liao et al., 2000). Probert (2000) reported that optimal rates of after-ripening commonly occur between 40 and 50 °C. However, there are also a few reports of slow after-ripening processes occurring at lower temperatures (below 10 °C), within a range typically used for medium-term seed storage (Widrlechner, 1991). For example, Schonbeck and Egley (1980) reported that, between 0 and 5 °C, after-ripening of redroot pigweed (*Amaranthus retroflexus* L.) seeds proceeded much more slowly than at higher temperatures, but that it was clearly observable after 6 months of storage. Cohn and Hughes (1981) were able to detect a loss of primary dormancy in a weedy rice (*Oryza sativa* L.) after 11 months of dry storage at 5 °C. And, by testing a range of different temperatures between 8 and 38 °C on dormancy-loss rates in malting barley (*Hordeum vulgare* L.), Favier and Woods (1993) found that the same loss of dormancy that took 10 days to achieve at 38 °C was observed in 100–120 days at 8 °C.

Murdoch and Ellis (2000) and Probert (2000) pointed out that seed moisture content is another important determinant of the rate of dormancy loss in after-ripening, reviewing evidence that after-ripening typically proceeds most quickly when cereals are held at 11%–15% moisture content, but slowing at lower moisture contents, and minimal below 8%, with some exceptions (Foley, 1994). So as seeds are dried and cooled to increase their longevity in storage, the after-ripening process could be

slowed two ways. Do these two phenomena (low temperature and low moisture content) interact to eliminate after-ripening, or do they just slow it down? Those of us who study ornamentals are often patient people, but how often do we have enough patience to design relevant experiments that might last 10, 20, or more years?

Fortunately, sometimes we don't need to design new experiments to gather sound data that shed light on slow-moving phenomena. In this paper, I present an example using historical germination data from the USDA-ARS North Central Regional Plant Introduction Station (NCRPIS) to help determine whether seeds in medium-term storage are just "asleep" (i.e., quiescent) or are also slowly losing their dormancy. I will focus solely on seeds of the ornamental genus *Calendula*, which includes both annuals and half-hardy perennials, native to the Mediterranean region and deserts of northern Africa and the Middle East. Although I have found no published reports of after-ripening in *Calendula*, it seems a likely candidate for investigation since after-ripening is widespread in species adapted to survive seasonal drought (Probert, 2000).

I have been working with *Calendula* seed production for more than 20 years and, during that time, have come to realize that when a sound seed lot is produced with a low initial-germination rate, if I am patient, I typically will be rewarded. Thus, when the topic of after-ripening being a warm-temperature phenomenon was discussed at the 2005 Eastern Region Annual Meeting in Atlantic City, I remembered *Calendula* and decided to evaluate our germination data to see whether it would be possible to document slow after-ripening under our medium-term storage conditions.

MATERIALS AND METHODS

Germination data from all seed lots of *Calendula* accessions regenerated and stored at the North Central Regional Plant Introduction Station were downloaded from the internal database of the Germplasm Resources Information Network (GRIN). Seeds were stored at 4 °C and at 40% relative humidity (RH) until 1991 and at 25% RH thereafter. Germination data were retained for further analysis only when the same seed lot was tested on three or more occasions over at least 9 years of storage. This resulted in the retention of 81 tests of 24 stored seed lots, including seven accessions of *C. officinalis* L., six of *C. arvensis* L., five of *C. suffruticosa* Vahl, two of putative hybrid populations, and two unidentified to species.

Specific test conditions were documented for all but six of the 81 tests. Of those with documented test conditions, each was conducted on 200-seed samples, either as two replicates of 100 or four reps of 50. All were conducted in plastic boxes on top of moist blotter paper with alternating light and darkness, and germination counts were made at 7, 14, and 21 days after test initiation. The most common test condition (49 of 81 tests) was at 20 °C, with 8 to 12 h of light daily and the addition of 0.1% KNO_3. The other tests were conducted at 15 °C (6 tests) or alternating 20/30 °C (3 tests) instead of at 20 °C, or involved the addition of a 7-day, moist pre-chill before the test, either at 20 °C (12 tests) or at alternating 20/30 °C (5 tests).

Although the GRIN database includes germination data on normal and abnormal seedlings and dormant and dead seeds, only the normal seedling data were considered to be consistently reliable. The inventory lot code for the seed sample, its age at the time of the test (rounded to the nearest half-year), and the percentage of normal seedlings were copied to an Excel spreadsheet for manipulation. Data on the percentage of normal seedlings were then standardized, a process that al-

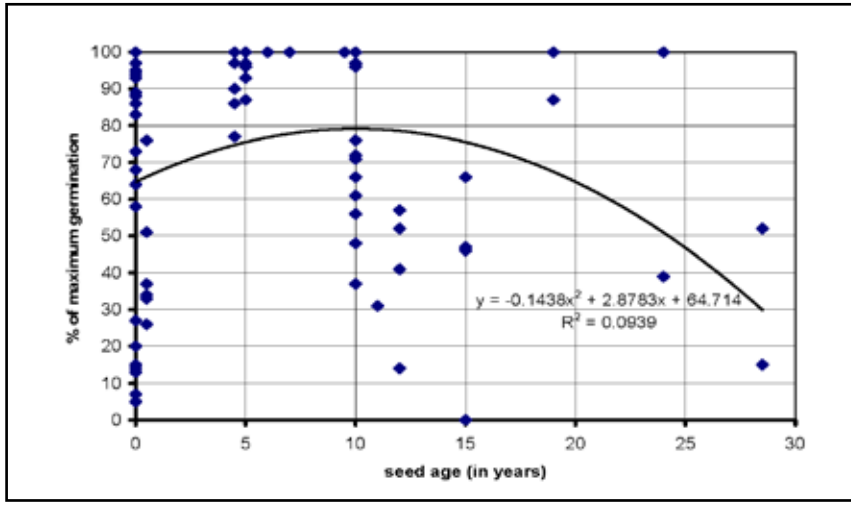

Figure 1. Percentage of maximum germination of *Calendula* seed lots in relation to seed age.

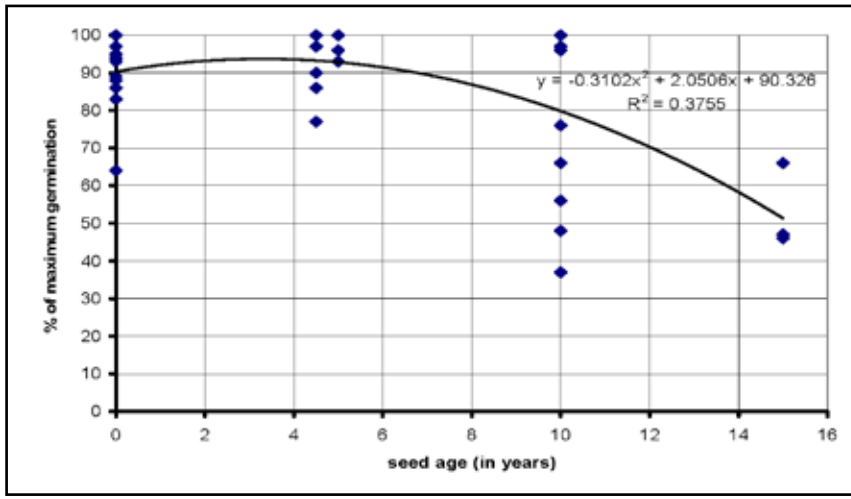

Figure 2. Percentage of maximum germination of *Calendula* seed lots with high initial germination tests (56% to 93%) in relation to seed age.

lows data from different tests to be compared. This was accomplished by coding the highest percentage recorded for each seed lot as "100%" and coding all tests with lower percentages as a percentage of the highest test result. Standardized data, denoted as percentage of maximum germination, and seed lot age were transferred to SAS (SAS Institute, 2003) for both linear and quadratic regression analyses. If the percentage of maximum germination is a product of the proportion of viable seeds (which decreases through seed aging) and the proportion of nondormant seeds (which increases through after-ripening), then one might expect a quadratic

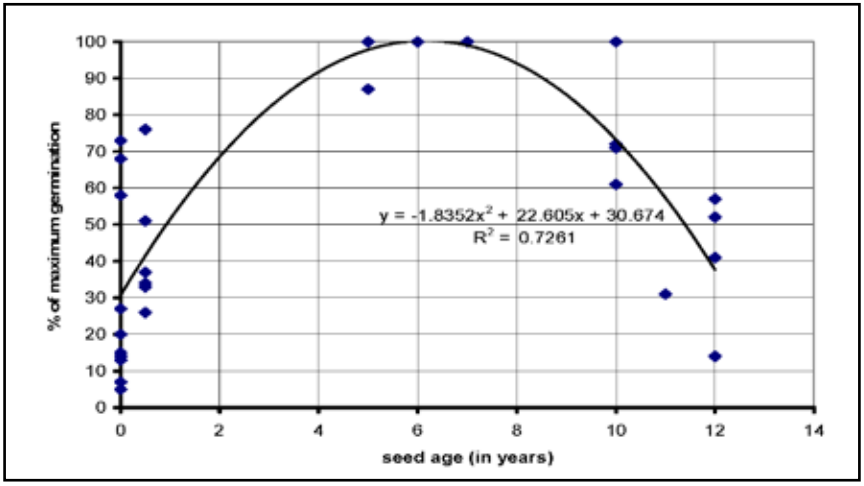

Figure 3. Percentage of maximum germination of *Calendula* seed lots with low initial germination tests (3% to 43%) in relation to seed age.

relationship, beginning with low values, rising to some peak as dormancy is eliminated, and then falling as seeds die in storage.

RESULTS AND DISCUSSION

When seed age was plotted against the percentage of maximum germination for all 81 tests (Fig. 1), no clear pattern was evident. The linear regression was not significant (data not shown), but the quadratic regression (Fig. 1) was significant at the $p < .05$ level, suggesting a weak relationship. Perhaps most importantly, this plot does indicate that *Calendula* seeds are relatively long-lived (25 to 30 years) under these storage conditions.

I then created two subsets of accessions from the entire data set: 11 lots with initial percentages of normal seedlings (raw data) above 50% (range 56% to 93%), and 10 lots with initial percentages below 50% (range 3% to 43%). Three lots were omitted from further analysis because they did not include test results conducted on seeds that were less than 1 year old. There were no statistically significant associations between individual species or for wild vs. domesticated populations and assignment to the two subsets.

Seed lots with high initial germination (Fig. 2) showed only very modest after-ripening effects, with an estimated peak of 94% of maximum germination attained about 3.5 years after seed production, but a significant quadratic regression ($p < .001$) and a weaker linear relationship ($R^2 = .25$). In contrast, seed lots with low initial germination (Fig. 3), likely the most dormant ones and perhaps also of lower overall quality, showed strong (and significant, $p < .0001$) increases in normal germination during initial storage, with an estimate of 100% of maximum germination reached about 6 years after seed production, but also a more rapid decline after reaching that peak.

This retrospective analysis strongly suggests that some *Calendula* seed lots after-ripened over a period of years while held at 4 °C and 40% RH until 1991 and

25% RH thereafter. However, the diverse germination test conditions incorporated into this analysis add a degree of uncertainty to the findings. And the possibility of some alternative explanation, such as the death of seed-borne pathogens in storage allowing the percentage of normal seedlings to increase during storage, cannot be evaluated from these data. Therefore, it would be prudent to consider these findings more as a source of testable hypotheses about slow after-ripening, rather than as definitive conclusions. Ideally, the resulting hypotheses should be used to design long-term storage experiments on well-defined, healthy seed lots with all germination tests conducted under uniform conditions.

Two specific ideas for practical propagation also emerge from this study. First, typical dormancy-breaking techniques may not be required for seeds that have spent many years in cold storage. Second, if one receives new seeds with unknown dormancy requirements, it might be wise to retain a subset in cold, dry storage for at least a few years. And finally, as an important sidelight to this work, there is evidence from rice (Cohn and Hughes, 1981) that low-temperature after-ripening is more effective when seeds are first held at room temperature for a week before transfer to cold storage. As a standard practice with ornamental seed regenerations at the NCRPIS, we hold new lots at room temperature for at least 2 months before transfer to cold storage to allow for some degree of more rapid after-ripening.

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Polyploidy: From Evolution to New Plant Development©

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INTRODUCTION

Polyploidy is an intriguing phenomenon in plants that has provided an important pathway for evolution and speciation. Although the first polyploid was discovered over a century ago, the genetic and evolutionary implications of polyploidy are still being elucidated (Bennett, 2004; Soltis et al., 2003). On a more practical level, there are many opportunities for utilizing polyploidy as a valuable tool in traditional plant breeding programs.

WHAT IS POLYPLOIDY AND HOW DOES IT ARISE?

A polyploid is simply an organism that contains more than two complete sets of chromosomes. For animals, this is a fairly rare occurrence (though a polyploid rat, the first polyploid mammal ever identified, was recently discovered in Argentina). In plants, however, polyploidy occurs naturally and is very common.

The term "ploidy" or "ploidy level" refers to the number of complete sets of chromosomes and is notated by an "x." An individual with two sets of chromosomes is referred to as a diploid (2x), three sets would be a triploid (3x), and so on with tetraploid (4x), pentaploid (5x), hexaploid (6x), etc. It is sometimes also important to identify if one is referring to the reduced (gametophytic) chromosome number following meiosis as would be found in egg and sperm (denoted as "n") or in nonreduced (sporophytic) tissue (denoted as "2n"). Thus, for example, a tetraploid birch tree would be presented as $2n = 4x = 56$.

Polyploidy can naturally arise in a number of different ways. In some cases a somatic (nonreproductive) mutation can occur, due to a disruption in mitosis, resulting in chromosome doubling in a meristematic cell(s) that will give rise to a polyploid shoot. These sports are sometimes evident on a plant by their enlarged "gigas" condition. Polyploids can also result from the union of unreduced gametes — eggs and sperm that have not undergone normal meiosis and still have a 2n constitution.

The origin of a polyploid can often determine if it will be fertile and may further indicate how it can best be used in a plant improvement program. If a tetraploid arises from spontaneous doubling in a shoot or from the union of unreduced gametes from two closely related (e.g., same species) diploid individuals, it will have four similar (homologous) versions of each chromosome. Despite different origins, both of these polyploids behave similarly reproductively and are often referred to as autotetraploids (or polysomic tetraploids). Autopolyploids may or may not be fertile. In diploids, meiosis involves the pairing of homologous chromosomes, which eventually segregate to form two separate gametes, each with one set of chromosomes. Infertility can arise in autopolyploids due to the fact that there are more than two homologous chromosomes. The presence of multiple homologous chromosomes often results in spurious pairing between multiple chromosomes, unpaired chromosomes, and gametes with unbalanced chromosome numbers (anueploids).

Offspring that result from sexual reproduction from unreduced gametes or somatic doubling in a hybrid of different species are referred to as allopolyploids (or sometimes amphidiploids or disomic polyploids). These plants also have four versions of each chromosome, but the two from one parent are sufficiently different from the two from the other parent, that they generally don't pair during meiosis. Due to this composition, allopolyploids are typically fertile. During meiosis each chromosome can pair with its homologous partner, meiosis continues, resulting in fertile germ cells.

In many cases polyploids fall somewhere in between an autopolyploid and allopolyploid whereby there is partial chromosome homology resulting in a combination of disomic and polysomic pairing and are referred to as segmental allopolyploids.

ROLE OF POLYPLOIDS IN PLANT EVOLUTION

In contrast to the gradual evolutionary process whereby new species evolve from isolated populations, new species of plants can also arise abruptly. The most common mechanism for abrupt speciation is through the formation of natural polyploids. Once a tetraploid arises in a population, it can generally hybridize with other tetraploids. However, these tetraploids are reproductively isolated from their parental species. Tetraploids that cross with diploids of the parental species will result in triploids that are typically sterile. This phenomenon provides a "reproductive barrier" between the polyploids and the parental species — a driving force for speciation.

Various estimates suggest that as many as 47%–70% of flowering plants are of polyploid origin (Grant, 1971; Goldblatt, 1980; Ramsey and Schemske, 1998). For example, the plants in the rosaceous subfamily maloideae (*Malus, Pyrus, Photinia, Chaenomeles*, etc.) are believed to have originated from ancient allopolyploids since they have $n = 17$ base chromosomes whereas plants in other rosaceous subfamilies have $n = 8$ or 9 (Rowley, 1993). In many genera, different species will have different ploidy levels (multiples of a base number) representing a series of polyploids. In the genus *Chrysanthemum* (syn. *Dendranthema*), different species have chromosome numbers of 2n = 18, 36, 54, 72, 90, and 198 — all multiples of a base chromosome number of 9.

There are a number of factors that may provide polyploids with adaptive and evolutionary advantages. Perhaps most importantly, polyploids can be significantly more heterozygous than their diploid counterparts. Polyploids can have 4 different genes (alleles) present at any given locus (location on a chromosome). The degree of heterozygosity may be a key factor in the growth, performance, and adaptability of a polyploid. Allopolyploids can have a much greater degree of heterozygosity (dissimilar genes) which can contribute to heterosis or hybrid vigor. Furthermore, this heterozygosity is somewhat fixed (chromosomes that originated from a given species preferentially pair with similar homologous chromosomes during meiosis, ensuring that the genomes of both parental species will continue to be present). On the other hand, the addition of multiple copies of homozygous chromosomes (as would be the case with autopolyploids), does little to enhance genetic superiority and can actually reduce vigor and fertility by creating a more "inbred" situation.

Since all polyploids have a certain amount of genetic redundancy, extra copies of genes can mutate and diverge resulting in new traits without compromising essential functions. Polyploid populations often demonstrate extensive genomic rearrangement including the origin of novel regions of DNA (Arnold, 1997; Song

et al., 1995; Wendel, 2000). Ancient polyploids can eventually undergo such changes to the extent that they effectively become "diploidized" where diploid gene ratios are restored.

Polyploids also tend to be more self-fertile (not requiring cross pollination) and apomictic (producing seeds with embryos derived directly from maternal tissue, not sexual fertilization). Since polyploids generally arise at a low frequency, greater self fertility and apomixis would help to compensate for their minority-disadvantage (Briggs and Walters, 1977) and would provide further benefits in areas where breeding systems are compromised in stressful environments. Furthermore, inbreeding is less deleterious for allopolyploids due to their greater heterozygous nature.

One question that frequently arises is whether or not polyploids inherently have greater stress tolerance. For example, it has often been observed that disproportionate number of polyploids are found in cold, dry regions. Some argue that this is a spurious correlation (Sanford, 1983) or possibly the result of intermixing of species and formation of allopolyploids during glacial periods (Stebbins, 1984). However, polyploids may also have certain characteristics that do provide some adaptive benefits. Molecular studies have demonstrated that allopolyploids exhibit "enzyme multiplicity" (Soltis and Soltis, 1993). Since allopolyploids represent a fusion of two distinctly different genomes, these polyploids can potentially produce all of the enzymes produced by each parent as well as new hybrid enzymes. This enzyme multiplicity may provide polyploids with greater biochemical flexibility; possibly extending the range of environments in which the plant can grow (Roose and Gottlieb, 1976). Other changes in gene expression, altered regulatory interactions, and rapid genetic and epigenetic changes could further contribute to increased variation and new phenotypes (Osborn, et al., 2003).

POLYPLOIDY AND PLANT IMPROVEMENT

Considering the profound importance of polyploidy in plant evolution, it is understandable that there was considerable interest in developing induced polyploids when mitotic inhibitors were first discovered in the 1930s. However, despite the fact that polyploids have been developed for many major crops, these plants are almost always found to be inferior to their diploid progenitors. Somatic doubling does not introduce any new genetic material, but rather produces additional copies of existing chromosomes. This extra DNA must be replicated with each cell division. Enlarged cell size is often associated with polyploids, which can result in anatomical imbalances. Other deleterious effects can include erratic bearing, brittle wood, and watery fruit (Sanford, 1983). High-level polyploids (e.g., octaploids) can be stunted and malformed, possibly resulting from the extreme genetic redundancy and somatic instability that leads to chimeral tissue.

Despite the drawbacks of induced autopolyploids, these plants may be valuable if they are in turn used in a breeding program to enhance the degree of heterozygosity and and further selected for desirable traits. In most cases it appears that inducing autopolyploids will do little for plant improvement unless substantial heterozygosity can be incorporated (Sanford, 1983). Historically, work with polyploids has not progressed much beyond somatic doubling — resulting in considerable genetic redundancy. Based on our knowledge of natural systems and evolution, it appears that much greater advances can be made by working towards enhanced heterozygosity, including the development of allopolyploids.

Polyploidy can result in a wide range of effects on plants, but the specific effects will vary dramatically based on the species in question, the degree of heterozygosity, the ploidy level, and the mechanisms that relate to gene silencing, gene interactions, gene dose effects, and regulation of specific traits and processes.

OPPORTUNITIES

Overcoming Barriers to Hybridization. In some cases, desirable crosses are difficult to obtain due to differences in ploidy levels between prospective parents. Such interploid barriers appear to arise from abnormal endosperm formation. In species where there is an interploid block, seeds will often only develop normally if there is a 2 maternal : 1 paternal ratio in the genomic makeup of the endosperm, which would be the normal case for two diploid parents (Ramsey and Schemske, 1998). Seeds that don't meet this criterion are often underdeveloped or abort. In some cases this ratio is not exact, but the greater the disparity, the lower the viability of the seeds (Sanford, 1983). In cases where interploid blocks exist, barriers to hybridization may be overcome by manipulating the ploidy levels to match prior to hybridization.

Developing Sterile Cultivars. The introduction and movement of invasive species can be a significant threat to certain ecosystems. Development of sterile forms of important nursery crops is an ideal approach for addressing this problem. In doing so, plants can be grown and used for landscaping while minimizing the possibility that these plants could sexually reproduce and become invasive. There are a number of methods available for developing sterile plants. However, one of the most rapid and cost-effective approaches for inducing sterility in a plant is by creating polyploids. In most cases these plants function normally with the exception of reproduction, specifically meiosis. In some cases doubling the chromosomes of an individual plant (autotetrapoid) will result in sterility due to multiple homologous chromosomes and complications during meiosis (as discussed previously). Despite these complications, autotetraploids of some species can produce fertile seeds. In this case, tetraploids can then be hybridized with diploids to create sterile triploids. Triploids have an additional reproductive barrier in that the 3 sets of chromosomes cannot be divided evenly during meiosis yielding unequal segregation of the chromosomes (aneuploids). Even in the unusual case when a triploid plant can produce a seed (apples are an example), it happens infrequently and seedlings are usually abnormal.

Development of triploids of some species can be complicated due to the presence of an interploid block that prevents the normal development of triploid embryos. However, embryo culture is an additional technique that can be employed to overcome this problem and produce sterile triploid plants.

An alternative approach for creating triploid plants is regeneration of plants from endosperm found in seeds. Although the embryo in most angiosperm seeds is diploid, the adjoining endosperm (nutritive tissue) originates from the fusion of three haploid nuclei (one from the male gametophyte and two from the female) resulting in triploid tissue. This tissue can be excised from developing seeds and cultured in vitro (tissue culture) to eventually give rise to regenerated embryos and plantlets. This approach has been successful for a range of plants including citrus, kiwifruit, loquat, passionflower, acacia, rice, and pawpaw.

Restoring Fertility in Wide Hybrids. It is not unusual for hybrids between distant taxa (different species or genera) to be sterile. This often occurs due to failure of the chromosomes to pair correctly during meiosis — referred to as chromosomal sterility. By doubling the chromosomes of a wide hybrid, each chromosome has an exact duplicate and chromosomal homology and fertility can be restored. This technique has been used successfully to restore fertility in *Rhododendron* 'Fragrans Affinity' and ×*Chitalpa tashkentensis* (Contreras, 2006; Olsen, 2006). However, in some cases this approach has been unsuccessful in restoring fertility, as was the case with tetraploid hybrids of *Alstroemeria aurea* × *A. caryophyllaea* (Lu and Bridgen, 1997).

Enhancing Pest Resistance and Stress Tolerance. The influence of polyploidy on adaptability and resistance to biotic and abiotic stresses has been widely studied in crop plants (Levin, 1983). In some cases polyploids have demonstrated greater resistance to pests and pathogens, greater nutrient uptake efficiency, better drought resistance, and superior cold tolerance. However, polyploidy often results in reduced resistance to these same stresses as well. It should not be assumed that polyploids are necessarily more stress tolerant.

There are a number of strategies for inducing polyploids as a means of enhancing adaptability. Increasing the chromosome number and related gene dose can sometimes enhance the expression and concentration of certain secondary metabolites and defense chemicals. However, this is not always the case and little is generally known about the relationship between gene dose, gene silencing, and expression of secondary metabolites. A more promising approach would be to create allopolyploids between plants with diverse endogenous secondary metabolites. A unique and valuable characteristic of allopolyploids is that the secondary metabolites from the parental species are typically additive. That is to say that allopolyploids often produce all the enzymes and metabolites (including defense chemicals) of both parents. This could be particularly effectively for combining the pest resistant characteristics of two species, and potentially contributing to a much broader, more horizontal form of pest resistance. A similar approach may have utility for enhancing tolerance to certain environmental stresses.

Enlargement and Enhanced Vigor. Although enlarged cell size found in some polyploids can have undesirable effects, it can sometimes also be beneficial. In some plants, polyploidy results in significant enlargement. Fruit from tetraploid apples can be twice as large as diploid fruit, though they tend to be watery and misshapen. For apples, triploids have proven to be a happy medium that combines larger fruit while retaining good quality and are often grown for commercial production. This type of enlargement can be particularly desirable for ornamental flowers. Flower petals can also be thicker and flowers can be longer lasting in polyploid plants (Kehr, 1996).

METHODS FOR INDUCING POLYPLOIDY

In the late 1930s it was discovered by that colchicine inhibits the formation of spindle fibers and temporarily arrests mitosis at the anaphase stage (Blakeslee, 1937). At this point, the chromosomes have replicated, but cell division has not yet

taken place resulting in polyploid cells. Other mitotic inhibitors, including oryzalin, trifluralin, amiprophos-methyl, and N_2O gas have also been identified and used as doubling agents (Bouvier et al., 1994; van Tuyl et al., 1992; Taylor et al., 1976).

Methods for applying these agents vary. One of the easiest and most effective methods is to work with a large number of seedlings with small, actively growing meristems. Seedlings can be soaked or the apical meristems can be submerged with different concentrations, durations, or frequencies of a given doubling agent. Shoots on older plants can be treated, but it is often less successful and results in a greater percentage of cytochimeras. Treatment of smaller axillary or sub-axillary meristems is sometimes more effective. Chemical solutions can be applied to buds using cotton, agar, or lanolin or by dipping branch tips into a solution for a few hours or days. Surfactants, wetting agents, and other carriers (dimethyl sulfoxide) are sometimes used to enhance efficacy.

VERIFYING POLYPLOIDY LEVELS

Plants with increased ploidy levels are sometimes apparent by their distinct morphology. Increasing ploidy often results in increased cell size that in turn results in thicker, broader leaves and larger flowers and fruit. Shoots are often thicker and can have shortened internodes and wider crotch angles. Plants with high ploidy levels (e.g., octaploids) can have distorted growth and reduced growth rates. When screening large numbers of plants, these visual characteristics are sometimes helpful for identifying putative polyploids. Other effective, but more time-consuming, measures that indicate polyploidy include larger pollen size, greater number of chloroplasts per guard cell (Solov'eva, 1990), and larger guard cells and stomates. Flow cytometry is a very useful tool for measuring DNA content which can be correlated with ploidy level for a given crop (Sharma and Sharma, 1999). Traditional cytology is often necessary to determine chromosomes number and ploidy level. Techniques include measurements on young leaves, root tips, and anthers (Ruzin, 1999).

When testing and breeding polyploids, it is important to recognize that induced polyploids can sometimes be cytochimeras where the ploidy level varies in different types of tissue. Meristems are typically divided into three histogenic layers L-1, L-2, and L-3. Mutations and doubling agents may result in increased ploidy levels in one, two, or all three layers. For information on reproductive behavior, it is important to measure the ploidy level of L-2, or cortical layer, which is reflected in pollen size and chromosome counts from reproductive tissue (e.g., anthers). Root tips would reflect the L-3 layer while the guard cells would reflect the L-1 layer.

SUMMARY

In the vast majority of cases, induction of autopolyploids will not, in of itself, result in substantially improved landscape plants. However, with knowledge of the origins of, variations in, and characteristics of different types of polyploids, there are many opportunities for developing and utilizing polyploids in plant improvement programs. Significant opportunities include developing sterile cultivars, overcoming barriers to hybridization, restoring fertility in wide hybrids, enhancing flower size, increasing heterosis and vigor, and improving pest resistance and tolerance to environmental stresses.

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New and Underused Woody Plants: A Personal Perspective©

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This is a personal selection of trees and shrubs, consisting of both recent introductions and others that have been around for longer periods of time that, for various reasons have not, I feel, received the recognition they merit. This latter category of plants have "stood the test of time," a claim that many recent introductions cannot assert!

Most of the subjects chosen exhibit one or more outstanding ornamental features, including flowers, fruits, foliage, and overall form or habit. By considering this "Four F Factor" when initially selecting plants, one can greatly enhance the worthy goal of extended seasonal ornamental interest. Selections are broadly listed by their main seasons of ornamental interest with a general hardiness range indicated.

WINTER

***Edgeworthia chrysantha* 'Red Dragon'.** Chinese rice paper plant, a daphne relative, has long lasting (6–8 weeks), fragrant, orange-red flower clusters in January, and yellow fall foliage. Zones 7–9.

***Mahonia* × *media* 'Winter Sun' (*M. japonica* × *M. lomariifolia*).** One of several outstanding clones. Year-round ornamental interest. Fragrant spires of yellow winter flowers: Blue spring fruits: glossy evergreen foliage: strong architectural form. Excellent hedge plant. Shade and drought tolerant.

***Pinus* 'Forest Sky' (*P. strobus* × *P. ayacahuite*).** Hardy selection of the Mexican white pine (*P. ayacahuite*). Excellent substitute for white pines (*P. strobus*) especially further south. Stocky, compact, handsome conifer with attractive blue-green foliage. Resinous, long pendulous cones. Very drought tolerant. Zones 4–9.

***Thuja occidentalis* Technito™ mission arborvitae ('Bailjohn').** Dwarf mission arborvitae. Dense, compact, pyramidal form. Dark green foliage holds color in winter. Requires very little shearing. Zones 3–8.

***Thuja occidentalis* Techny Gold™ Arborvitae ('Walter Brown').** Golden mission arborvitae. Nonburning, rich golden foliage. Color intensifies in winter. Excellent specimen, evergreen, screen, or hedge plant. Zones 3–8.

***Corylus avellana* Red Majestic® filbert.** Classic winter-interest shrub with contorted stems. Red-purple young foliage turning green especially further south, as the season advances. Aim to produce plants on their own roots—avoids sucker growth. Zones 4–8.

***Betula nigra* Fox Valley™ ('LITTLE KING').** Dwarf Illinois selection of native river birch. Compact, rounded habit, 8 ft tall ×12 ft wide in 25 years at Morton Arboretum. Attractive exfoliating bark year-round interest. Prune to expose bark. Superb specimen or low hedge. Zones 4–8.

SPRING

***Forsythia* 'Happy Centennial'.** Canadian introduction. Very reliable bloomer in North, cold-hardy flower buds. Attractive narrow serrated leaves turn purple-red in fall. Graceful, low habit, 2–3 ft tall. Zones 4–8.

***Forsythia viridissima* 'Kumson'.** Korean forsythia white-veined "reticulated" leaves. Effect intensifies during summer. Attractive contrast with heavy spring bloom. Upright arching form. Zones 5–8.

***Cercis chinensis* 'Don Egolf'.** First named U.S. National Arboretum red bud introduction. Ideal for small gardens. Thick leathery, healthy foliage. Excellent in South and best species for West Coast. Zones 7–9.

***Cercis canadensis* 'Little Woody'.** North Carolina selection. Dwarf, upright grower with very short internodes. Attractive leathery bluish green "corrugated" leaves. Excellent for small gardens. Zones 6–9.

***Corylopsis spicata* 'Aurea'.** Some what neglected Japanese-genus winter hazels. Striking yellow-chartreuse foliage. Holds color. Pendulous clusters of 6–12 pale yellow flowers during spring. Graceful mounded to spreading habit. Light shade. Zones 5–8.

***Fothergilla gardenii* Beaver Creek® fothergilla ('KLMtwo').** Roy Klehm selection. Excellent performer in Midwest. Dense compact grower whose bluish-green leaves turn orange-yellow in fall. Heavy blooming, clustered creamy-white honey-scented flowers. Good pest and disease resistance. Light shade. Ideal for small landscapes. Zones 4–8.

***Fothergilla* ×*intermedia* 'Blue Shadow'.** Outstanding sport of *F.* 'Mt. Airy' from Gary Handy. Pale powder-blue foliage. Color retained through summer even in South. More vigorous and easier to grow than *F.* 'Blue Mist' Zones 4–8.

***Rhododendron* 'Mikkeli'.** Marjetta hybrid from Dr. Peter Tigerstedt, University of Helsinki, Finland. Cold hardy (-35 to -40°F). Elepidote. Compact 4–6 ft tall. Truss of white, green flowers. Several of these hybrids have thrived for 15 years at the Longenecker Arboretum, Madison, Wisconsin. Zones 4–7.

***Rhododendron* 'Haaga'.** Upright grower. 5–7 ft tall. Coarse, dark green foliage. Early trusses of deep pink flowers. (Note: Select a sheltered location from sun and wind in winter-especially further North.).

***Rhododendron* 'Lemon Lights'.** Lights Series, Dr. Harold Pellett, University of Minnesota Landscape Arboretum. Extremely hardy. (35–45 °F.) with no winter damage. Excellent disease resistance-powdery mildew. Beautiful yellow selection. Color carries in landscape, some fall rebloom. Excellent fragrance. Maroon fall foliage. Zones 4–8.

***Rhododendron* 'Fragrant Star'.** Polyploid form of *R.* 'Snowbird' (*R. atlanticum* × *R. canescens*). One of the most fragrant deciduous azaleas, very heat tolerant. Large white flowers and handsome blue-green foliage than R. 'Snowbird' Zones 6–9.

***Magnolia* 'Daybreak'.** Dr. August Kehr, possibly his finest hybrid. Large (10–12 inches) strongly fragrant pink flowers. Late blooming (April, May) avoids late frosts. Has flowered after -28 °F. Good flower bud hardiness. Golden yellow fall color. Zones 5–8.

***Magnolia* 'Coral Lake'.** Dr. David Leach hybrid between two yellow cultivars—*M.* 'Legend' × *M.* 'Butterflies'. Stunning new color-complex blend of coral/yellow and pink. Very fragrant. Prolific bloomer. Late, avoids late frosts. Vigorous, small, semi-fastigate tree. Zones 5–8.

***Magnolia virginiana* 'Green Shadow'.** Don Shadow selection of our native evergreen sweet bay. Narrow, upright form-striking landscape impact. Larger than normal lemon-scented cream flowers. Very long blooming season. Flowers and fruits together in late summer. No damage at -15 °F. Zones 5–9.

***Malus* 'Satin Cloud'.** Father John Fiala introduction. Octoploid. One of the finest small crabapples. Dense, dwarf, spreading, 15 ft tall × 20 ft spread. Prolific pink buds. Cinnamon-scented satin-white flowers. Small yellow fruits. Thick dark green, scab-resistant leaves turn a stunning fiery red in fall. Zones 4–8.

***Malus* 'Louisa'.** Selected and named for her granddaughter by Polly Hill. Neat weeping habit, 15 ft × 15 ft. Ideal for small gardens. Numerous yellow fruits. Healthy dark, glossy green foliage. Zones 4–8.

***Syringa vulgaris* 'Little Boy Blue' (syn. 'Wonder Blue').** One of numerous outstanding Father John Fiala hybrids. Dwarf compact habit 5–6 ft tall. Very fragrant sky-blue flowers from red-purple buds. Flowers displayed at eye and nose level! Excellent disease resistance. Zones 3–7.

***Syringa* Tinkerbelle™ lilac ('Bailbelle').** Neil Holland, North Dakota first of the Fairytale Lilacs (*S. meyeri* × *S. macrophylla* 'Superba'). Growth/bloom time of the dwarf Korean lilac and foliage of the little-leaf lilac. Very hardy, upright compact form. 5–6 ft. Wine red buds form spicy fragrant pink flowers. A new color for dwarf lilacs. Neat mildew resistant foliage. Zones 3–7.

***Chionanthus virginicus* 'Emerald Knight'.** One of the few selections of our native fringe tree. Seedling selection by Brian Upchurch, North Carolina. Large thick leathery leaves held late in season. Golden-yellow fall color. Lacy white flowers prior to emerging spring foliage. Zones 5–9.

SUMMER

***Rosa* 'Hawkeye Belle'.** One of Griffith Buck's (Iowa State University) finest creations—an overlooked group of hardy roses. Best on own roots. Grandiflora, extremely fragrant, fully double, blush pink flowers all summer. Healthy dark green foliage. Vigorous, compact (3½ ft) Roses should be thought of as flowering shrubs. Zones 4–8.

***Hydrangea macrophylla* 'Big Daddy'.** Japan selection by Itsaul Plants, Atlanta, GA. Huge flower heads (mophead). Very attractive large glossy dark green foliage. Strong grower. Zones 6–8.

***Hydrangea macrophylla* 'Nachtigall' (syn. 'Nightingale').** Teller Series selection from Germany. Strikingly beautiful lacecap, large flower heads. Strong upright grower, very strong stems. Thick glossy, dark green leaves. Pleasing yellow fall color. "One of the finest selections!" Zones 6–8.

***Hydrangea quercifolia* 'Little Honey'.** Unique dwarf, yellow foliage form of our native oak leaf hydrangea. Sport of *H.* 'Pee Wee' from Briggs Nursery, Washington. Foliage color breakthrough. Zones 5–8.

***Hydrangea quercifolia* 'Vaughn's Lillie'.** Georgia selection. Huge pendulous, pyramidal, densely packed inflorescences of creamy-white flowers. Striking red-purple fall color. Zones 5–8.

***Hydrangea paniculata* 'Dharuma'.** Low, mounded Japanese selection. Superb for container production. Very early flowering 5–6 weeks ahead of other clones. White inflorescence turns rose in fall. Flower heads in scale with plant size, 3 ft tall ideal for small landscapes. Zones 4–8.

Xanthoceras sorbifolium. Pink-flowered form of the Chinese yellowhorn. Roy Klehm selection. Greatly underused/overlooked species. Early summer flowering. Airy divided foliage. Picturesque winter branching. Small shrub to tree of year round ornamental interest. Zones 4–8.

***Styrax japonicus* 'Variegatus'.** Neat, crisp, clean variegated foliage, which retains its charm throughout summer. Pendulous early summer flowers. Handsome small tree. Zones 5–8.

***Halesia carolina* 'Hawksridge Pink'.** Hawksridge Nursery, North Carolina introduction. Large clear mid-pink flowers in early summer. Zones 4–8.

***Viburnum dentatum* Cardinal™ arrowwood viburnum ('KLMthree').** Roy Klehm selection of the native arrowwood viburnum, outstanding performer in the Midwest. Healthy, vigorous summer foliage turns a spectacular red in fall. White inflorescences followed by clusters of vibrant blue fruits in late summer. Superb landscape subject.

***Physocarpus opulifolius* 'Center Glow'.** Harold Pellett introduction. Landscaped Plant Development Center, Minnesota (*P.* 'Diabalo' × *P.* 'Dart's Gold'). Compact ninebark with reddish-pink and yellow emerging foliage turning red and finally dark maroon as the leaves mature. Zones 3–7.

***Cornus angustata* Empress of China™ dogwood ('Elsbry').** John Elsley seedling selection. Vigorous dark green evergreen foliage holds color in winter. Extremely free flowering even at a young age. Greenish-white flowers in late June–July. Becomes whiter with age and lasts from 6–8 weeks. Blooms 2–3 weeks after *C. kousa.* Red strawberry-like fruits during late summer. Hardy at 0 °F in Winchester, Tennessee. Zones 6b–9.

***Cornus kousa* 'Summer Fun'.** Talon Buchholz selection, Oregon. Broader, bolder creamy leaf margin and no crinkled edge as with *C.* 'Wolf Eyes'. Pleasing pinkish fall color often observed. Very eye catching in landscape. Zones 5–8.

***Corus alternifolia* Golden Shadows® pagoda dogwool ('W. Stackman').** Illinois selection of the native pagoda dogwood. Elegant tiered habit with leaves displaying a bold golden-yellow margin. Excellent substitute for closely related oriental counterparts. Zones 3–7.

***Illicium floridanum* 'Shady Lady'.** Tom Dodd selection of the native Florida anise. A variegated sport of the white-flowered *I. floridanum* 'Semmes'. Pleasing gray-green leaves with yellow margins. Fragrant pale pink late spring flowers. Zones 6–9.

***Davidia involucrata* 'Sonoma'.** Californian form of the paper handkerchief tree, which blooms at a very young age, often 2–3 years old. Flowers in summer with very large (10–12 inch long) bracts — twice the size of normal form. Zones 6–8.

***Caryopteris* ×*clandonensis* 'Dyraisey', Summer Sorbet® bluebeard.** Blue mist shrub. Neat yellow-margined foliage holds color throughout growing season and creates a spectacular color combination with the dark blue flowers in late summer. Zones 6–9.

***Buddleia alternifolia*.** A much overlooked Chinese native. The hardiest buddleia. The first buddleia to bloom. Long arching pendulous shoots are clothed with clusters of lilac-purple flowers in mid-summer. Attractive silvery-gray foliage, especially the cultivar 'Argentea'. Hardy in Minneapolis. Zones 4–7.

***Hibiscus syriacus* 'Helene'**. One of several superb sterile forms from Dr. Don Egolf, U.S. National Arboretum. White flowers with a prominent red-purple eye in late summer. Fresh healthy foliage. Tough, underused group of late-flowering, easily grown shrubs. Zones 5–8.

***Clematis* 'Matka Urzula Ledóchowska'.** Outstanding Polish hybrid from Brother Stephan Franchek. Vigorous, healthy, very free flowering. Large white flowers with contrasting red stamens. Silky golden seed heads. Zones 4–9.

***Clematis* 'Dawn'.** Compact Swedish cultivar. Ideal for container growing. Flowers exhibit spectacular combination of colors-white, suffused pink, blue, and green. Bronze young foliage. Excellent winter hardiness. Zones 4–9.

***Clematis* 'Rooguchi'.** Spectacular Japanese *C.* integrifolia hybrid. Prolific repeat bloomer throughout summer. Large, pendulous deep violet-purple bell-shaped flowers. Silky seed heads form together with flowers. Tolerant of light shade. Zones 4–9.

***Fallopia baldschuanica* (syn. *aubertii*) 'Lemon Lace'.** Bluebird Nursery, Nebraska introduction. Golden-yellow foliage with reddish young stems. Holds color all summer, full sun. Foamy white flowers in late summer. Not quite as vigorous as the species and not so invasive. Superb combined with clematis. Zones 4–8

***Acer palmatum* 'Hefner's Red Select'.** Hefner's Nursery, Conover, North Carolina introduction. Outstanding nonburning deep purple, almost black foliage. Young leaves red. Sun or light shade. Zones 5–8.

***Acer shirasawanum* 'Autumn Moon'.** J. D. Vertrees introduction. Excellent heat/humidity tolerance — much better in south than *A. shirasawanum* 'Aureum'. Outstanding orange-copper young foliage produced throughout the summer. Zones 4–7.

***Sambucus nigra* Black Lace™ elderberry ('Eva').** One of several recent introductions from East Malling Experimental Station, England. Finely divided almost black foliage color. Pinkish flower heads create a beautiful contrast to the foliage. Vigorous, prune formatively. Zones 4–7.

***Sambucus nigra* f. *porphyrophylla* 'Guincho Purple'.** Forms beautiful small multistemmed or single-stem tree with formative pruning. Handsome strongly furrowed bark of year-round ornamental interest. This older cultivar holds its dark foliage color well in cooler climates. Zones 4–7.

***Disanthus cercidifolius* 'Ena-nishiki'.** Japanese witch hazel relative — deserves greater recognition. Gray-green redbud-shaped leaves with an irregular creamy-white margin. Holds color during summer — turns orange-red, purple in fall. Small maroon fall flowers. Beautiful addition to any woodland garden. Zones 5–7.

***Callicarpa dichotoma* 'Duet'.** Recent release from U.S. National Arboretum Research Station, McMinnville, Tennessee. Strong-growing arching shrub with distinctly variegated creamy-white foliage-color retained all season. Purple fall berries. Striking in lightly shaded location.

***Rhus typhina* Tiger Eyes™ staghorn sumac ('Bailtiger').** Bailey Nursery introduction. Golden-yellow foliage turns typical orange-red in fall. Holds color through summer. Full sun. Zones 4–8.

***Rhus copallina* 'Lanham's Purple'.** Selection of the native flame-leaf sumac from Gary Lanham, Lebanon, Kentucky. Female selection with shiny, deep purple compound leaves, which turn scarlet-red in fall. Spectacular foliage effect. Zones 4–9.

***Corylus* 'Rosita'.** First ornamental release from the Oregon state Hazelnut Breeding Programme led by Shawn Mehlenbacher. A *C. avellana* 'Rotezeller' × *C. colurna* selection. Small upright compact tree. Ruffled edged leaves emerge a dark purple hold this color well into summer. Excellent pest and disease resistance, Eastern filbert blight and big bud mite. Zones 4–8.

***Ginkgo biloba* 'Majestic Butterfly'.** Variegated foliage "sport" of *G.* 'Jade Butterflies'. Dense slow-growing dwarf. Ideal for small gardens. Leaves boldly irregularly marked yellow. Zones 4–8.

***Fagus sylvatica* 'Klein's Copper'.** Seedling selection of the European beech by Theodore Klein, Yew Dell Gardens, Kentucky. Majestic copper beech with burgundy-red young foliage that soon turns copper-purple. Holds color throughout summer. A rare American selection of this classic tree. Zones 4–7.

***Betula nigra* 'Summer Cascade'.** Graceful pendulous river birch from Shiloh Nursery, North Carolina. Very strong grower, 5–6 ft a year. Stake leader to achieve best height and shape. Good foliage and attractive bark of year-round appeal. Zones 4–8.

***Carpinus betulus* 'Vienna Weeping'.** Beautiful European hornbeam from the grounds of the Harsburg Palace in Vienna. Dense elegant pendulous habit. Dark green leaves turn golden yellow in fall. Bark becomes mottled and exfoliating with age. Zones 5b–8.

***Parrotia persica* 'Vanessa'.** Handsome narrow, strongly vertical selection of an under-appreciated small tree. Foliage turns a splendid red/orange in fall. Bark becomes mottled and exfoliating with age. Zones 4–8.

***Alnus glutinosa* 'Pyramidalis'.** Beautiful columnar form of the European black alder. A striking affect that lasts year round. Its unique form is retained into old age. Appreciates constant moisture. Zones 4–7.

***Alnus glutinosa* 'Razzamataz'.** New Zealand selection of the European black alder. Dark green leaves have an irregular light green/yellow margin, color retained during summer. Fall color a golden yellow. Cherry-like bark extends ornamental interest. Thrives in moist locations. Zones 4–7.

***Taxodium distichum* 'Cascade Falls'.** New Zealand selection of our native swamp cypress. Graceful weeping pendulous form. Need to stake leading shoot to achieve height. Zones 4–11.

***Taxodium distichum* 'Peve Minaret'.** Dwarf, narrow Dutch selection reaching 6 ft tall × 2–3 ft wide in 10 years. Superb in small landscapes. Soft lush spring foliage turns orange in fall. Zones 4–11.

***Gymnocladus dioca* 'Stately Manor'.** Handsome male form of the Kentucky coffee tree at the Minnesota Landscape Arboretum. Stately narrow, upright form. Potentially a magnificent urban tree. Late to leaf out in spring. Zones 4–8.

***Robinia pseudoacacia* Chicago Blues™ black locust ('Benjamin').** selected by Chicago City Forester Bob Benjamin from a seedling block near O'Hare Airport. Extremely adaptable tree for harsh urban conditions. Minimal thorns and beautiful blue-green foliage. Excellent borer resistance, fragrant white summer flowers. Upright with oblong crown. Zones 4–8.

***Nyssa sylvatica* 'Carolyn'.** Superbly shaped black gum. Raised from seed collected in New Hampshire, extreme northern location. Selected and named for his granddaughter by Dr. Ed Hasselkaus, parent tree at Longenecker Arboretum, Madison, Wisconsin. Develops a strong leader. Attractive fruits and outstanding fall color. Zones 4–9.

***Nyssa sylvatica* 'Wild Fire'.** Selected by Steve Hootovy Beyond Green Nursery, Oregon, from seed collected in central Indiana. New growth always red and present all summer. Forms an attractive regular-shaped specimen tree, with a strong leader and excellent branching. Excellent fall color. A production dream — no staking needed. Zones 4–9.

***Nyssa sylvatica* 'Autumn Cascades'.** Australian black gum selection with a strongly weeping habit. Leader needs staking to attain height. Large dark green glossy foliage producing superb fall color. Zones 5–9.

***Nyssa sylvatica* 'Zydeco Twist'.** A Louisiana black gum selection with twisted, contorted stems. Zones 5–9.

FALL

***Hamamelis virginiana* 'Green Thumb'.** Alex Neubauer selection whose leaves display a dark green center with a lighter green outer margin. A unique color effect especially early in the year. Yellow fall color. Delicate strongly fragrant yellow flowers during late fall and early winter. Zones 4–8.

***Hamamelis vernalis* 'Autumn Embers'.** Roy Klehm introduction with outstanding burgundy-red fall color. Upright growing, very early blooming. This species replaces the *M.* ×*intermedia* selections further north. Zones 4–8.

***Symphoricarpos* ×*doorenbosii* 'Mother of Pearl'.** A snowberry with large, persistent white berries with a pinkish sheen. Low, spreading shrub ideal for naturalizing. Zones 4–7.

***Callicarpa americana* 'Welch's Pink'.** Recent heavy fruiting selection from Texas with striking soft pink clustered berries. Very attractive to birds. Zones 7–9.

***Aronia melanocarpa* Iroquois Beauty™ black chokeberry ('Morton').** Chicagoland Grows introduction of the native black chokeberry with wine-red fall foliage. Low, compact, mounding shrub. Zones 3–8.

***Spiraea betulifolia* 'Tor'.** One of the most outstanding fall foliage shrubs. Extremely long lasting color display of changing orange hues. Dense, low 2–3 ft grower, which creates a beautiful low hedge.

New Plant Forum©

Complied and Moderated by Jack Alexander

Presenters:

H. William Barnes
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Ampelopsis arborea
Cercidiphyllum japonicum 'Titania'

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Alstroemeria 'Mauve Majesty' PPAF

Steve Castorani
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Helenium flexuosum 'Tiny Dancer'
Rudbeckia subtomentosa 'Henry Eilers'
Silene caroliniana var. *wherryi* 'Short and Sweet'

Tim Wood
Spring Meadow Nursery, Inc., 12601 120th Ave., Grand Haven, Michigan 49417 U.S.A.
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Hibiscus syriacus 'Antong Two' ppaf, Lil' Kim™ rose of Sharon
Rosa 'Chewground' PP 15,981, Oso Easy™ Fragrant spreader rose
Rosa 'Horcoherent' PP 15,982, Oso Easy™ Peachy Cream rose
Rosa 'ChewMayTime' ppaf, Oso Easy™ Paprika rose
Weigela florida 'Eyecatcher' ppaf

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Carpinus caroliniana 'J.N. Globe', Ball O' Fire™ musclewood
Carpinus caroliniana 'J.N. Upright', Firespire™ musclewood

Alstroemeria 'Mauve Majesty' PPAF

Alstroemeria 'Mauve Majesty' PPAF is a new garden lily-of-the-Incas that was selected for its distinct mauve flower color, continuous flowering, and strong, upright flower stems. It was also selected because it is winter hardy to temperatures as low as those experienced in U.S.D.A. Zone 5. Plants grow neat and upright in habit and

produce an abundance of speckled, mauve flowers all summer and fall until frost. Flowering of 'Mauve Majesty' begins in late June in Zone 5 and in May in Zone 7. The flowers of this plant are excellent for cutting because flower stems last for up to 2 weeks in arrangements. The flowers of 'Mauve Majesty' are sterile and do not produce seed. Plants are asexually propagated by rhizome division and tissue culture. This cultivar is patented through Cornell University; propagation is permitted with license from the University.

This herbaceous perennial plant thrives in fertile, well-drained garden soil in full sun or partial shade. Flowering continues as long as their roots (rhizomes) are kept cool. Good soil drainage is especially important to ensure survival during the winter in colder climates.

Ampelopsis arborea

Ampelopsis arborea is a North American native vine ranging from Florida to Virginia along the Atlantic coastline. It roots easily from cuttings taken in early June for the Philadelphia area and in spite of its coastal southern heritage it is hardy to Zone 6. It is not a rapid grower in the Northeast, and this could well be an asset since it does not tend to want to take over the back forty with any virulence, unlike its close kin *A. brevipedunculosa.* The bipinnate foliage emerges red to pink and turns a soft green. It will climb and needs a suitable trellis. In 5 years it has not flowered and perhaps as far north as Philadelphia it cannot do so with any regularity.

***Carpinus caroliniana* 'J.N. Upright', Firespire™ musclewood**

Selected by Michael Yanny at Johnson's Nursery, Inc. in 1993. The tree was selected for its narrow, upright form and outstanding, consistent orange-red fall color. After 10 years the original plant, which was transplanted twice, was 7 ft tall and $3\frac{1}{2}$ ft wide.

Single stemmed plants are very useful as street trees. It can be used as a large hedge plant or screening plant.

Grower's licenses are available from Johnson's Nursery, Inc. at the address above.

***Carpinus caroliniana* 'J.N. Globe', Ball O'Fire™ musclewood**

Carpinus caroliniana 'J.N. Globe' was selected in the fall of 2000 by Michael Yanny at Johnson's Nursery's Jackson Farm. It originated from a 1990 crop of seedlings that was grown from wild-collected seed, a Waukesha Wisconsin ecotype.

The 11-year-old plant was 6 ft tall and $5\frac{1}{2}$ ft wide in 2001. 'J.N. Globe' forms a dense globe head and has an outstanding orange-red fall color in Washington County, Wisconsin.

This new cultivar has potential as a landscape plant for use as a screen or a specimen plant to show off its superior shape, density and fall color.

A grower's license may be obtained by contacting Michael Yanny, at the address above.

***Cercidiphyllum japonicum* 'Titania'**

This plant was found in a block of seedlings that had an unusually high number of variations; out of 50 seedlings seven were naturally weeping and one was exceptionally fastigiated. 'Titania' was selected out due to the very upright character since there is no recorded near columnar form of *Cercidiphyllum*. Like most katsura, grafting or budding is the preferred method of propagation because cuttings are unreliable. A 4-year-old plant is now 12 ft high and maintains its narrow character.

***Helenium flexuosum* 'Tiny Dancer'**
Delightful purple-brown spherical cones are surrounded by a flowing fringe of bright yellow reflexed petals looking like hundreds of yellow-skirted dancers in motion atop a compact, bushy plant. An exceptionally floriferous and low-growing whimsical native that joyfully greets the heat of mid-summer. Tolerant of a wide range of conditions, it performs the best in average to well-drained soils that are consistently moist. Plants are compact and heavily branched.

Helenium flexuosum is found in meadows, thickets, and along roadsides in most states east of the Rockies. Though it is said to be intolerant of dry soils, we have found it to be quite a reliable garden plant through summers wet and dry. It combines beautifully with summer *Phlox* or *Echinacea.*

- 18–24 inches tall.
- Full sun, light shade.
- Seed cultivar.
- Mid to late summer bloom, 4–6 weeks of flower.
- Works well as a cut flower.
- Tolerates drought once established.
- Zones 4–10.

***Hibiscus syriacus* 'Antong Two' ppaf, Lil' Kim™ rose of Sharon**
Lil' Kim™ rose of Sharon is a new dwarf, Korean selection. A unique little shrub with dainty little white flowers punctuated with a showy red eye. The plant appear to be polyploid because it has thick, dark green leaves and the flowers last for 3 days instead of the typical 1 day before falling. Creates many new landscape and garden uses; great for mixed containers, mixed perennial beds, or for around decks or entry gardens. Developed by noted plantsman Dr. Shim of South Korea. Zone 5, 3–4 ft

***Rosa* Oso Easy™ Rose Series**
For many years we've been searching for a better rose; a rose that can be grown like any other shrub on the farm — without fungicides. Working with breeders from across the globe, we tested many new plants but most flunked the test by developing either black spot or mildew. It turns out, however, that a few select plants met the challenge and remained clean after 4 years without a single fungicide treatment. And thus the Oso Easy roses were born and have emerged as a whole new class of rose. So throw away the sprayer and enjoy these roses because they are Oso Easy for both the grower and the gardener.

- ***Rosa* 'Chewground' pp 15,981, Oso Easy™ Fragrant Spreader rose**
  A new disease resistant ground cover rose adorned with loads of fragrant, single, pink flowers. It's a low growing rose for covering large areas, banks or other difficult locations. We've never sprayed this rose, and we've never shown a spec of black spot or mildew. Hybridized by Chris Warner of the U.K. Zone 5, 1–2 ft.
- ***Rosa* 'Horcoherent' pp 15,982, Oso Easy™ Peachy Cream rose**
  Put a smile on because Oso Easy Peachy Cream is going to make you happy. This lovely low-mounded rose delivers clouds of blooms that emerge peach and transform to cream. The large, doubled flowers are self-cleaning and contrasts wonderfully against the

glossy dark green foliage. We've never sprayed this rose in production and it has never shown signs of black spot. Hybridized by Colin Horner of the U.K. Supplies are limited so order early. Zone 5, 1–3 ft.

- ***Rosa* 'ChewMayTime' ppaf, Oso Easy™ Paprika rose**
  Spice up your life with Oso Easy Paprika, a remarkable low-mounded rose with loads of spicy, reddish-orange single blooms accentuated with a bright yellow eye. The glossy green foliage emerges with attractive hints of red in the new growth. This Oso Easy rose comes to us by from renowned hybridizer Chris Warner of the U.K. We've never sprayed this rose in production, and it has never shown signs of black spot. Zone 5, 1–2 ft.

***Rudbeckia subtomentosa* 'Henry Eilers'**
Named by Larry Loman of Ridgcrest Nursery for the person who discovered it along a stream in Montgomery County, Illinois. It produces strong upright clumps 4 to 5 ft tall and bears numerous clusters of finely quilled light yellow flower petals with brown cones in August and September. It has captivated many visitors to North Creek, many of whom asked us to grow it. Great with Joe-Pye weeds and grasses, it also has significant potential as a cut flower with its long stems and unusual flowers.

Rudbeckia subtomentosa is found in prairies, low meadows, open slopes, stream banks, roadsides from New York to Texas, north to Wisconsin and Michigan. It prefers average soils and even moisture, though it will easily tolerate long periods of drought.

- Blooms in late summer for 4–5 weeks.
- 4–5 ft tall, spreads 2–3 ft.
- Fragrant foliage.
- Propagation: cuttings, division.
- Zones 4–8.

***Silene caroliniana* var. *wherryi* 'Short and Sweet'**
This delightful setection of *S. caroliniana* var. *wherryi* is compact and easy to grow in bright shade or full sun. An excellent groundcover for average to rocky soil, it is covered in deep pink flowers in late spring. It has been very reliable for us through wet and dry seasons for 5 years now. In a cool spring it seems to bloom forever. Though tolerant of shade, it will have more blooms in sun.

Silene caroliniana occurs in dry, rocky woods, clearings from Vermont to Florida, west to Missouri. It is a great native substitute for *Dianthus* and more tolerant of shade and moisture! Grow as you would dianthus, in a mix with very good drainage, place in full sun or light shade, water regularly, but sparingly and fertilize lightly.

- Blooms in early spring for 4–5 weeks.
- 6–12 inches tall, spreads 12–15 inches.
- Propagation: Cuttings.
- Zones 4–7.

***Weigela florida* 'Eyecatcher' ppaf**
Electric yellow variegated foliage and dark red flowers in the spring make 'Eyecatcher' live up to its name. It's a great impulse plant that easily gives season long color to any garden, container, or landscape. Noted plantsman David Tristram delivers another great plant. Zone 5, 2 ft.

The University of Rhode Island Ornamental Breeding Program©

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The selection of superior ornamental plants combined with effective marketing strategies and production methods drives much of the economic growth in the nursery industry. The majority of newly introduced ornamental plants derive from chance discoveries of unique seedlings or branch mutations in nurseries, arboreta, and botanical gardens. There are, however, many public and private ornamental breeding programs both in the U.S.A. and abroad developing new plants using traditional methods and biotechnology to target specific traits. Unfortunately, lack of genetic variability for a particular trait in many important woody ornamentals is a significant impediment to plant improvement using traditional breeding methods. No amount of crossing alone will introduce or enhance a desirable trait, whether physiological or aesthetic, if the genetic potential does not exist in a population. In nature, living organisms "overcome" genetic shortcoming by tolerating mutations that may bring about genetic changes leading to novel traits. Natural genetic mutations and genome reorganization are primary survival mechanisms, allowing plants to adapt to their changing environment over time. Plant breeders have been taking advantage of this knowledge for many years by inducing mutations in agronomic and horticultural plants (Ahloowalia and Maluszynski, 2001).

Current ornamental breeding efforts at the University of Rhode Island are focused on developing protocols for ethylmethanesulphonate (EMS) mutagenesis of seeds and tissue cultures of several woody plants. Two outcomes are expected: (1) individual seedlings and plantlets stably expressing novel characteristics will be selected as potential cultivars, and (2) breeding populations exhibiting a range of novel traits will be developed for use in future breeding efforts. Mutagenesis of the multicellular plant seed results in first generation plants that are genetic mosaics, and observed traits may be chimeral. In addition, most mutations are recessive and will not be revealed in the first generation. Self-compatible plants can be self-pollinated, and a portion of the existing mutations will be revealed in the resulting progeny. Further rounds of self-pollination would reveal additional mutation-induced traits. For outcrossing species, plants can be selected as potential cultivars if an observed novel trait is stable and can be maintained by asexual propagation. Additional selection among outcrossing plants can be made in subsequent generations following either controlled or open pollination. Also in outcrossing or self-incomplatilbe plants, isolating half-sib populations can greatly increase the odds of acquiring progeny having recessive mutant genes in the homozygous state.

The preferred chemical mutagen for seeds is EMS and has also been used for inducing mutations in plant tissue cultures (Koornneef, 2002; Latado et al., 2004; Omar et al., 1989). Ethylmethanesulphonate results in mainly transitional point mutations occurring randomly in each exposed genome. The use of in vitro methods is of particular interest because of its potential for overcoming the problem

of genetic mosaicism. Both approaches have proven valuable, but require different approaches for generating non-chimeric plants. Ethylmethanesulphonate acts randomly within treated tissues, and results are dependent on time of exposure, EMS concentration, and the genome size of the target plants. The optimum concentration and timing of EMS treatments for an ornamental plant of interest can be estimated based on published reports or protocols for EMS mutagenesis of other plants and conducting relatively simple multifactor experiments (Alcantara et al., 1996; Penmetsa and Cook, 2000).

Multigenic traits tend to show the highest mutation-induced variability since there are more potential "targets" for mutation than traits controlled by a one or only a few genes (Koornneef, 2002). For instance, variegated mutants often result from induced mutations since many different genes control chlorophyll synthesis and degradation processes. Chlorophyll mutants can often be identified soon after germination following the emergence of the first true leaves. Other traits require longer evaluation periods such as flower color mutations. Natural and induced mutations have already contributed greatly to the improvement of fruit, vegetable, and agronomic and ornamental crops and have great potential for contributing new many more plants for the horticulture industry and novel germplasm for ornamental plant breeders.

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Understanding Remontant Flowering in *Hydrangea macrophylla*©

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There has, over the past several years, been a great deal of interest and discussion about remontant flowering (repeat flowering on current season's growth) driven primarily by the introduction of the remontant flowering *Hydrangea macrophylla* 'Bailmer', Endless Summer™ hydrangea. Although Endless Summer™ hydrangea and other remontant flowering *H. macrophylla* have certainly energized hydrangea interest, the genetic underpinnings of remontant flowering remains unknown. The elucidation of these responsible genetic mechanisms would certainly help to facilitate the introduction of the remontant flowering trait into improved cultivars. A traditional genetic approach could be used; however, this approach is impractical because of the long generation time of *H. macrophylla* and the fact that floral induction is known to be under the control of many genes. The basic pathway and genetic mechanisms involved in floral induction have been revealed in model plants such as *Arabidopsis thaliana*, and this knowledge can be used to develop a reasonable hypothesis for the variation in floral induction among *H. macrophylla*.

A model for the molecular control of flowering in *Arabidopsis* has been developed (Searle and Coupland, 2004). In this model, the 24-h cycle is controlled by a negative feedback loop involving the known clock genes LHY/CCA1 and TOC1. *Arabidopsis*, a facultative long day (LD) plant, flowers rapidly under long-days. According to the model, flowering is controlled by the central oscillator which controls expression of the genes CONSTANS (CO), GIGANTEA (GI), and FLOWERING LOCUS T (FT).

CONSTANS shows a diurnal expression pattern, and its protein requires light-mediated modification for activation. The activated CO protein then induces expression of FT leading to floral induction (Searle and Coupland, 2004). Analysis of the diurnal expression patterns of CO in plants grown under either LD or short day (SD) provided insight into how photoperiodism acts to control floral induction. In *Arabidopsis* plants grown under short days, CO expression and protein accumulation peaks during the dark period when light-mediated modification cannot occur. However, under long days, peak expression and protein accumulation occurs late during the light period and corresponds with increased expression of FT. The FT is dependent of CO for activation and is believed to be act directly on floral meristem identity genes (adapted from Searle and Coupland, 2004).

Can the model for photoperiod controlled flowering in the LD plant *Arabidopsis* be applied to SD plants such as hydrangea? Could this model help explain the natural variation in floral timing observed in *H. macrophylla*? Some data from the SD plant *Ipomoea* (*Pharbitis*) *nil* illustrates some important similarities (Kim et al., 2003; Liu et al., 2001). A single mutation could alter expression of a CO-like gene in hydrangea causing expression under LD (normally non-inductive) to occur during

daylight hours when the CO protein can undergo the needed modification. Similar shifts in CO expression timing have been observed following mutagenic treatments in *Arabidopsis* causing enhanced flowering under SD.

In collaboration with Dr. Tim Rinehart (United States Department of Agriculture – Agriculture Research Service), we are developing expressed sequence tags (ESTs) of genes expressed under either inductive or non-inductive conditions. Once these ESTs are available we will be able to compare expression patterns between remontant flowering and nonremontant flowering hydrangeas. This should lead us to the identity of genes responsible for the variation in floral induction. This information can then be used for marker-assisted breeding of new and improved remontant-flowering hydrangea.

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Rooting Possibilities of *Fraxinus chinensis*©

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INTRODUCTION

Fraxinus chinesis Roxb is found in the more northern areas of China and Korea. Griffiths (1994) gives it a Zone 6 rating, and trees growing in and around Philadelphia, Pennsylvania, a Zone 6 climate, have shown no climate-related difficulties. Since there has been no damage to temperatures as low as -10 °F there, a suggestion can be made that perhaps it is more cold hardy considering the natural origin of the species. It would be worth testing in Zones 5 and 4.

METHODS OF PRODUCTION

When most plants are brought to the North America from Asia the propagation material of choice is seed. With respect to *F. chinenis* Roxb., seedling production is not difficult following the traditional methods for *F. pennsylvanica.* Dirr and Heuser (1987) do not list *F. chinensis* but a protocol for *F. pennsylvanica* specifies 2–3 months moist cold stratification, which under most circumstances should also work for *F. chinensis* considering its natural origin.

Other methods such as budding or grafting might be worthwhile but to do so would undoubtably call for *F. pennsylvanica* as the appropriate rootstock. Since little or no information exists for this particular cross species graft it would be inadvisable to produce many without checking for graft incompatibilities. It would be worthwhile to pursue this course.

Work at Lorax Farms found that unlike most other *Fraxinus*, *F. chinensis* can be rooted.

In July terminal shoots were selected that did not have a fully formed terminal bud or a fully expanded terminal set of leaves. Cuttings selected were four nodes long, about 4–6 inches long and had four sets of leaves, all the leaves were retained. The cuttings were wounded on two sides and dipped in 5000 ppm IBA liquid [ethanol and water (1 : 1, v/v) mixture). The cuttings were stuck in 2¼-inch pots with a substrate of peat, sand, and perlite (1 : 3 : 1, by volume). Upon sticking the filled trays were placed under mist with bottom heat set at 70 °F and given supplemental lighting of 4 h from 10 PM to 2 AM.

After 6 weeks the cutting were evaluated with 100% rooting.

This contrasts with work by Barnes (1988) on *F. pennsylvanica* 'Summit' with a rooting percentage of 24%. Undoubtedly not all *Fraxinus* are created equal, and the ability to root is species specific. Not much work has been done with the genus *Fraxinus* probably due to the poor rooting response of the more common forms but freely rooting forms might be of significant importance to the nursery industry, especially with the development of new cultivars.

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Grafting White Barked Birches onto *Betula nigra*: Practice and Possibilities©

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INTRODUCTION

Industry experience indicates that for the most part cultivars of many white-barked birches are commonly grafted onto *Betula pendula,* European white birch. Examples such as *B. pendula* 'Youngii', *B. pendula* 'Laciniata', and *B. pendula* 'Tristis' grafted on to *B. pendula* seedlings are fairly common. When these graft combinations were grown in their native habitat or situations close to that, this should not present any particular problems. However, when these graft combinations are used in the United States where the climate considerations are significantly different they are frequently short lived and prone to insect and disease problems.

Dr. J.C. Raulston of North Carolina State University, Department of Horticulture, and I decided to look at this phenomenon and thought that by grafting white-barked birches onto a more appropriate rootstock a more adaptable plant could be obtained. We made a general supposition that if some of the stress factors that contributed to white bark birches were reduced in high heat areas they might be more adapted to a larger geographic area, including the southern portions of the U.S.A. Grafting is one way to achieve this, and the use of specific graft combinations to alleviate environmental stresses is not new. The grafting of *Citrus* species to *Poncirus trifoliata* to bring a small but significant degree of cold hardiness as well as inducing dwarfism is a long established practice (Barnes, personal observation; Dirr and Heuser, 1987). Other graft combinations are made with an emphasis on dwarfing, as in the East Malling rootstocks for apples, and establishing desirable cultivars on rootstocks tailored to unique soil conditions or make some selections more readily available, such as *Amelanchier* cultivars being grafted to *Crataegus* (Barnes, personal observation) and *Mespilus* to *Crataegus* (Barnes, 2005). As a consequence we decided on a number of white birch combinations with *B. nigra* as the understock of choice.

Betula nigra was picked as our understock because of its tolerance to high humidity and heat conditions, low requirements for chilling, particularly in the Deep South, and especially for *B. nigra*'s ability to tolerate water-saturated soils under very warm environments.

As a starting point to test the hypothesis of increased stress tolerance of white-barked birches *B. nigra* grafts had to be produced; they were not (and are still not) commercially available.

The purpose here is to outline what white-barked and some brown-barked birches functioned best on *B. nigra* at the initial propagation phase. Field and container testing was a further continuation of this project.

MATERIALS AND METHODS

Betula nigra seedlings were grown for 1 year in quart containers and were ready for grafting after that period with a stem diameter of 4–6 mm. Understocks were

watered and fertilized regularly and had vigorous root systems at the time of grafting in mid-October.

Scion wood was chosen to match as much as possible the diameter of the understock. Scion wood length varied from 4–8 nodes. A linear measurement is not accurate, and proper sizing of scions given as quantities of nodes is more reliable. Scions were side-grafted onto the rootstocks and tied with rubber bands followed by a wrapping of Parafilm. Completed grafts were placed in a high humidity tent and allowed to knit for 21 days. Then they were gradually aerated to acclimate to normal greenhouse conditions. Ambient air temperatures were on the order of 25 °C during the day and 20 °C at night. Humidity though was kept very high by frequent syringing with water mist, with care being taken to not saturate the soil of the understock nor get water along the scions. The tent was vented starting at 21 days to allow for acclimation to a normal greenhouse environment. Completed grafts were allowed to go into winter in a cool greenhouse kept at 3 °C. After 90 days grafts were brought into a warm greenhouse and allowed to flush. A tally was made of the various graft combinations (Table 1).

Table 1. *Betula nigra* rootstock combinations.

Betula scions species	Bark color	Native origin	Take (%)
B. costata	white	China	100
B. ermanii	white	North eastern Asia	100
B. occidentalis (*fontinalis*)	brown	western U.S.A.	100
B. maximowicziana	brown/white	Japan	100
B. papyrifera	white	U.S.A., Canada, Greenland	100
B. pendula	white	north western Europe	100
B. pendula 'Youngii'	white	north western Europe weeping cultivar	100
B. platyphylla var. *japonica*	white	Japan	100
B. pubescens	white	Central Europe, Siberia	100
B. schmidtii	white	Japan, Korea, China	25
B. lenta subsp. *uber*	brown	U.S.A. (Virginia)	100

DISCUSSION

Table 1 details certain aspects of the grafting of a range of birches onto *B. nigra* rootstock. From a grafting perspective *B. nigra* seems to be an acceptable rootstock with 100% take on all the species grafted with the exception of *B. schmidtii*. Since all the conditions for the grafts were uniform the variation for such a poor take with *B. schmidtii* is most likely a physiological phenomenon or an environmental factor specific to *B. schmiditii*, but a specific explanation is not readily apparent.

Shortly after this work was begun we tragically lost our good friend, Dr. J.C. Raulston to a car accident and much of the work that he was conducting on this project was lost.

However, several grafts of *B. pendula* 'Youngii' and *B. utilis* var. *jacquemontii* from other work were kept at Lorax Farms and were planted out. After 12 years

they are now mature and are setting seed. No graft incompatibility problems have been detected in that time; although the *B. jacquemontii* did die from borer attack. After the work of Barnes and Raulston, researchers at the North Carolina State Mountain Crops Research Center, Fletcher, North Carolina, did further work on studying graft combinations of white-barked birches on *B. nigra.* Dr. Tom Ranney and Research Extension Specialist, Dick Bir, looked at flood tolerance of a range of graft combinations (1994). One of their results was that white-barked birches grafted onto *B. nigra* showed superior growth and increased survival to induced flooding as compared to other rootstocks. They go onto say that *B. nigra* rootstocks may also be more tolerant to hypoxic soil conditions. While a scientific planting plan was not addressed, the *B. pendula* 'Youngii' grafts mentioned above were deliberately planted in soil conditions that exhibited frequent flooding and near hypoxic conditions. The sites were selected because other plant genera, *Cornus* and *Halesia*, succumbed to fall and winter rains and soil saturation with water with low oxygen levels; the *B. pendula* 'Youngii' grafts on *B. nigra* planted in the same area have not done so.

Further work by Ranney and Whitmann (1995) again looked at *B. platyphylla* var. *japonica* grafted onto *B. nigra* as well as four other white-barked birches. In this study *B. platyphylla* var. *japonica* grafted well onto *B. nigra* and in comparison to the other species of rootstocks in general had greater trunk diameters and tree height, except for *B. pendula* as a rootstock. However, frost cracks developed with the *B. nigra* rootstock combinations that did not occur with the other *Betula* species as rootstocks. Also the *B. nigra* rootstock grafts developed chlorosis due to high pH problems and iron deficiency brought on by the pH situation, which is a common condition with *B. nigra* itself when grown in soils with high pH. Their recommendation was to utilize *B. nigra* grafts for acid soils with care being taken to avoid alkaline conditions that might lead to the chlorosis problems.

In spite of these physiological conditions Ranney and Whitmann (1995) stipulated that *B. nigra* should be considered to be an appropriate rootstock for *B. platyphylla* var. *japonica*.

Another early supposition was that perhaps the resistance to bronze birch borer (*Agrilus anxius* Gory) could be conveyed by grafting onto *B. nigra*. *Betula nigra* is a birch known to be resistant to the harmful insect as it has little or no presence of rhododendrin, which when converted in the plant to the aglycone form becomes a chemical that attracts *Agrilus anxius* (Santamour, 1999). However subsequent work with grafts of *B. jacquemontii* on *B. nigra* that initially showed promise failed to remain immune to the bronze birch borer once the grafts reached maturity and started setting seed (Barnes, personnel observation). This suggests that the chemicals involved, rhododendrin and its aglycone, rhododendrol, are produced in the arboreal portions of the white birches and not in the root systems. Grafting then would have only a marginal affect on the rhododendrin production. However, the *B. pendula* 'Youngii' grafts listed above have been setting seed for a number of years, and they have remained free of bronze birch borer. One condition that may account for this is that the *B. nigra* graft combination affords a certain degree of tolerance to stress situations, which normally would weaken the tree and set it up for bronze birch borer infestation, which seems to be most likely the case.

Santamour (1999) suggests that rhododendrin, a natural component of many white-barked birches, as a result of senescence of leaf tissue, undergoes hydroly-

sis to rhododendrol, a known phytochemical that attracts the bronze birch borer. Although Santamour in his study did not mention any correlation with the presence of bronze birch borer and flowering of birches, casual observation over years of seed collecting by myself from white-barked birches indicates that there is more than circumstantial evidence to suggest that there is a direct relationship between the increasing age of the plants, the presence of flowers, and the infestation with bronze birch borer (Barnes, personal observation). Actually this goes in hand with some of Santamour's assessment of leaf senescence since flowering and the formation of flowers is derived from leaf tissue. Could it be that the same physiological factors that contribute to the hydrolysis of rhododendrin to rhododendrol are the same in flower formation and maturing as in leaf senescence? Could a quantitative analysis of leaf tissue show an increase in rhododendrol as a function of plant age and flowering and in turn give an indication of susceptibility to infestation by *Agribus anxius*. Shetlar (2000) contends that stress factors that contribute to leaf tissue degradation and senescence include heat stress, drought, flooding, and hypoxic soils thereby setting sensitive birches up for rapid attack by the bronze birch borer. By limiting the incidence of stress factors *B. nigra* grafts may be reducing the potential for borer infestation. It should be noted that in agreement with Santamour (1999) and Shetlar none of the *B. pendula* 'Youngii' grafts have exhibited abnormal leaf senescence and have remained borer free.

Specific recommendations from this work and that of Ranney et al. (1994, 1995) indicate that *B. nigra* should be an effective rootstock for many of the white-barked birches and the use of *B. nigra* as a rootstock contributes a range of positive attributes to the graft combination. The very good graft takes and the continued thriving of the *B. pendula* 'Youngii' indicates that using *B. nigra* as a rootstock for grafting other birches is a realistic possibility.

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Propagation of *Jamesia americana*©

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INTRODUCTION

Jamesia americana Toor. and A. Gray., cliffbush, is a western North American species occurring in the Rocky Mountain states of Colorado, Utah, Arizona, Idaho, California, and New Mexico (Anonymous, 2005). It grows primarily in high, well-drained sites. A member of the *Hydrangeaceae*, it becomes a shrub to around 1.5 m or close to 5 ft. Stems are pubescent and slowly develop peeling bark. Flowers are generally white with a pink form being reported (Griffiths, 1994).

PROPAGATION AND PRODUCTION

Seedling Production. Being a species in the Hydrangeacea, production from seed is pretty straightforward, with a surface sowing that is not covered. The seed should be watered in but not kept especially moist. Cold moist stratification is a must, and an ideal approach is to sow the seed, which is fine and dust-like, on to moist surface media in a pot and enclose the pot in a polybag and refrigerate the entire pot for 4 months. Upon satisfying the cold treatment, the pot can then be removed from the polybag and placed in a greenhouse environment and watered only when necessary. Since *Jamesia* is endemic to rather arid climates care should be taken to ensure that the medium is especially well drained and not overwatered. A prophylactic application of Daconil or similar type of fungicide might prove to be beneficial to prevent damping off of the seedling.

Transplanting into individual pots should be delayed until the seedlings are well established. Once transplanted, the seedlings should be placed in sealed clear polyethylene boxes with a moist layer of perlite to provide humidity. The seedlings should be left in these humidity chambers for about 1 week.

Cutting Production. While normally kinship to the hydrangeas would indicate an easy production from cuttings, *Jamesia* is not so user-friendly, although it can be accomplished. It is unlikely that the proper timing for the taking of cuttings from wild populations will give promising results.

However, containerized plants do offer some degree of opportunity to grow this plant via cuttings. Potted seedlings should be brought into the greenhouse after sufficient winter vernalization and forced into new growth. After the first flush has produced about 2–3 inches of growth the soft tips can be utilized. Cuttings should be about 24 nodes long with 2–4 leaves. Cuttings should be wounded and direct stuck into individual pots with a substrate of Grace 500 growing mix and perlite (1 : 2, v/v) which provides the necessary drainage to facilitate rooting. Cuttings should be given bottom heat set at 70 °F and mist of 10 sec every 10 min.

Cuttings root in about 3 weeks, with 50%–60% rooting. The mist can be especially harmful to the heavy pubescent leaves and cause rotting. A humidity chamber as outlined about might offer more consistent rooting with less damage to the foliage.

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Propagation and Use of *Adina rubella*©

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INTRODUCTION

Adina rubella, (Rubiacea) Chinese buttonbush, or glossy *Adina* is from eastern China (2003), Japan (Woodlanders**,** 2006), and other parts of Asia. It is an upright open shrub and will attain heights of 8–10 ft with an equal spread. It occurs naturally along stream banks, ditches, and other areas of water, although there are conflicting references to the plants acceptance of poorly drained sites with Evans (2003) listing wet conditions as possible while others (SmallPlants.com, 2006) indicate such conditions can be deleterious. Evans (2003) also lists it with a hardiness of Zone 6 while others (Plants for a Future, 2006) stipulate that Zone 5 is applicable. In Zone 6 and higher the plant is user-friendly and will accept conditions from full sun to partial shade. Soil conditions do not seem to be particularly significant, with pH differences from acid to alkaline being tolerated.

The overall appearance of the plant is satisfactory with the bright shiny dark green leaves being a plus. Flowering is copious for most of the summer, but the small stature of the lightly fragrant flowers does not allow a strong presence. The flowers of *Adina* can be thought of to be miniature forms of the North American native, *Cephalanthus occidentalis*, to which it is closely related.

PROPAGATION

Cuttings of *Adina* were obtained in early September. They were about 4 inches long with 6–8 nodes. The soft tips were left intact. The cuttings were wounded and given a hormone treatment of 2000 ppm IBA / 1000 ppm NAA, [Dip 'N Gro 1 : 5, (v/v)]. They were stuck into individual pots with peat, sand, and perlite mixture (1 : 3 : 1, by volume) as a substrate. Bottom heat was provided at 70 °F and mist came on for 10 sec every 10 min during daylight hours. After 23 days, 75% of the cuttings had rooted. Over-wintering is not a significant problem.

DISCUSSION

With the relative ease of propagation and the large adaptability to the soil and environmental conditions, this plant should be used more for specific areas even if its overall appearance does not rival showier plants. However, the potential for a Zone 5 hardiness and tolerance for alkaline soil conditions might make this a useful ornamental for the Midwestern plain states where the plant palate is not as large as what can be found in the Eastern parts of North America.

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Production of *Fortunearia sinensis* from Seed©

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INTRODUCTION

Fortunearia sinensis Red. & Wils. is a little known member of the Hamamelidaceae, and little if any information is available for either horticultural or research purposes. It is a large shrub with pubescent leaves that are obovate and look similar to a pubescent *Corylopsis* to which it is related. The green flowers are insignificant and occur in terminal racemes and are not particularly showy. Female flowers emerge with leaves and the male flowers are catkin-like in appearance. Fall color is yellow. Griffiths (1994) suggests a Zone 8 designation but plants growing at the Morris Arboretum in Philadelphia suggest a much hardier plant. Zone 6 is a more likely and appropriate classification. The plant occurs naturally in central and eastern China.

While sparingly effective as an ornamental horticultural plant, it deserves recognition and study to further understand the nuances of the Hamamelidaceae.

PROPAGATION

Since little is written about this plant, information is scarce. An Internet search failed to turn up even one reference. Seed is not readily obtained on the commercial market, and there are few plants available anywhere for a thorough study on its propagation. However, a large plant at the Morris Arboretum in Philadelphia did have an ample seed crop, and this served as a starting place for some experimentation on seed germination.

When confronted with a species that is not well known the most appropriate approach to its propagation is to see what techniques are available for members of the same genus, and if that is not available, then reference should be made to members of the same family and further up the phylogenetic profile until some kinship can be established. Being in the hamamelis family, there is ample literature on closely related genera such as *Corylopsis*, *Hamamelis*, and *Parrotia*.

Since the other members of the Hamamelis family can readily be grown from seed it was decided to try the same techniques with *F. sinensis*.

Dirr and Heuser (1987) mention two techniques for germination of *Hamamelis* ×*intermedia* hybrids. One suggestion was for 3 months warm moist stratification followed by 3 months cold moist stratification. Another entry reported 12 months warm followed by 3 months cold. They go on to say that fall sowing will result in germination the second spring. With *H. vernalis* they mention a series of tests with 5 months warm followed by 3 months cold gave an 85% germination rate.

Following this lead, the 5-month warm moist period followed by the 3-month cold moist period was implemented. The fruit was collected fresh before dehiscing and placed in a paper bag so that the expelled seed could be captured. The fresh seed was not stored and was placed in the warm moist stratification regimen once all the pods had released their seed. The stratification substrate was moist perlite. Seed was mixed with moist perlite (1 : 10, v/v) and enclosed in a clear zippered polybag.

The warm moist stratification and cold stratification was carried in total darkness. After the required stratification periods were met the seed was removed and sowed in a large tray with a count being taken to ascertain germination percentage.

After a period of several weeks in normal greenhouse temperatures of 20 °C, germination percentages were checked. The results were good with 100% germination. Thus it appears that *F. sinensis* is easily grown from seed like many other members of the *Hamamelis* tribe.

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Production of *Sinojackia rehderiana* and *Sinojackia xylocarpa* from Seed©

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INTRODUCTION

Sinojackia rehderiana Hu, jack tree, and *S. xylocarpa* Hu are two deciduous members of the Styraxcaceae from Eastern China (Griffiths, 1994). Both trees are hardy to Zone 6 and could be significant additions to the flowering tree market from Zone 6 to 8.

In the landscape the trees are somewhat shrubby and can form a single stem, which persists for a limited time only to be followed by fast growing basal shoots that quickly convert the tree to a clump form. However in deep shade this tendency is reduced, and single stem specimens can be found. Flowering is in the spring for both species, and the trees have a strong resemblance to other members of the *Styrax* family, particularly *S. japonica*. Differences between the *Sinojackia* and *Styrax* pertains to the strong central leader and stem of *S. japonica* as contrasted to the more open clump characteristics of *Sinojackia* species and pubescent leaves of *Styrax* as opposed to the glaucus leaves of *Sinojackia*.

Culturally they are pretty much the same with very similar requirements and little or no pest problems. Being ready clump formers *Sinojackia* taxa are overall smaller in stature and do not have the robust nature of *Styrax*. Both of the *Sinojackia* can be raised in full sun to part shade, which opens up greater usage in the landscape as compared to the *Styrax*. Treated as understory trees they perform quite well and do give a good floral display with white pendulous fragrant flowers quite reminiscent in shape and form to that of *S. japonica*. The fruit, however, differs substantially with the *Sinojackia*. *Styrax japonica* fruit is smooth and round with a light green outer shell holding a very dark nut-like seed. *Sinojackia* have fruits that are elongated, being 2–3 times in length as compared to diameter and quickly tapering to a very sharp point. The seed coat of both species is brown with dark speckling. Also the fruit of *Sinojackia* is much larger than that of *Styrax* and hangs down on the very long peduncle that once supported the flower. There are some subtle differences in the fruit characteristics of *S. rehderiana* as compared to *S. xylocarpa* with a few features sufficient to tell them apart but otherwise they are quite similar. The fruit of both *Sinojackia* is so unusual as to extend a unique contribution to the landscape uses of the plant that none of the *Styrax* offer.

Two cultivars of *S. xylocarpa* have been introduced to the trade. Efforts of the J.C. Raulston Arboretum in Raleigh, North Carolina (J.C. Raulston Arboretum, 2003) have produced *S. xylocarpa* 'La Grima', a narrow fastigiate form and Brian Upchurch from Highland Creek Nurseries, Fletcher, North Carolina, (PendulousPlants.com, 2005) has introduced *S. xylocarpa* 'Linda Carol', a unique weeping form. To date no cultivars of *S. rehderiana* are available.

PRODUCTION

While it seems plausible that the *Sinojackia* taxa could be rooted, no reports of this method of production are available. Highland Creek's method of *S. xylocarpa* 'Linda Carol' depends on grafting to *S. xylocarpa* seedlings with no particulars being mentioned. It is probably a safe bet that the J.C. Raulston Arboretum's cultivar 'La Grima' is also produced by grafting.

For the purpose of raising either of the two *Sinojackia* species for landscape use or for root stock seedlings are required. The production of *Sinojackia* seedlings pretty well follows the same pattern of other members of the *Styrax* family. As with *Halesia carolina,* (Dirr and Heuser, 1987), *H. diptera* (Barnes, 2005), *S. japonica*, and *S. obassia* (Dirr and Heuser, 1987), after ripening is a fundamental requirement. This is usually accomplished with 5–6 months warm moist stratification in the dark. After this initial after-ripening period is achieved a moist cold period of 60–90 days is necessary to break dormancy. From that point on seeds can be sown in cell trays or beds or pots depending upon how the seedlings are to be handle. Germination though is sporadic and has properties that are similar to the difficulties encountered with *H. diptera.* Once the seedlings are growing to the point of having several normal leaf pairs they can be handled much the same as with *S. japonica.*

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Scion and Rootstock Effects on Growth and Early Acorn Production of Grafted Swamp White Oaks©

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Swamp white oak (*Quercus bicolor* Willd.) is an important mast species, producing medium-sized acorns found highly desirable by wildlife in both upland and bottomland forests. In addition, the Northern Nut Growers Association <www.nutgrowing.org> is promoting acorns from selections within this species as a new edible food crop. Dey and others (2004) reported wide variation in both precocity and acorn productivity for swamp white oak within their bottomland oak plantings. They reported that 3.5% of the swamp white oak saplings started producing acorns in as few as 3 years from seed. This early fruiting trait is highly desirable and should be the basis of selection when identifying individuals for deployment in bottomland plantings.

There appears to be little information available documenting the heritability of precocity and acorn production in swamp white oak. In addition, we have found no information on how scion and/or rootstock source may affect precocity or productivity of grafted swamp white oak trees. For a grafting program to be successful, it is desirable that the grafted ramets exhibit similar patterns of precocity as the selected ortets and that any rootstock effects on precocity are clearly defined. Our objectives for this study were to determine if grafted swamp white oaks exhibit a similar trend in precocity as their selected ortets and to determine the magnitude of any rootstock effects on fruiting in grafted swamp white oaks.

MATERIALS AND METHODS

In fall 1995, acorns were collected from a single swamp white oak tree in Boone County, Missouri. Acorns were sent to the Forrest Keeling Nursery to produce both 1-0 bare-root seedlings and their patented Root Production Method (RPM) seedlings (Lovelace 1998). In spring 1997, seedlings were planted on an upland ridge with deep loess soils at the University of Missouri, Center for Agroforestry (UMCA), Horticulture and Agroforestry Research Center in Howard County, Missouri. Eight seedlings of each stock type (i.e., bare-root seedlings vs. RPM containerized seedlings) were planted in each of four single row plots within a larger study comparing growth and early fruiting of saplings for eleven hardwood species. Factorial treatments with and without drip irrigation and with and without annual fertilization using slow-release 27N-3P-6K were applied to pairs of trees of each stock

type within each 16-tree row plot. Initial tree spacing was 10 ft within row and 20 ft between rows. Within-row vegetation was controlled with periodic application of glyphosate from 1997 through 2002 while the between row tall fescue sod was periodically mowed. Individual tree height and basal diameter as well as annual acorn production were measured from 1997 through 2002.

In fall 2001, acorns were collected from six precocious trees and used to grow seedlings following the RPM method (Lovelace, 1998). In this method, acorns were sown on the surface of potting medium within $15 \times 15 \times 4$-inch deep Anderson trays, which were then stacked, placed within a closed polyethylene bag and then stratified for 3 to 4 months at 36 °F within a walk-in refrigerator. Trays were moved to a heated greenhouse in March 2002. One-flush germinates were shifted up to Anderson ($3^5/_8 \times 3^5/_8 \times 5$ inch) plant bands and then to 1-gal pots to produce 1-year-old, three-flush container-grown seedlings during the 2002 growing season and then overwintered outdoors under 0.25-inch thick closed-cell white polyethylene foam covered by a single layer of 4-mil white polyethylene sheeting.

In January 2003, scionwood was cut from five precocious and three non-precocious trees from the study established in the spring 1997. Whip and tongue grafts were made in the greenhouse in early spring 2003 on the 1-gal potted rootstocks produced in 2002. Successful grafts were shifted up to 3-gal pots in June 2003 and maintained in a shade house under 55% shade screen with daily overhead irrigation. A total of 127 grafts representing 8 scion × 6 rootstock combinations were planted in October 2003 on a north-facing slope at the Horticulture and Agroforestry Research Center. Grafts were randomly planted on a 12×15-ft spacing within a 0.5-acre plot with no obvious site variation. Grafts have received annual spot weed control with glyphosate and periodic mowing to control grass competition.

In September 2006, survival, diameter at breast height, and the number of nuts were recorded for each graft. These data were subjected to analysis of variance for a completely randomized design. Due to unbalance, Type III sums of squares were used to determine if differences existed among scion, rootstock, and/or scion × rootstock at the 5% level. Fisher's unprotected least significant differences were calculated to separate statistically different means at the 5% levels.

RESULTS AND DISCUSSION

The RPM™ seedlings in the study established in 1997 were only slightly larger in basal stem diameter (11.2 vs. 8.3 mm) and stem height (1.1 vs. 0.5 m) than the bare-root seedlings. It is unknown what effect size may have; however, recent advances in the RPM technology now produce much larger swamp white oak seedlings such as those used by Dey and others (2004) in their bottomland reforestration project. Although the RPM seedlings in our study maintained a slight size advantage over the bare-root seedlings, differences were not statistically significant after the second growing season. We also found no differences between stock types as to the age when trees began producing acorns (Table 1). Lack of statistical differences between stock types for cumulative total acorn production from 1999 through 2002 may in large part be due to two exceptionally productive trees established as bare-root seedlings (Ortet #1 and #3). Likewise, neither fertilization nor irrigation increased acorn production of either stock type on this excellent oak site (data not shown).

The wide variation in acorn precocity and production found among the 64 half-sib seedlings grown on a deep soil with adequate soil moisture and nutrients suggests that fruiting is likely under strong genetic control. If so, it may be better to vegetatively propagate these highly productive trees via grafting rather than by seed.

Table 1. Stem diameter and number of acorns produced for 10 swamp white oak trees used as sources for either scionwood and/or acorns for production of rootstocks.

Ortet number[1]	Stock type	Fall 2002 DBH (cm)	First year for acorns	Acorn production by year				Acorns total
				1999	2000	2001	2002	
1	Bare-root	8.6	1999	10	205	158	220	593
2	RPM	6.4	1999	4	10	48	140	202
3	Bare-root	7.3	2000	0	188	181	142	511
4	Bare-root	7.4	2000	0	28	56	96	180
5	RPM	7.3	2000	0	98	91	46	235
6	Bare-root	6.8	2000	0	31	175	24	230
7	Bare-root	7.8	2000	0	59	52	116	227
8	RPM	8.2	2001	0	0	20	106	126
9	RPM	7.3	2002	0	0	0	14	14
10	RPM	6.1	>2002	0	0	0	0	0
All[2]	RPM	7.3	2002	5	650	275	695	1625
All	Bare-root	6.7	2002	9	511	896	1168	2584

[1] Ortet #1 through #7 were considered to be precocious and ortet #8 through #10 non-precocious.

[2] All equals the total acorns produced by all 32 trees established as either bare root or RPM seedlings.

Table 2. Stem diameter and acorn production by 4-year-old ramets grafted with scionwood of the eight ortets described in Table 1.

Ortet number[1]	Ramets (no.)	Percent bearing	Acorns per grafted ramet		Average DBH (cm)	Acorns/ TCSA (no./cm²)
			Average	maximum		
1	21	100	41	126	2.8	1.55
2	16	100	33	77	3.3	0.91
3	22	96	75	186	2.8	2.59
6	12	100	57	112	3.4	1.52
7	8	83	51	105	2.9	1.67
8	10	67	13	57	2.2	0.64
9	16	45	5	25	3.4	0.13
10	10	19	4	22	2.6	0.09
5% lsd=		30	----	0.5	0.37	

[1] Scions were not collected from ortet #4 and 5.

Table 3. Stem diameter and acorn production averaged across eight scion sources when grafted onto half-sib seedling rootstocks derived from the ortets described in Table 1.

Ortet no.	Ramets (no.)	Percent bearing	Acorns per grafted ramet		Average DBH (cm)	Acorns/ TCSA (no./cm²)
			Average	maximum		
1	22	83	51	126	2.9	1.66
2	10	100	57	146	3.1	1.78
3	23	92	27	126	2.8	0.98
4	22	75	44	186	3.2	1.32
5	15	62	21	116	2.7	0.73
6	23	85	34	91	2.9	1.23
5% lsd=			26	----	0.9	0.28

We found that swamp white oak can be easily grafted. We observed no evidence of any graft incompatibilities (i.e., reduced growth or stunted foliage) among the 48 scion × rootstock combinations. Survival after 3 years for grafts planted into the field exceeded 90%. Although we did not find any significant stock × scion interactions, we did find both significant scion and rootstock effects for stem diameter and for number of acorns produced per grafted tree (Tables 2 and 3).

Acorn productivity was more strongly influenced by the source of the scionwood than the rootstock based on the probabilities for significant differences. The average number of acorns per grafted tree for the ramets from the precocious (Ortet #1 through #7) and non-precocious (Ortet #8 through #10) sources closely paralleled cumulative acorn production of the ortets themselves (Table 1). Because the grafts had slightly different growth rates, acorn production data were standardized by converting to number of acorns per cm^2 trunk cross-sectional area (TCSA). We also found that the ortet rankings for cumulative acorn production during the 4-year period from 1999 to 2002 were identical to the scion rankings for the number of acorns produced in 2006 on a TCSA basis except for Ortet #1. None of the half-sib progeny from the highly productive swamp white oaks yielded a superior rootstock for grafting (Table 3). There was a trend for seedlings of Ortet #5, when used as a rootstock, to exhibit reduced stem diameter growth and acorn productivity.

CONCLUSIONS

Our study demonstrated that swamp white oak can be easily propagated using a whip and tongue graft. Field-planted grafts showed high survival rates with no graft incompatibility evident after four growing seasons when using scion and rootstocks originating from a common maternal source. Unlike half-sib seedlings, the 127 grafts used in this study exhibited similar patterns of precocity and acorn production as the source tree used for scionwood. The nonsignificant rootstock × scion interaction for acorn production in this species will provide the flexibility to utilize a range of swamp white oak seed sources for use as rootstocks, if needed. It is suggested that the number of acorns produced per unit TCSA in young swamp white oak grafts can serve as an indirect measure of ortet acorn productivity when such cumulative seed production figures are unknown. Based on these findings, highly precocious individual swamp white oak trees can be readily identified and potentially utilized as grafted stock for planting in landscapes which may include wildlife enhancement as a management objective.

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Shrub Liner Growth and Development Control with Plant Growth Regulators and Water Stress©

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INTRODUCTION

Producing compact, well-branched shrub liners often requires pruning several times during a plant's production cycle. This process requires significant labor and often results in severe plant stress. The goal of the experiment was to determine if plant growth regulators could be used to effectively control growth of shrub liners and also to determine to what extent water stress alone could control growth. The effect on branching was also a point of interest.

MATERIAL AND METHODS

There were three series of experiments in which four growth regulators and water withholding were tested on 12 species. For each growth regulator, three rates were tested. Species tested were *Buddleia davidii* 'Peakeep', Peacock™ butterfly bush; *Caryopteris* ×*clandonensis* 'Minbleu', Petit Bleu™ bluebeard; *Cornus sericea* (syn. *stolonifera*) 'Farrow' Arctic Fire™ redstemed dogwood; *Helianthemum* 'Rhodanthe Carneum' (syn. 'Wisely Pink'); *Hydrangea macrophylla* 'Paris Rapa', Cityline® Paris; *H. macrophylla* 'Jōgasaki'; *H. paniculata* 'Bylk', Quick Fire™ panicled hydrangea; *Physocarpus opulifolius* 'Monlo', Diablo™ ninebark; *Potentilla fruticosa* 'Pink Beauty'; *Sambucus nigra* f. *porphyrophylla* 'Eva', Black Lace™ eldeberry; *Spiraea japonica* 'Little Princess', and *Weigela florida* 'Alexandra', Wine & Roses™ weigela. Plant growth regulators tested were Bonzi (30, 40, 60 ppm), Sumagic (10, 20, 40 ppm), Atrimmec (500, 1000, 1500 ppm), and Florel (500, 750, 1500 ppm). Plants were sprayed twice 2 weeks apart, except for Atrimmec experiments where plants were sprayed only once. Plant height and branching were recorded weekly. For water stress experiments, plants were dried to the point of wilting between watering.

RESULTS AND DISCUSSION

All experiments provided interesting results (Figs. 1 and 2). Some degree of height control was observed in nearly every species. Branching was not affected much in the case of Bonzi and Sumagic, but Atrimmec and Florel did significantly increase branching on some species. Future experiments must be conducted to determine most appropriate rates, appropriate timing of applications, and the end effect of the applications after transplanting. Perhaps one of the most interesting observations was the amount of height control achieved through water stress alone.

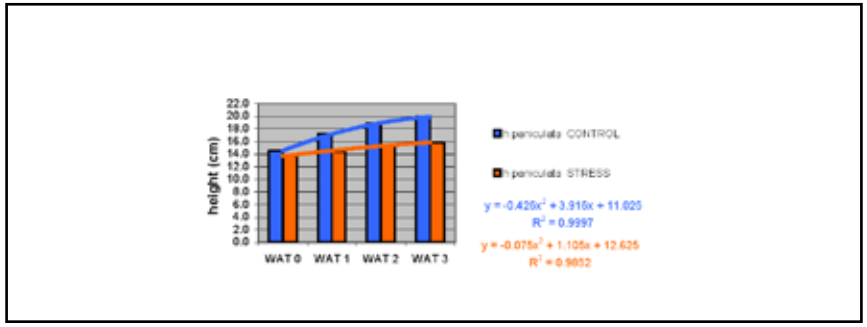

Figure 1. Water stress and *Hydrangea paniculata* height evolution.

Note: T0 = Control, B=Bonzi (ppm), A= Atrimmec (ppm).

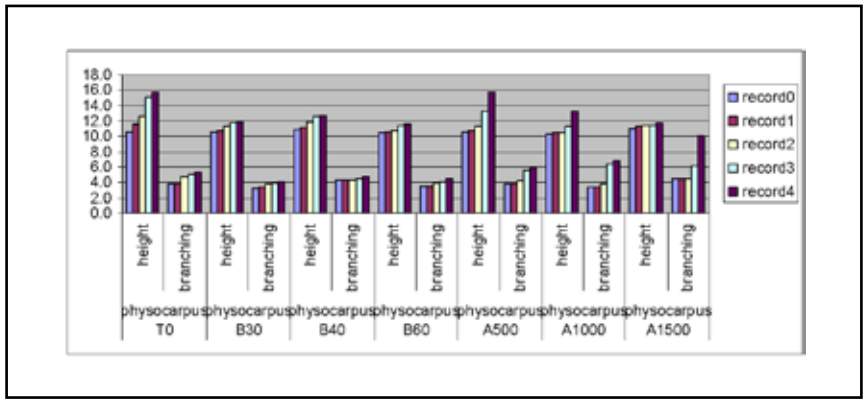

Figure 2. Effects of Bonzi and Atrimmec on the growth of *Physocarpus opulifolius* 'Monlo', Diablo™ ninebark.

Micropropagation of *Physocarpus amurensis*©

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***Physocarpus amurensis* (Maxim.) Maxim. is an endangered deciduous shrub in the family of Rosaceae only native in China. Micropropagation of *P. amurensis* was conducted by taking axillary buds from field plants and apical buds from greenhouse seedlings as explants. Protocols were developed for axillary bud and apical bud sprouting, axillary-bud- and apical-bud-derived shoot proliferation, enlongating and strengthening of proliferated apical-bud-derived shoots, in vitro rooting of axillary-bud-derived shoots and ex vitro rooting of enlongated and stronged apical-bud-derived shoots.**

INTRODUCTION

Physocarpus amurensis is a deciduous shrub in the family of Rosaceae. The genus *Physocarpus* includes approximately 20 species in the world. The world geographic distribution of this species is centered in North America, and only one species found in China (Zhou, 1986). *Physocarpus amurensis* is the only species distributed in China, it is a relic species (Lu, 1999). It is not only an excellent ornamental shrub (Chen, 2003), but also a medicinal tree species (Yang, 2004). There is a small isolated population on the peak area of Maoershan in our University Forest at Maoershan Town, ShangZhi City, Heilongjiang Province, China. Because of extremely narrow distribution, population spread was restricted. There was almost no seed regeneration. Clonal propagation is crucial to evolution and survival of the population. Currently, the areas of distribution and the population size of this species in China are much less than in the past. So it was believed an endangered plant species and must be protected (Qin et al., 1993).

Tissue culture techniques have been extensively used for mass propagation of forest and cultivated tree species (Khurana et al, 2003). The micropropagation of *P. amurensis* offers important conservation possibilities, which have the potential to support in situ protection strategies (Bensone et al., 2000). Ex situ conservation using in vitro methods provides a "safe" repository for populations of *P. amurensis* derived from locations severely at risk. In vitro propagated plants may be transferred to ex vitro environments. The rapid production of large numbers of in vitro plantlets, (without seasonal dependency) for ex situ commercial cultivation purposes reduces the risks of *P. amurensis* plants being sampled from wild habitats and thus safeguards existing natural populations. The aim of this study was to develop an effective micropropagation method for *P. amurensis* for commercial and conservative purposes.

MATERIALS AND METHODS

Initiation. We collected the axillary buds from the mature mother dormant trees (1 or 2 years old) and apical buds from 3-month-old greenhouse seedlings of *P. amurensis* as explants of micropropagation.

Axillary bud explants were surface sterilized with 70% (v/v) ethanol for 10 sec (two times, 5 sec for each), and then sterilized with 10 min immersion in 0.1% mercuric chloride containing two drops of Tween-20, followed by being rinsed 3–5 times in sterile water and aseptically transferred to tissue culture tubes containing woody plant medium (WPM) basal medium supplemented with 0.01 $mg \cdot L^{-1}$ TDZ for axillary bud sprouting in vitro.

Apical buds explants were washed under running tap water for 30 min to remove superficial contamination and were surface sterilized with 75% (v/v) ethanol for 10–20 sec, then sterilized with 3 min immersion in 3% H_2O_2 containing two drops of Tween-20, followed by being rinsed 3–5 times in sterile water and aseptically transferred to tissue culture tubes containing Murashige and Skoog (MS) basal medium.

For all the experiments, MS (Murashige and Skoog, 1962) basal culture medium was used, supplemented with 2.5% (w/v) sucrose and 0.65% (w/v) agar. The pH was adjusted to 5.8 before adding agar. The media was subsequently autoclaved under 105 KPa at a temperature of 121 °C for 20 min. Explants were placed in a culture tube (50 ml) with 25 ml of MS media and kept under controlled conditions at 25±2 °C, with a 16-h photoperiod (irradiance of 30~40 $\mu mol \cdot m^{-2} \cdot s^{-1}$) under cool white light, relative humidity 60%–70%. The development state was observed after 30 days culture.

Multiplication. Multiplication media for shoots derived from axillary and apical bud explants were MS supplemented with different concentration NAA and BA. Because of the mean length of multiple shoots from apical buds of greenhouse seedlings were very short (< 1 cm), and not suitable to root, the shoots were elongated and strenthened. The MS medium supplemented with different concentration IBA and GA_3 were used as the shoot elongation and strengthening medium (strengthening refers ot the fact that the shoots obtained during proliferation are too weak for rooting and need to be subcultured one more cycle before rooting).

Rooting. Rooting of shoots derived from axillary buds was in vitro on MS medium supplemented with 0.1 $mg \cdot L^{-1}$ IBA. In vitro rooting of the multiplicated shoots from apical buds was not good, therefore, ex vitro rooting was tried. The basal end of multiplied microshoots from apical buds (approx. 2–4 cm long) were immersed in liquid with different concentration of NAA for 30 min or dipped 1000 $mg \cdot L^{-1}$ NAA for 10 sec, after thoroughly washed under running water to remove the adhered agar. The treated microshoots were transferred to plastic plots (33 × 22 × 11 cm) containing steam-sterilized peat and vermiculite mixture (2 : 1, v/v). The plots were transferred into a culture room maintained at 25±2 °C with a relative humidity of 80%–90%. The plantlets were harvested after 30 days and washed carefully to expose the roots. Shoots survival rate, rooting rate, total primary roots, and root length were measured.

RESULTS AND DISCUSSION

Shoot Regeneration from Axillary Buds of Natural Field Plants. A MS medium supplemented with 1.0 $mg \cdot L^{-1}$ NAA and 1.0 $mg \cdot L^{-1}$ BA was the best for proliferation. Mean number of multiple shoots per bud was 18 shoots (Fig. 1) and the shoot growth was normal. A MS medium supplemented with 2.0 $mg \cdot L^{-1}$ NAA and 0.6 $mg \cdot L^{-1}$ BA was the best for strong growth and mean length of multiple shoots was >2 cm. A MS medium fortified with 0.1 $mg \cdot L^{-1}$ IBA was suitable for in vitro root development. In vitro rooted healthy shoots transferred directly to plastic plot containing steam-sterilized peat and vermiculite mixture (2 : 1, v/v) revived growth after 30 days of transplantation and 65% plantlets survived in field conditions.

Figure 1. Proliferation of axillary bud derived shoots of *Physocarpus amurensis*.

Figure 2. Ex vitro rooting of enlongated and strengthened apical bud derived shoots of *Physocarpus amurensis* (1 month).

Table 1. Effect of benzyladenine and naphthaleneacetic acid on proliferation of apical bud sprouted shoots of *Physocarpus amurensis*

Treatment media	BA mg·L^{-1}	NAA mg·L^{-1}	Preliferation coefficient*	Regeneration rate (%)
1	0.8	0.4	> 18.5	100
2	0.8	0.6	5.3	100
3	0.8	0.8	3	66.7
4	1.0	0.4	7	100
5	1.0	0.6	7.5	100
6	1.0	0.8	9.3	100
7	1.2	0.4	9	66.7
8	1.2	0.6	> 10.7	100
9	1.2	0.8	7.7	100

Note: *mean number of multiple shoots per bud.

Micropropagation from Apical Buds of Greenhouse Germinated Seedling. The MS medium supplemented with 1.0 mg·L^{-1} NAA and 1.0 mg·L^{-1} BA was the best for apical bud sprouting, and bud sprouting rate could reach 100%. NAA at 0.4 mg·L^{-1} in combination with BA at 0.8 mg·L^{-1} was the best hormone combination for shoot proliferation. Mean number of multiple shoots per bud was >18 (Table 1), but the mean length of multiplied shoots were very short (< 1 cm), and not suitable to root. The short shoots were elongated and strengthened**.** MS medium supplemented with 0.5 mg·L^{-1} IBA and 0.3 mg·L^{-1} GA_3 was the best for shoot elongation and strengthening (Table 2). The best treatment for ex vitro rooting of the elongated and stronged shoots was soaking the microshoots in 100 mg·L^{-1} NAA for 30 min (Fig. 2). The rooted plantlets were transferred to field conditions with 93.1% survival rate (Table 3). In view of Debergh and Maene (1981) ex vitro rooting accounts 35%–75 % reduction of the total cost of plants propagated through tissue culture, current result implies prospective for commercial micropropagation of *P. amurensis*.

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Table 2. Effect of gibberellic acid and indolebutyric acid on elongation of apical bud derived shoots of *Physocarpus amurensis*.

Treatment media	IBA mg·L^{-1}	GA_3 mg·L^{-1}	No. of shoots	Proportion of shoots of different length (%)			
				≥ 3cm	2~3cm	1~2cm	≤ 1cm
1	0	0	10	0	0	0	100
2	0	0.5	11	0	0	90.9	9.1
3	0	1.0	30	3.3	30.0	66.7	0
4	0	2.0	28	25.0	35.7	35.7	3.6
5	0	3.0	31	45.2	25.8	29.0	0
6	0.5	0.3	33	63.6	36.4	0	0

Table 3. Effect of NAA on ex vitro rooting of enlongated and strengthened apical bud derived shoots *Physocarpus amurensis* (±SE: standard error).

NAA mg·L^{-1}	Shoots tested	Survival shoots	Survival rate (%)	No. of roots (strip)	Length of roots (mm)
0	28	4	14.29	10.5±2.10a	11.37±1.96a
50	29	5	17.24	11±1.53a	19.4±4.39ab
100	29	27	93.1	18.67±3.33bc	29.98±0.79c
200	25	22	88	20.5±1.55c	21.39±3.27bc
1000	30	14	46.67	13.67±1.33ab	17.35±2.74ab

Note: Means follow by different letter indicate significant difference at 5% level.

Growing Shrub Liners on Flood Floors©

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A flood floor is an ebb and flood system that utilizes the concrete floor of a greenhouse as the water basin for subirrigating a crop. Plants are grown directly on the floor. All water is recycled and stored in large water storage tanks. The growing area is flooded with 1–2 inches of water, which is absorbed from the bottom of a container through capillary action into the growing medium. Generally flood floors are divided into sections or irrigation zones, which can be flooded separately. This technology is often utilized in monoculture production settings with container-grown crops. More recently it has been used in production of bedding flats, liners, and even plugs.

We have found that there are several advantages in using flood floor technology to grow shrub liners: consistency of water delivery, crop uniformity, reduced foliar diseases, reduction in water and fertilizer requirements, reduced labor, and zero water run-off. Foliar diseases spread by splashing water can be eliminated in a flood floor environment. Fertilization in a subirrigation system generally requires only ½ of the concentration as overhead watering, but soil EC should be monitored carefully, as salts can build up in the growing medium because they are not leeched as they are in overhead irrigation systems. Water absorption is also very uniform across a crop, ultimately resulting in greater crop uniformity. Most flood floor irrigation systems also incorporate floor heat, provided by an underground system of hot water pipes within the concrete floor. Floor heat can allow a grower to dry the floor when weather is less than desirable, as well as provide increased temperature of the root zone promoting additional root growth during cooler months of the year, which is important in the production of shrub liners.

Some challenges with producing shrub liners on flood floors are: high cost of installation, the need for water filtration, managing and coordinating different species, different aged crops, and different sized liner cells in the same irrigation zone. Different sized containers, and different sized plants will have different water requirements. Flood floor irrigation zones are often very large. This can make it challenging to group crops with similar water requirements together in a liner production setting. In any water recirculation system, the spread of disease through irrigation water can potentially become a problem. The most important aspect of water treatment in a recirculation system is filtration. For most pathogens to survive in water, a source of organic material is required. Organic matter must be filtered out of the water to prevent pathogens from existing in water storage tanks and plumbing pipes. A filter of < 30 microns will typically remove most organic matter capable of harboring pathogens. Other methods of water treatment and disinfection have recently become synonymous with flood floor irrigation systems and water recirculation systems, including chlorine, ozone, heat pasteurization, hydrogen per-

oxide, and ultraviolet light. All methods provide some additional sanitation after filtration, although which method is most effective is often debated. Root pathogens often seem to be not only species specific, but cultivar specific. When growing multiple genera, species, and cultivars in a flood floor system, total crop failure due to disease is very rare. We have learned of some species and cultivars that do not perform well in our flood floor environment. We have found many that perform very well and result in a better quality liner.

Finishing a Liner Faster Using Multiple Stem Cuttings©

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The production process for Spring Meadow Nursery begins with rooting stem cuttings. The propagation department has sought different methods to increase rooting success and reduce finish time. One method tried was sticking selected taxa of plants with unacceptably low rooting percentages into small-sleeved plugs (20–30 mm) containing a peat-based medium. While this method did increase rooting percentages for many finely rooted taxa, we discovered that, in many cases, roots were not growing out of the plug and into the predominately perlite-based medium following transplant. The root ball remained mostly confined to the plug itself, and few, if any, roots penetrated the walls of the plug sleeve to fill out the pot. As a result, even though rooting was increased, production of these taxa in the long run was slower and less efficient. It was apparent that we needed to find another way to finish our liners more quickly.

We decided to stick two stem cuttings per $2^{1}/_{4}$-inch pot of the following taxa: *Abelia* ×*grandiflora* cultivars, *Genista Lydia, Helianthemum* cultivars, *Hypericum kalmianum* cultivars, *Indigofera pseudotinctoria* 'Rose Carpet', *Kerria japonica* 'Picta', *Rhus aromatica* 'Gro-Low', *Spiraea thunbergii* cultivars, and *Tamarix* cultivars.

The double-direct-stuck trial yielded a higher rooting percentage than single stem cuttings, especially for many of these thin-stemmed cuttings. Additionally, the liners finished and were ready to ship much faster than upgrading from the sleeved plugs. Direct sticking has the benefit of reducing handling since the plugs do not have to be picked up for shifting into the finished container. Spending less time under mist is also another benefit. The double direct stuck method enabled us to root a liner in 4–6 weeks and finish it in an additional 2–6 weeks, depending on the plant. *Abelia* ×*grandiflora* and *G. lydia* cutting-to-finish time was reduced from 6–9 months to 10–16 weeks. The other taxa could be finished in approximately 80% of the time it took to finish a single cutting. The only drawback with multiple stems per pot is having sufficient plant material on hand to provide the cuttings.

This method can also be used for other pot sizes. We have reduced finished time and amount of handling required in 4-inch and quart-sized pots by sticking 2 or 3 stems per pot instead of transplanting $2^{1}/_{4}$ inch cells.

Examples of positive results using multiple stems in 4-inch and quart pots: *Caryopteris* × clandonensis 'Durio', Pink Chablis™ bluebeard; *Deutzia* gracilis 'Duncan', Chardonnay Pearls™ slender deutzia; *Itea virginica* 'Sprich', Little Henry® sweetspire; *Rosa* hybrids; and *Weigela florida* 'Elvera', Midnight Wine™ weigela.

August Field Planting of June Stuck Softwood Cuttings©

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At Mariani Nursery most of our summer softwood propagation is rooted in sand beds in greenhouses. We also have a greenhouse with a concrete floor with hot water tubes embedded in the concrete. This house was built specifically for winter evergreen propagation. In an effort to increase our softwood production without building another greenhouse and also to make use of the evergreen house during the summer months we developed a new production method, which I will share here.

The plants we chose for this system were all plants that would root fast so that we could transplant them by the middle of August. Genera that have worked consistently over the past 3 years are *Spiraea, Cornus, Physocarpus*, and *Rosa*. Genera that rooted well for us but didn't transplant well under this system were *Rhus* and *Hydrangea*.

Cuttings are taken in June and stuck in 32-count trays in a bagged commercial soil mix and set on the floor under mist. The cuttings root in about 3 weeks and are immediately put on a liquid feed program. Plants are pruned two to three times prior to transplanting.

By the middle of August plants are ready to transplant to the field. We spend a day pulling the rooted plugs out of the trays and laying them in baskets lined with a plastic bag. The baskets are put in a cooler set at 55 °F and left over night. Early the next day we start planting the plugs in the field using a three-row bed transplanter. As soon as a block is planted, about 25,000 plants, we water the plants in well with an Ag-rain water reel. We get over 90% stands using this method. The plants are harvested bare root the following fall. The spireas are a good 12–15 inches wide and the *Cornus* and *Physocarpus* are a good 24–48 inches high depending on the plant.

Efficacy of Wastewater Irrigation for Rooting of Ornamental Cuttings©

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INTRODUCTION

Wastewaters from diverse sources including municipalities, composting farms, and anaerobic digesters have been used in crop production systems (Alam and Chong, 2006). The objective of this study was to propagate cuttings of different species in media irrigated with different sources and/or concentrations of wastewaters.

MATERIALS AND METHODS

Experiment 1. Under mist and shade in summer, cuttings of common ninebark [*Physocarpus opulifolius* (L.) Maxim], potentilla (*Potentilla fruticosa* 'Pink Beauty' L.), and deutzia (*Deutzia gracilis* Siebold & Zucc.) were rooted in 100% perlite or peat and perlite medium (1 : 1, v/v) (Table 1). To prevent the mist from entering the media, cuttings were inserted and rooted through holes in styrofoam platforms, positioned over 15 cm long × 10 cm wide × 2.5 cm deep trays with the base of the cuttings protruding into the medium (Fig.1). Trays were soaked daily for ½ h in deionized water (control) or in municipal compost tea (MCT), spent mushroom compost leachate (SMC), and anaerobic intra-process wastewater (AIP), each diluted to an electrical conductivity (EC, a measure of soluble salts concentration) of 0.20 $dS \cdot m^{-1}$ (Table 1), our previously recommended threshold for salt level in rooting media. This experiment was a split plot design with both media and wastewater as main plots and species as subplots. There were four replications and 10 cuttings per subplot treatment.

Analysis of variance (main plot effects, Table 2) indicated significantly more rooting (expressed in terms of percent rooting, mean root number per cutting, and length of longest root) in 100% perlite than in the peat and perlite medium (1 : 1, v/v). The wastewaters had marginal but significant effect only in root length. Cuttings irrigated with MCT wastewaters were comparable in length to those irrigated with SMC, but higher than those irrigated with AIP or water control. There were some variation in root number and root length responses due to species and media (S × M) interactions (Table 2).

Experiment 2. Under greenhouse (no mist) conditions in January, cuttings of wandering jew (*Tradescantia zebrina* hort. ex Bosse) were rooted similarly in 100% perlite, drenched daily with deionized water (EC = 0 $dS \cdot m^{-1}$), Plant Products 20.0N–8.7P–16.6K liquid fertilizer (PP) or the wastewaters described, each diluted to 0.25, 0.50, 0.75, and 1.00 $dS \cdot m^{-1}$. This experiment was a randomized complete block design with 4 replications and 10 cuttings per plot.

Regression analysis indicated that percent rooting was similar (98%) regardless of EC levels in MCT, SMC, and PP treatments (Fig. 2). With AIP, percent rooting was maximum (100%) at 0.29 $dS \cdot m^{-1}$, decreasing to 81% at 1.0 $dS \cdot m^{-1}$. Root number

Table 1. Chemical properties of two rooting media and of three wastewater irrigation sources at EC 0.2 dS·m^{-1} dilution.

	Medium[z]		Wastewater[y]		
	1:0	1:1	MCT	SMC	AIP
pH	8.0	4.0	7.1	7.7	8.2
EC (dS·m^{-1})	<0.10	0.15	0.24	0.22	0.23
Macronutrients (ppm)					
Nitrate-N	1	2	7	<0.5	1
Ammonium-N	<0.5	2	1	6	14
P	<1	1.5	1.2	<1	<1
K	<1.0	3	20	27	6
Ca	<1	<1	<1	1	<1
Mg	<1	<1	<1	<1	<1
Na	12	18	24	7	19
Cl	4	12	321	14	15
SO_4	9	23	5	7	<1
Micronutrients(ppm)					
Fe	0.07	0.19	0.50	0.09	0.05
Mn	<0.01	0.06	0.02	0.01	<0.01
Zn	<0.01	0.03	0.02	0.01	0.01
Cu	<0.01	0.03	0.01	0.02	0.01
B	0.02	0.04	0.02	0.02	0.05
Mo	0.15	0.56	0.03	0.01	0.01

[z]Medium: 1:0 = 100% perlite; 1:1 = 1 perlite: 1 peat (v/v).

[y]Wastewater: MCT = municipal compost tea; SMC = spent mushroom compost leachate; AIP = anaerobic intraprocess wastewater.

Table 2. Rooting of three species in response to two different media and three wastewater irrigation sources.

Treatment	Rooting (%)	Root number	Root length (cm)
		Main plot effect	
Media (M)[z]	**	**	**
1:0	94 A[x]	21 A	2.4 A
1:1	81 B	15 B	0.9 B
Wastewater (W)[y]	NS	NS	*
MCT		1.9 A	
SMC		1.8 AB	
AIP		1.4 C	
Control			1.5 BC
		Subplot effect	
Species (S)	NS	**	**
Potentilla		10 b	2.3 a
Ninebark		4 c	1.5 b
Deutzia		40 a	1.2 c
		Interactions	
M × W	NS	NS	NS
S × W	NS	NS	NS
S × M	NS	*	*
Potentilla × 1:0		12 c	3.6 a
Potentilla × 1:1		9 c	0.9 d
Ninebark × Perlite		6 cd	2.2 b
Ninebark × 1:1		3 d	0.7 d
Deutzia × Perlite		47 a	1.4 c
Deutzia × 1:1		33 b	1.0 d
S × M ×W	NS	NS	NS

[z]Medium: 1:0 = 100% perlite; 1:1 = 1 perlite: 1 peat (v/v).

[y]Wastewater: MCT = municipal compost tea; SMC = spent mushroom compost leachate; AIP = anaerobic intraprocess wastewater.

[x]Mean separation within columns and factors by Duncan multiple range test; **, * NS, significantly different respectively at 1%, 5% and not significantly different at the 5% level of probability

Figure 1. Rooted cuttings of ninebark, deutzia, and potentilla.

decreased minimally with increasing EC levels in MCT, SMC, and PP (slope -0.3), but quite substantially with AIP (slope -1.6) (Fig. 2). Root length was unaffected by the treatments (data not shown).

DISCUSSION

In previous studies (Chong et al., 2005), cuttings of three woody and one herbaceous species were rooted hydroponically in two wastewater sources used in this study (e.g., AIP and MCT). Optimal percent rooting, root number, and/or root length occurred at EC levels between 0.25 and 0.5 $dS \cdot m^{-1}$. Salt levels higher than 0.5 $dS \cdot m^{-1}$ were not tested.

With the three woody species (Experiment 1), the MCT wastewaters stimulated root length in comparison with SMC and AIP (Table 2). With the herbaceous species (Experiment 2), there was little sign of toxicity of the MCT and SMC wastewaters, e.g., marginal decrease in root number with increasing EC values (Fig. 1). In contrast, the AIP wastewater caused a moderate decline in percent rooting at EC levels > 0.6 $dS \cdot m^{-1}$, accompanied by a drastic reduction in root number over all EC levels.

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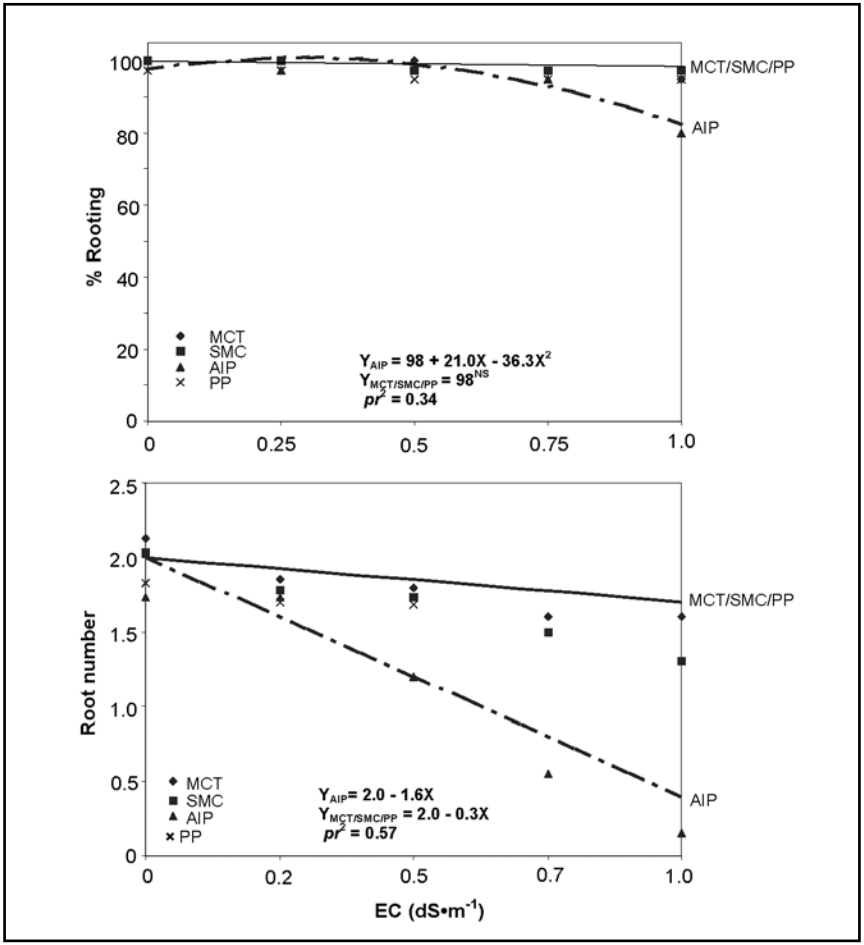

Figure 2. Percent rooting and mean root number of *Tradescantia zebrina* cuttings in response to increasing EC levels. Response was regressed over EC levels in Plant Products fertilizer source (PP) and in each of three wastewater sources (MCT, SMC, and AIP). A common regression was fitted when two or more curves were not significantly different. The coefficient of determination was expressed in terms of partial r^2 (pr^2) which measured the strength of the response relationships of all curves combined together, after removing replication effects. NS = not significantly different from horizontal.

Hydrangea macrophylla and *Hydrangea serrata* Trials at the University of Kentucky©

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NATURE OF WORK

During the last decade, *Hydrangea macrophylla* has enjoyed a resurgence as a dominate landscape plant. Selection and hybridization has yielded many new cultivars. During the late 1990s we concluded little was known about the usefulness of the wide range of cultivars for establishment in landscapes in the Ohio River Valley. Starting in 2000, we have established several evaluation plots at three locations (Table 1) across Kentucky as material of landscape size (No. 1 container) became available for use. Cultivars established after 2000 have six replications at each site. Specific cultivars have been established at one, two, or three sites. Data is included for cultivars at multiple sites. We have now evaluated over 100 cultivars. Plants have been evaluated for winter hardiness and ability to flower. Quicksand and Lexington sites are on drip irrigation while the Paducah site is hand watered on an as-needed basis. All three sites are in USDA Hardiness Zone 6.

RESULTS AND DISCUSSION

Table 1 lists many of the cultivars evaluated. The data denotes number of plants which survived from the original planting when evaluated during spring 2006. Plants without numbers were not located at the respective site.

Table 1. *Hydrangea macrophyll* and *H. serrata* cultivar survival rate. Number of plants surviving spring 2006 from original six plants installed in field plots at the three Kentucky sites.

Cultivar	Paducah	Quicksand	Lexington
All Summer Beauty	4	6	6
Alpenglühen		3	4
Altona		6	1
Amy Pasquier		6	5
Arburg	4	5	6
Bailmer, Endless Summer™ hydrangea	4	2	6
Blau Donau	5	4	6
Blaumeise	6	5	
Blue Billow		5	3
Blue Deckle		5	6
Bodensee		6	4
Böttstein	6	4	6

Cultivar	Paducah	Quicksand	Lexington
Brestenburg		4	5
Brugg	6	5	0
Brunegg	2	5	6
Brunette	5		6
Burg Königstein	4	4	3
Burg Rosenburg	4	4	6
Cardinal Red		3	6
Chaperon Rouge (syn. Red Cap)	0	4	2
Curtis' Legacy (syn. Coerula Lace)		6	6
David Ramsey	6	2	6
Decatur Blue	5		3
Dooley		6	6
Doctor Benard Steiniger	3		6
Dundalk	5	5	5
Freudenstein	5	6	6
Fuji Waterfall	3	2	4
Gartenbaudirektor Kuhnert (syn. Kuhnert)	6	6	6
Général Vicomtesse de Vibrayé	4		4
Goffersburg	2		2
Goliath	5		3
Habsburg	5	6	6
Hamburg	4	4	
Harlequin	3	2	
Hildegard	1	5	0
Holstein	3	4	3
Horben	3	6	5
Hörnli		5	5
Kasteln	5	3	6
Kiyosumi (syn. Kyosume)		3	1
Koralle	2	3	5
Kurohime	6	4	5

Cultivar	Paducah	Quicksand	Lexington
Lenzburg	4	6	4
Libelle (syn.Teller White)		6	6
Liebegg	1	2	6
Madame Emile Mouillère	5	6	3
Madame Faustein Travouillon			6
Mariesii Lilacina		6	1
Masja		5	5
Mathilda Gütges	2	0	6
Merritt's Supreme		6	5
Mereille	1		6
Monte Forte Perle	0	3	2
Nikko Blue		6	6
Oak Hill	6	2	6
Oregon Pride	2	5	6
Parzifal		5	3
Penny Mac	6	4	5
Raymond Draps	3	3	6
Regula	5	6	6
Rosarita	6	5	6
Rose Supreme	2	5	0
Rotdrössel		3	6
Rotschwanz (syn. Red Star)	6	6	4
Schenkenburg	3	4	6
Setsuka-yae (syn. Domotoi)	3		6
Souvenier du President Paul Doumer	4		6
Stafford	1	4	6
Tegerfelden	0	5	3
Ticino	1	4	6
Trotsburg	3	3	1
Wartburg	4	5	4
Wildegg	5	5	6
Wildenstein	4	3	6

Seed Propagation of Rare and Unusual *Acer* Species: A Review of Propagation at the Morris Arboretum

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INTRODUCTION

For the past quarter-century one of the primary missions of the Morris Arboretum has been domestic and international plant exploration, evaluation, and introduction. Since the late 1970s, staff of the Arboretum has participated in 19 plant collecting expeditions, including trips to South Korea, China, the Caucasus Mountains, and the United States. The goals of the plant exploration program include broadening the genetic pool of known species, conserving rare and endangered species, and introducing appropriate new species. These plant collecting expeditions have resulted in a living collection that contains approximately 4,000 plants of wild-collected and documented origin, representing just over 900 taxa. The diversity of *Acer* (maples) in the Arboretum is one of the most significant collections developed through our plant exploration efforts.

This paper reports on two aspects of *Acer* seed germination at the Morris Arboretum. One aspect is a compilation of germination records from the past 25 years for approximately 80 taxa of maple. These germination results represent many years of trial and error when faced with taxa of *Acer* for which little if any information was available. The second aspect of *Acer* seed germination reported in this paper concerns germination trials with seed that was received at the Arboretum in the fall of 2005 from two collecting expeditions, one to Gansu Province, China, the other to central Japan. By sharing the results of our propagation trials (and tribulations) we hope to expand the knowledge of seed propagation of rare and unusual maples.

MATERIALS AND METHODS

Arboretum Propagation Records. Beginning in the 1970s, the Arboretum's propagation records have been maintained on 5 inch × 8 inch index cards. For this project, propagation information from these cards on *Acer* taxa was reviewed and compiled, with a summary of successful and unsuccessful strategies (Table 1). For each taxon the data reported represent the highest germination percentage recorded in the Arboretum's propagation records.

***Acer* Seed Germination: Fall 2005.** In the fall of 2005, the Arboretum participated in the North America China Plant Exploration Consortium collecting expedition to Gansu Province, China (NACPEC05). We received six maple taxa from this expedition. Concurrently, additional maple seed was obtained from a plant-collecting trip to Japan (BBMJT) conducted by Quarryhill Botanical Garden, Royal Botanic Garden Edinburgh, Polly Hill Arboretum, and Howick Hall Arboretum. There were 25 taxa of *Acer* from the combined expeditions. Table 2 summarizes the propagation trials for 15 of these taxa, which were begun with an abundance of seed and the need to process the seed as quickly as possible.

Because of the difficulties of processing, storing, and transporting seed from China and Japan to the United States, the seed arrived at the Arboretum with varying levels of moisture content. Viability was determined by a cut test. Although there is not published information for many of these taxa, our germination protocols were guided by standard propagation references (Dirr and Heuser, 1987; U.S.D.A., 1974; Young and Young, 1992) as well as reference to the Arboretum's propagation records. An effort was made to perform as many treatments on each seed lot as practical while replicating the protocol on different species. Seeds were sown in a medium that was a mixture of perlite and peat (3 : 2, v/v) mix in seed trays to which RootShield® granules (*Trichoderma harzianum*) were added. After treatment the trays were placed in a fog and mist room with bottom heat of 70 °F (21 °C). Light was at 200 Wm^2 for 16 h duration. Seed treatments included:

- **Cold stratification** (c) was accomplished by placing seeds in polyethylene bags filled with moistened perlite and refrigerated at 41°F (5 °C).
- **Warm stratification** (w) was accomplished by placing seeds in polyethylene bags filled with moistened perlite and maintained at room temperature of 72 °F (22 °C).
- **Gibberellic acid** treatments (GA) were by immersion in a solution of 1000 ppm GA_3.
- **Acid scarification** is defined as immersion in undiluted sulfuric acid (H_2SO_4) for the referenced time period.
- **Embryo excision** (XP) is defined as removal of the pericarp. Testa remained intact unless inadvertently removed or ruptured.

Germination was defined as emergence of the cotyledon unless the radical was observed to have emerged during the stratification process.

RESULTS AND DISCUSSION

Arboretum Propagation Records. In over 25 years of plant exploration, Morris Arboretum has received seed collections of approximately 80 taxa of *Acer* (van Gelderen et al., 1994); of those taxa, 83% have been successfully propagated (Table 1). For these taxa, the results show the treatment utilized and the germination percentage where available. In many cases we received very few seeds and germination was attempted on only one occasion. So, these results are preliminary and represent well-informed trials rather than controlled and replicated experiments.

We have included both successful and unsuccessful germination as a means of stimulating interest in the germination requirements of little known maple species. In many cases propagation percentages were very low (< 1%) but for the purpose of adding maple taxa to our living collections, growing a few plants is generally adequate. Clearly for commercial propagation, even for specialty nurseries, further work is required to increase these percentages. These results are intended as a basis for furthering the understanding of the propagation of unusual maples and a way to stimulate additional research on germinating these taxa.

***Acer* Seed Germination: Fall 2005.** Several observations can be made based on the 2005 propagation trials (Table 2). Treatments with cold stratification in excess of 3 months showed increased germination percentages. *Acer palmatum* ssp. *matsumurae* (2005 × 156) had no germination with 3 months cold stratification, but

Table 1. Results of *Acer* taxa propagated at the Morris Arboretum (MOAR) from 1979 through 2005.

Acer taxon	Times propagated (no.)	MOAR propagation no. of most successful treatment	Treatment[1]	Highest germination (%)[2]
acuminatum	1	94 × 139	3c	2%
argutum	2	2005 × 138	1 w/4c XP	5%
barbinerve	10	2003 × 010	1w/3c/MH	4%
buergerianum	12	88 × 173	3c	68%
caesium	1	94 × 135	3c	< 1%
caesium subsp. *giraldi*	1	---	3c	0
campbellii	1	93 × 635	1w/3c	20%
campbellii subsp. *sinense*	1	95 × 076	4c	> 10%
campbellii subsp. *wilsonii*	1	96 × 420	3c	< 1%
campestre	7	92 × 005	4w/4c	> 1%
capillipes	2	89 × 272	1c	100%
cappadocicum	1	94 × 143	3c	14%
cappadocicum var. *sinicum*	1	81 × 248	3c	< 1%
carpinifolium	6	94 × 160	3c	< 1%
caudatifolium (*morrisonense*)	2	79 × 278	3c	> 1%
caudatum subsp. *multiserratum*	4	2005 × 116	1w/3c	1%
caudatum subsp. *ukurunduense*	9	97 × 164	4c	10%
caudatum (var. *prattii*)	2	---	3c	0
circinatum	2	92 × 182	2w/3c/MH	10%
cissifolium	3	2005 × 146	XP/1c/1w/3c	6%
crataegifolium	8	96 × 246	3c/MH	5%
davidii	6	2002 × 273	3c	< 1%
davidii subsp. *davidii*	2	96 × 481	3c	> 5%
davidii subsp. *grosseri*	2	94 × 461	3c	13%
diabolicum	1	2005 × 149	1w/3c	0
distylum	2	93 × 571	3c	100%
erianthum	2	---	3c	0
fabri	1	86 × 014	2c	> 1%
forresti	1	---	3c	0
glabrum	2	93 × 667	1w/6c/MH	2%
glabrum subsp. *douglasii*	3	97 × 103	6w/6c	16%
glabrum var. *torreyi*	2	2000 × 327	6w/6c	21%
grandidentatum	2	90 × 257	1.5c	> 1%
griseum	22	84 × 58	Knick/1.5c	> 20%
heldreichii	1	---	3c	0
heldreichii subsp. *trautvetteri*	2	2002 × 250	MH	39%
henryi	2	93 × 581	3c	> 1%
japonicum	4	98 × 217	5c	> 1%
kawakamii	1	---	3c	0

laxiflorum	2	---	3c	0
macrophyllum	4	92 × 547	2c	27%
mandshuricum	15	97 × 225	XP/3c	15%
maximowiczianum	1	---	direct sow	0
micranthum	3	2005 × 152	GA/1w/1.5c	4%
miyabei	2	98 × 231	3c	> 1%
miyabei subsp. *miaotaiense*	3	98 × 268	GA/MH	> 1%
mono	22	96 × 061	3c	> 10%
mono subsp. *okamotoanum*	4	90 ×416	No strat	< 1%
monspessulanum	2	87 × 166	3c	> 1%
nigrum	1	93 × 408	3c	3%
nipponicum	2	2004 × 136	3c	71%
oblongum	1	---	3c	0
oliverianum subsp. *oliverianum*	1	96 × 428	3c/MH	> 1%
palmatum	3	91 × 222	5c	< 1%
palmatum subsp. *amoenum*	2	88 × 035	5c	10%
palmatum subsp. *matsumurae*	3	2005 × 156	1w/4c	21%
pectinatum subsp. *maximowiczii*	6	2005 × 105	3c/3w/3c	4%
pensylvanicum	1	93 × 016	3c	> 10%
pseudoplatanus	1	---	3c	0
pseudosieboldianum	14	91 × 587	3c	< 1%
pseudosieboldianum subsp. *takesimense*	2	91 × 539	3c	> 1%
rufinerve	9	2001 × 093	3c	14%
schneiderianum	1	---	3c	0
serrulatum	2	79 × 277	?	> 1%
shirasawanum	5	2005 × 158	1w/5c	32%
sieboldianum	4	---	3c	0
spicatum	5	2003 × 018	3c	33%
stachyophyllum	3	---	1w/3c	0
stachyophyllum var. *pentaneurum*	1	93 × 168	1w/3c	44%
sterculiaceum subsp. *franchetii*	6	93 × 167	1w/3c	50%
tataricum	2	92 × 555	3c	< 1%
tataricum subsp. *ginnala*	5	80 × 6	3c	> 50%
tataricum subsp. *semenovii*	1	93 × 401	1w/4c	35%
tegmentosum	7	97 × 195	1w/4c	4%
tetramerum subsp. *betulifolium*	3	---	6.5c/XP	5%
triflorum	19	97 × 205	9w/3c/MH	3%
truncatum	5	85 × 025	2c	> 1%
tschonoskii	4	2001 × 232	1wkw/3c	> 10%
tschonoskii var. *rubripes*	2	90 × 418	None	> 1%
yui	1	2005 × 126	3c/3w/3c	4%

[1] 1w = 1 month warm, 1c = 1 month cold, GA = gibberellic acid, MH = Medicinal House [seed flats overwintered in glass house heated to 35 °F (2 °C)], XP = pericarp removed.

[2] Percentages indicated by < or > are used when seeds were not counted and accurate germination percentages could not be calculated.

Table 2. *Acer* germinated beginning in the fall of 2005. Seed collected on the NACPEC05 expedition to China and BBMJT 2005 expedition to Japan.

Acer species or subspecies (collector no.)	Greenhouse Propagation (no.)	TRT[2]	Seed (no.)	Pretreatment	Stratification Warm	Stratification Cold	Stratification Warm	Stratification Cold	Additional TRTS[2]	Germination Date	Germination (%)
argutum	2005 × 138	1	100	acid 5 min.	1 mo	4 mo					N/A 0
(BBMJT-223)		2A	22		1 mo	4 mo				N/A	0
		2B	20		1 mo	4 mo			XP 5/16	05/22/06	5%
caudatum subsp.	2005 × 116	1	100		1 mo				MH		1%
multiserratum		2	100		1 mo	3 mo				06/26/06	1%
(NACPEC05-057)		3	131		1 mo	3 mo				05/15/06	< 1%
		4	100		2 mo	6 wk			GA 24 h 2/9	02/16/06	1%
caudatum subsp. ukurunduense (BBMJT-252)	2005 × 144	1									< 1%
cissifolium	2005 × 146	1	89			1 mo	1 mo	2 mo	XP 2/11	N/A	0
(BBMJT-278)		2	100	XP		1 mo	1 mo	3 mo	stratify in pot		6%
davidii subsp. *grosseri*	2005 × 110	1	100			1 mo				MH	05/20/06
1%	(NACPEC05-043)		2	100		1 mo	2 mo				N/A 0%
			3	100		1 mo	3 mo				N/A 0%
			4	100		2 mo	6 wk			GA 24 h	02/26/06
1%				5b	33		2 mo	3 mo			GA 26 h
04/10/06	1%				5c	33		2 mo	5 mo		XP af-
ter strat	06/08/06	7%									
diabolicum	2005 × 149	1	45	acid 8 min.	1 mo	3 mo				N/A	0
(BBMJT-190)		2	44	nick	1 mo	3 mo					N/A 0
distylum	2005 × 150	1	13			3 mo			XP 5/5	N/A	0
(BBMJT-062)											
micranthum	2005 × 152	1	28	GA 21 h	1 mo	6 wk				05/06/06	4%
(BBMJT-240)		2	23	knick	1 mo	1 mo				N/A	0

miyabei	2005 × 153	1	14		1 mo	4 mo			XP	N/A	0
(BBMJT-267)		2	12	XP	1 mo	3 mo				N/A	0
palmatum subsp.	2005 × 155	1	60		1 mo	5 mo				06/13/06	17%
matsumurae		2	60	GA 2/14	1 mo	1 + 3				05/21/06	3%
(BBMJT-077)											
palmatum subsp.	2005 × 156	1	67	acid 7 min.	1 mo	3 mo				N/A	0
matsumurae		2	67		1 mo	4 mo				05/19/06	21%
(BBMJT-135)											
pectinatum subsp.	2005 × 105	1	200	direct sow					MH	06/07/06	4%
maximowiczii		2	200		1 wk	3 mo				03/23/06	< 1%
(NACPEC05-034)		3	200		1 wk	3 mo	3 mo	3 mo		08/04/06	4%
		4	200		2 mo	6 wk			GA 24 h	04/12/06	< 1%
argutum	2005 × 138	1	100	acid 5 min.	1 mo	4 mo					N/A0
shirasawanum	2005 × 158	1	29		1 mo	4 mo				05/10/06	7%
(BBMJT-191)		2	29		1 mo	5 mo				strat	32%
tetramerum subsp.	2005 × 093	2	100		1 wk	3 mo					0%
betulifolium		3	100								
(NACPEC05-020)		4	100		2 mo	6 wk			GA 24 h		0%
		5	80		1 wk	indef.				05/18/06	1%
		6	20		1 wk	indef.			XP	05/19/06	5%
tschonoskii	2005 × 161	1	28		1 mo	3 mo				N/A	0
(BBMJT-005)		2a	12		1 mo	4 mo				N/A	0
		2b	10		1 mo	4 mo			XP	05/21/06	10%
yui	2005 × 126	1	143		1 mo	3 mo				03/12/06	1.40%
(NACPEC05-071)		2	141		1 mo	3 mo	3 mo	3 mo		strat	4%

Note: Acid = sulfuric acid scarification; GA = gibberellic acid; MH = medicinal house [seed flats overwintered in glass house heated to 35 °F (2 °C)]; XP = pericarp removed; strat = stratification; TRT, TRTS = treatment and treatments; mo = month; wk = week; min = minute; strat = stratification.

21% germination after 4 months. *Acer shirasawanum* (2005 × 158) had 7% germination after 4-months cold stratification, but 32% germination after 5 months. Of six treatments of *Acer davidii* ssp. *grosseri*, its highest germination percentage (7%) occurred with 2 months warm and 5 months cold stratification.

Removal of the pericarp was not universally successful. This indicates either that the testa is impeding germination or that the embryo has a physiological dormancy that was not overcome by the stratification period (Wiegrefe, 1998). In two cases, removal of the pericarp after stratification resulted in higher germination rates (Table 2: *A. tetramerum* ssp. *betulifolium* and *A. tschonoskii*). *Acer cissifolium* germinated when the pericarp was removed prior to stratification rather than after stratification, although the two treatments differed in the length of the cold stratification (Table 2).

Alternating periods of warm and cold stratification show potential for increasing germination percentages (Table 2). One treatment of *A. pectinatum* (2005 × 105 Trt. 1) was direct sown and placed in a greenhouse heated in the winter to 35 °F (2 °C). A second treatment had alternating periods of warm and cold stratification (2005 × 105 Trt. 3). Both treatments resulted in 7% germination, higher than those treatments that received only one period of warm and one period of cold stratification. *Acer yui,* a rare species for which propagation protocol is virtually nonexistent, germinated after 1 month warm and 3 months cold stratification, but more than doubled germination when given a second period of cold stratification (Table 2). These results raise the question of whether the periods of cold stratification are cumulative; thereby reinforcing the finding that increasing cold stratification often increases germination, or whether the critical factor is the alternating periods of warm and cold stratification (Coggeshall, 1999; Krautmann, 1999).

SUMMARY

The results presented in this paper represent more than 25 years of seed propagation of a large number of *Acer* taxa. In many cases, germination rates were low but the resulting plants added important and unusual maples to the collection of the Morris Arboretum. Because the genus *Acer* is a large and variable group, it is difficult to make generalizations about germination protocols. A sensible approach is to base germination on the type of seed coat (Krautmann, 1999) which may or may not correspond to the taxonomic sections of the genus.

Our results, as expected, show a wide range of responses to various treatments. These propagation trials will be used by the Arboretum, and hopefully by others, to expand and refine our procedures for germination of maples. As mentioned previously, these trials are preliminary in nature and represent our efforts to germinate maple taxa for which there is little if any published information on germination requirements. When reviewing the number of maple taxa added to the collection of the Morris Arboretum, we have successfully achieved our plant exploration goals of broadening the genetic pool of known species and introducing appropriate new species.

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Somatic Embryogenesis in White Oak (*Quercus alba*)©

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INTRODUCTION

White oak (*Quercus alba*) is an important forestry species. The implementation of forest fire controls in the 20th century have resulted in a major decline of native stands of white oak (Abrams, 2000). Further complicating oak survival is their potential susceptibility to sudden oak death (*Phytophthora ramorum*). Propagated by seed in the nursery industry, white oak availability is limited due to nursery production difficulties. There is a need for a clonal propagation system for selection of desirable characteristics such as fall color, hardiness, pathogen resistance, and improved nursery production characteristics.

White oak seed can be sown immediately after collection without any special treatments. This method of propagation however does not provide superior cultivars to the nursery industry. A clonal in vitro system of propagation produced from superior mature clones could result in increased profits for both liner and field production of white oak. In addition, somatic embryogenesis has proven to be a useful tool for recovering transgenic plants. This could be an important component in a strategy to develop plants resistant to diseases such as sudden oak death. However, the development of complete somatic embryogenesis systems has generally been difficult in oaks (Wilhelm, 2000).

In 2005, a single staminate catkin explant produced a somatic embryogenic culture. A low frequency of somatic embryogenesis from male catkins has been previously reported in other oak species (Gingas, 1989 and Wilhelm, 2000). This culture has continued to produce secondary somatic embryos for the past year. Therefore, the specific objectives of the current study were to evaluate the impact of stage of catkin development and growth regulator treatment on somatic embryo induction and to attempt to convert secondary somatic embryos from the 2005 culture into seedlings.

MATERIALS AND METHODS

Staminate catkins were collected three times during April and surface sterilized in 10% bleach for 15 minutes followed by a triple rinse in distilled water. The first collection (April 17) resulted in catkins less than 0.7 cm. Samples this small would not allow for the removal of male flowers and the entire staminate catkin was used. The final two collections (April 20 and 24) resulted in fully expanded catkins prior to anther dehiscence. Male flowers were removed from half of the staminate catkins. At each collection, five explants were placed per Petri dish on MS media (Murashige and Skoog, 1962), containing 1 or 5 μM 2,4-dichlorphenoxyacetic acid (2,4-D) plus 1 μM benzlyadenine (BA) or 5 μM naphthalene acetic acid (NAA) plus 1 μM BA. Explants were cultured in the dark or under cool white fluorescent lamps (PAR 60 $\mu mol \cdot sec^{-1} \cdot m^{-2}$) at 21 °C. There were ten replicate Petri dishes per treatment for the first collection and five replicate dishes per treatment for subsequent collections. The percentage of explants forming callus was evaluated after 1 month.

A single staminate explant from 2005 formed somatic embryos. It entered a cycle of repeated secondary embryo formation. In May 2006, individual somatic embryos

Table 1. The percentage of staminate catkin explants with stamens removed forming callus after treatment with placed on a medium with 1 or 5 μM 2,4-dichlorphenoxyacetic acid (2,4-D) plus 1 μM benzlyadenine (BA) or 5 μM naphthalene acetic acid (NAA) plus 1 μM BA under light or dark conditions.

BA [1μM] media plus	Light	Dark
2,4-D [1μM]	43	100
2,4-D [5μM]	66	83
NAA [1μM]	0	33

Table 2. Somatic embryo development in white oak secondary somatic embryos derived from mature anthers placed on several conversion media.

	Stage of somatic embryo development			
Conversion media	Globular	Cotyledon	Germinating	Secondary embryos
Untreated	33.3a[z]	29.2a	0	37.5c
GA_3 [5 μM]	8.3b	16.7b	16.7a	58.3b
BA [1 μM]	0c	4.2c	0	95.8a
BA [1 μM] + ABA [5 μM]	29.2a	4.2c	0	66.7b

[z] Means followed by the same letter within a column were not different at $P \leq 0.05$ by Tukey's HSD test.

(globular stage) were moved either to basal MS medium or media containing 5 μM gibberellic acid (GA_3) alone, or 1μM BA plus 1 or 5 μM abscisic acid (ABA). There were six explants per Petri dish and four dishes per treatment. Explants were cultured as previously described. Germination and progression to cotyledon stage embryos without secondary embryo formation was evaluated after one month.

RESULTS AND DISCUSSION

The loss due to fungal contamination was 64% or greater. Removal of male flowers significantly decreased the percentage of contamination and increased the percentage of callus formation. Catkins from the first collection (April 7) failed to make callus, while those from the second two collections responded similarly. Therefore, data in Table 1 was for explants from the second two harvest dates that were not contaminated and had the flowers removed.

After 1 month, explants treated with 2,4-D formed a higher percentage of callus than those treated with NAA (Table 1). Callus developed along the peduncle on 2,4-D media, while the slight appearance of callus growth on NAA cultures occurred only at the site of removal from the mother plant and did not spread along the length of the peduncle as observed with 2,4-D treated explants.

Cultures placed in the dark produced more callus than light grown cultures. Dark grown cultures also produced a more friable callus without any green pigmentation compared to light grown cultures where the callus was denser with islands of green pigmentation. At present, no cultures have become embryogenic.

Some development to the cotyledon stage of development was observed on the growth regulator free medium, but the greatest percentage of secondary embryos beginning to germinate was induced on the medium containing GA_3 (Table 2). A similar effect of GA_3 on somatic embryo development was previously observed in willow oak (*Q. phellos*) cultures derived from seedling explants (Wells et al., 2005). These encouraging data suggest that plantlets can be derived via somatic embryogenesis in white oak but additional work is needed to produce an efficient system to induce somatic embryos from staminate catkins that convert to viable plantlets.

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Adventitious Root Formation in Tomato Hormone Mutants©

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INTRODUCTION

The role of plant hormones during adventitious rooting has been studied for many years, yet their specific interaction(s) during rooting is still difficult to determine. It is accepted that auxin is the key hormone responsible for initiating adventitious roots. The other major hormones—gibberellin (GA), abscisic acid (ABA), and ethylene—have been shown to promote, have no effect, or inhibit rooting depending on the species or rooting environment (Hartmann et al., 2002).

Part of the reason for this confusion is that traditional model systems used to study rooting (i.e., pea, mung bean, sunflower) were selected based on their ease of rooting and experimental manipulation rather than their genetic characteristics as a rooting system. Ernst (1994) described the characteristics of an ideal model system for conducting meaningful rooting studies. These included important genetic and developmental characteristics of the model species. He felt that *Arabidopsis* and tomato best approximated the characteristics of a model system for studying rooting. Importantly, *Arabidopsis* and tomato have numerous, characterized genetic mutants for plant development and hormone function (Arabidopsis Biological Resource Center, Columbus Ohio; Tomato Genetics Resource Center, Davis, California; SOL genomics network, Cornell, New York). Also, the genome sequence is available for *Arabidopsis* and should be available for tomato in the near future.

The objective of this research was to study hormone interactions during adventitious rooting in tomato leaf discs taken from stock plants with mutations for hormone synthesis or perception. Leaf discs were chosen because they fail to root without exogenous auxin application (Coleman and Greyson, 1977) and exogenous hormones were easily applied in the in vitro rooting medium.

METHODS AND MATERIALS

Hormone mutants of tomato (*Lycopersicon esculentum* Mill.) deficient in gibberellin (*gib-1*) and abscisic acid (*not*) production or ethylene perception (Nr) were obtained from Tomato Genetics Resource Center (University of California, Davis). Tomato stock plants were grown under greenhouse conditions with a day/night temperature of 24/20 °C and supplemental lighting in commercial potting substrate (Metro Mix 280, SunGro, Belleve, Washington) in Com-pack 606 deep cells (T.O. Plastics, Bloomington, Minnesota). Plants were fertilized at each watering with 200 ppm N from Peat-lite Special (Peter's 20N–10P–20K Fertilizer Products, Fogelsville, Pennsylvania).

To approximate normal phenotypes in *gib-1* and *not*, stock plants were sprayed with 10 μM GA_3 once per week or 50 μM ABA every 3 days, respectively. A gibberellin deficient phenotype was attained by germinating seeds in Petri dishes containing 34 μM paclobutrazol (gibberellin biosynthesis inhibitor) prior to moving seedlings to pots in the greenhouse.

Stock plants were grown to the seven-leaf stage (approximately 3 weeks) and the third leaf was harvested for rooting experiments. Six-mm diameter leaf discs

were cut over a mid-vein using a cork borer, surface sterilized for 15 min with 10% Clorox and rinsed three times with sterile water. Five leaf discs were placed in 9-cm Petri dishes with 25 ml sterile MS media (Murashige and Skoog, 1962) supplemented with 30 $g \cdot L^{-1}$ sucrose, 7 $g \cdot L^{-1}$ agar. Treatments were 25 µM K-IBA alone or in combination with 50 µM GA_3, ABA, or ACC (1-aminocyclopropane-1-carboxylic acid—immediate precursor to ethylene). Leaf discs were cultured under a 16/8 h photoperiod provided by cool white fluorescent lamps (PAR 45 $\mu mol \cdot sec^{-1} \cdot m^{-2}$) at ~22 °C. There were four dishes per treatment and roots were counted after 12 days.

RESULTS

Untreated leaf discs from wild type and hormone mutants or leaf discs treated with GA_3, ABA, or ACC failed to root unless treated with auxin (data not shown). There was no difference in rooting between wild type and *gib-1* leaf discs treated with IBA, while rooting was reduced for leaf discs from *not* and *Nr* (Table 1).

Wild type discs showed reduced rooting when placed on media containing GA_3, ABA, or ACC, but there was no difference in rooting when leaf discs were taken from wild type stock plants treated with GA_3 or ABA (Table 1).

GA_3 applied to *gib-1* stock plants induced growth that resembled wild type stock plants. Leaf discs taken from these plants responded to IBA in a similar manner to discs taken from wild type and *gib-1* plants with only a slight reduction in root number (Table 1). However, rooting was reduced in *gib-1* leaf discs placed on GA_3 medium.

Stock plants from paclobutrazol-treated seeds showed a phenocopy to *gib-1* stock plants, and leaf discs taken from these plants showed no difference in rooting compared to wild type or *gib-1* plants (Table 1).

Leaf discs from wild type and mutant stock plants showed reduced rooting on ABA media (Table 1). However, rooting in leaf discs from ABA-treated wild type stock plants was not different from wild type alone and ABA treatment partially recovered rooting in *not* stock plants to wild type levels (Table 1).

Leaf discs from *not* stock plants showed reduced rooting on ACC media and discs from *Nr* on ABA media were severely impaired for rooting (Table 1).

DISCUSSION

As previously described, auxin was required for rooting in isolated leaf discs from tomato (Coleman and Greyson, 1977). Therefore, the effects observed in the current study were for interactions with auxin.

Gibberellin is generally thought to be inhibitory to rooting (Hansen, 1988). This is based on studies where exogenous application of gibberellin (mainly GA_3) reduced rooting, while gibberellin biosynthesis inhibitors promoted rooting (Davis and Sankhla, 1988). In the few studies where endogenous gibberellin levels have been measured, they were negatively correlated with rooting. For tomato leaf discs, exogenous GA_3 inhibited auxin-induced rooting (Table 1; Coleman and Greyson, 1977). However, since there were no effects on rooting in the gibberellin biosynthesis mutant (*gib-1*) or wild type stock plants dwarfed by reducing gibberellin biosynthesis with paclobutrazol, it does not appear that endogenous gibberellin plays a significant role in mediating auxin-induced rooting in tomato.

There have been two postulated roles for ABA in rooting (Hartmann, et al., 2003). It possibly acts to antagonize the inhibition of rooting by gibberellin and to attenuate

Table 1. Root initiation in tomato leaf discs taken from mutants for gibberellin (*gib-1*), abscisic acid (*not*), and ethylene (*Nr*) treated with a combination of indolebutyric acid (IBA) and various growth regulators.

	Genotype							
	Wild type		*gib-1*		*not*		*Nr*	
Growth regulator	Percentage	Root number	Percentage	Root number	Percentage	Root number	Percentage	Root number
IBA (25 µM) alone	95a[z]	14.8a	95a	15.8a	70b	9.7c	85b	60d
IBA (25 µM) plus								
GA_3 (50 µM)	65c	1.7e	100a	3.9d				
GA_3 treated stock plant			100a	12.5b				
Paclobutrazol treated stock plant	90a	15.3a						
ABA (50 µM)	60c	4.1d	35d	2.2e	40d	1.6e	30d	0.6e
ABA treated stock plant	95a	16.6a			90a	13.4b		
ACC (50 µM)	70b	10.5b			80b	6.1d		

[z]Means followed by the same letter were not significantly different at the 5% level by Tukey's HSD test.

water stress in cuttings prior to rooting. However, exogenous application of ABA has both promoted and inhibited rooting depending on the species (Davis and Sankhla, 1988). In general, endogenous ABA levels have positively correlated with rooting, particularly in seasonal variation observed in woody plants (Blakesley et al., 1991). In addition, ABA has been suggested as one of the cofactors postulated to positively interact with auxin during rooting (Basu et al., 1968). Previous work with tomato showed that exogenous ABA had no effect on auxin-stimulated rooting and ABA could not reverse GA_3 rooting inhibition (Coleman and Greyson, 1977). In the current study, exogenous ABA inhibited rooting in leaf discs in wild type as well as all the mutant backgrounds (Table 1). However, in the ABA deficient *not* mutant, auxin-induced rooting was reduced and this reduction could be complemented with exogenous application of ABA to *not* stock plants. The mutant data suggests that ABA could have a direct physiological role in rooting, but the impact of stock plant water stress in the ABA mutant could also account for the observed differences in rooting.

The effects of ethylene on rooting have also been mixed depending on the system used to evaluate rooting (Hartmann, et al., 2002). However, ethylene has been previously shown to inhibit rooting in tomato leaf discs (Coleman et al., 1980) and the authors concluded that ethylene was an endogenous inhibitor of the rooting process. The current study confirms the inhibitory effect of ethylene (via ACC application) on rooting in tomato leaf discs (Table 1). However, its endogenous role as a rooting inhibitor is doubtful given the reduced rooting in the ethylene perception *Nr* mutant (Table 1) as has been previously shown tomato stem cuttings by Clark et al. (1999).

Alternatively, there is also the possibility that the reduced rooting seen in *Nr* was caused by increased tissue sensitivity to ABA. Ethylene and ABA share downstream elements in the signal transduction pathway and ethylene mutants can be more sensitive to ABA compared to wild type (Gazzarrini and McCourt, 2003). However, the reduction in rooting with ABA application affected all genetic backgrounds in a similar manner (Table 1), although it was most severe in the ethylene perception mutant where rooting percentage and number were reduced 64 and 90%, respectively.

In conclusion, the current study demonstrates that tomato is a useful model system for studying adventitious root formation. Results with the hormone mutants often contradicted conclusions drawn by exogenous application of hormones alone. The combination of a genetic approach complimented with exogenous application of hormones to stock plants and rooting media provided a more powerful tool for interpreting the endogenous physiological roles for these hormones in rooting.

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Propagation of Spicebush (*Lindera benzoin*)©

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INTRODUCTION

Lindera benzoin, commonly known as spicebush, of the Lauraceae family, is a shrub native to most of the Eastern United States from Maine to Florida and west to Kansas (Dirr, 1998). Spicebush has a dense, rounded growth habit in full sun, a more open growth habit in shade, and prefers moist, well-drained soil. It bears small clusters of yellow flowers in early spring and has smooth light green leaves in the summer that turn bright yellow in the fall. In addition to the aesthetic qualities, there are no serious insect or disease problems (Dirr, 1998).

There is an increasing interest in the introduction of native plant alternatives as concern grows about nursery production of species designated as exotic invasive plants. Thus, there is potential for spicebush to be utilized in the landscape industry as a marketable native shrub.

Previous anecdotal research shows that vegetative propagation of spicebush by cuttings has been difficult (Dirr, 1998). Therefore, propagation from seeds is currently the most common production method. The most often referenced suggestion for a dormancy release treatment for spicebush is 1 month of warm followed by 3 months of chilling stratification (Dirr and Heuser, 1987) (Young and Young, 1992). Dirr and Heuser (1987) also suggest that spicebush seeds only require 3.5 months of chilling stratification for dormancy release. The objective of the current study was to determine the need for both warm and chilling stratification on dormancy release in a native Kentucky accession by finding an appropriate stratification treatment. In addition to dormancy-breaking requirements, ease of seedling establishment was determined.

METHODS AND MATERIALS

Seeds for this study were collected near Nicholasville, Kentucky in early November of 2005. The seeds were removed from the fruits, and broken seeds were discarded. Seeds were cleaned, and dry seeds were placed into cold storage at 5 °C until the start of the experiment. Prior to stratification, seeds were surface disinfested by soaking in a 10% bleach solution for 10 min followed by three rinses of sterile water. Seeds were placed in 15 mm plastic Petri dishes with 60 g of autoclaved sand and 15 ml sterile water (20 seeds per plate). Plates were wrapped with Parafilm and placed into germination chambers set to warm or cold temperatures. Using a factorial experimental design, dormancy release treatments included 0, 4, and 6 weeks of warm stratification at 25 °C, followed by 0, 6, 12, and 18 weeks of chilling stratification at 5 °C, for a total of 12 treatment combinations with 80 seeds (four plates) per treatment. Upon completion of the stratification period, dishes were moved to a growth chamber of 25 °C with 16/8 h of light and dark. Germination (radicle emergence) was recorded weekly for 4 weeks following the stratification treatment(s).

Upon germination, seedlings were removed from the Petri dishes and potted up into 7 in. × 5¼ in. × 3¾ in. six-cell packs using 560 Metro Mix and placed under greenhouse conditions. The seedlings were watered as needed and fertilized with a Peters 20N–10P–20K solution every 7–10 days.

Table 1. Seed germination of spicebush exposed to combinations of warm followed by chilling stratification.

Stratification		Germination
Weeks at 25 °C	Weeks at 5 °C	percentage[z]
0	0	15.8 c
	6	50.0 b
	12	90.0 a
	18	86.3 a
4	0	15.8 c
	6	18.8 c
	12	37.5 b
	18	53.8 a
6	0	12.5 c
	6	8.8 c
	12	57.5 b
	18	68.8 a
ANOVA	F-value[y]	
Main effects		
Warm stratification (W)	45.24**	
Chilling stratification (C)	101.78**	
Interaction Effects		
W × C	7.54**	

[z] Means followed by the same letter within a warm stratification treatment were not significantly different at $P < 0.01$ by Tukey's HSD test.

[y]** indicates significant differences at the 0.01 level.

RESULTS

Germination data shows that approximately 15% of spicebush seeds germinate without any stratification treatment. The highest germination percentages occurred after 12 weeks of chilling stratification without a prior warm stratification period (Table 1).

The 12 weeks of chilling stratification treatment showed a mean germination percentage of 90%.

In terms of seedling establishment, a survival rate of 84.7% (188 of 222) was achieved for seeds potted up immediately following germination. Seedlings were similar in survival, appearance, and vigor across all germinated seedlings regardless of stratification treatment.

DISCUSSION

Those seeds exposed to warm stratification prior to chilling stratification showed significantly lower germination percentages compared to chilling alone. In addi-

tion, the warm pre-treatment appeared to delay dormancy release during the subsequent chilling period. Therefore, a warm stratification period is not necessary to achieve a high germination percentage. There is also morphological evidence that supports this conclusion in that spicebush seeds have a fully developed embryo; therefore, a warm stratification period is unnecessary for embryo growth.

The spicebush seed lot used in this study displayed an intermediate physiological endogenous type of dormancy (Hartmann, et al., 2002) that only required chilling stratification. The negative effect of warm stratification appears to be due in part to the induction of secondary dormancy that requires a longer chilling stratification period for dormancy release (Table 1). Additionally, some seed contamination due to exposure to warm temperatures and moist conditions may be reducing overall viability in the warm stratified seeds.

A second germination study is currently under way using a Pennsylvania seed lot to further determine the chilling stratification requirement of spicebush, as well as any geographical differences in dormancy release treatments that may require the combination or warm and chilling stratification.

The combination of high germination percentages and seedling establishment indicate the ability of spicebush to be grown commercially for the landscape industry.

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The Western Red Lily Centennial Project©

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INTRODUCTION

The western red lily (*Lilium philadelphicum* var. *andinum*) is the floral emblem of the province of Saskatchewan, Canada. This showy lily is protected under the Provincial Emblems and Honours Act, but its numbers continue to decline due to anthropogenic activities such as cultivation and fire suppression (Government of Saskatchewan, 1988). The SaskPower Shand Greenhouse undertook the task of propagating large quantities of the western red lily as part of the province's centennial celebration in 2005. Several research trials were initiated in order to determine appropriate propagation methods along with techniques for accelerating growth and blooming.

TRIALS AND RESULTS

Germination trials were set up to determine the effects of seed source, seed pretreatments, stratification temperatures, moisture levels during stratification, and light exposure on the germination of western red lily seed. Results were analysed using an ANOVA F-test. It was found that pre-soaking and cold stratification had the most significant effect on germination. A 3-day soak in room temperature water with 5 daily water changes followed by a 30-day cold stratification at 5 °C (41 °F) gave the highest levels of germination. Seed was sown with a light covering of medium.

Once seed germination procedures were established, a trial was performed to determine the effectiveness of tissue culture propagation in comparison to seed propagation. Western red lily tissue culture bulblets were produced at the University of Saskatchewan using standard tissue culture techniques. In our growing conditions, seed-propagated plants showed greater growth, more robust plants, more vegetative stalks, and greater survival and blooming after outplanting.

Table 1. Treatments involved in one forcing cycle.

Phase	Location	Photoperiod (h)	Media Temperature (°C/ °F)	Time (days)
Growth	Greenhouse	18	18-20 / 64-68	77
Pre-cooler conditioning	Walk-in cooler	8	7-10 / 45-50	28
Cooler	Walk-in cooler	0	2-5 / 36-41	63
Post-cooler conditioning	Walk-in cooler	8	7-10 / 45-50	14

One of the main goals of this study was to speed both growth and blooming in western red lily. This was done using artificially accelerated growth cycles. Each trial started with a 14-day germination and establishment period. The plants were

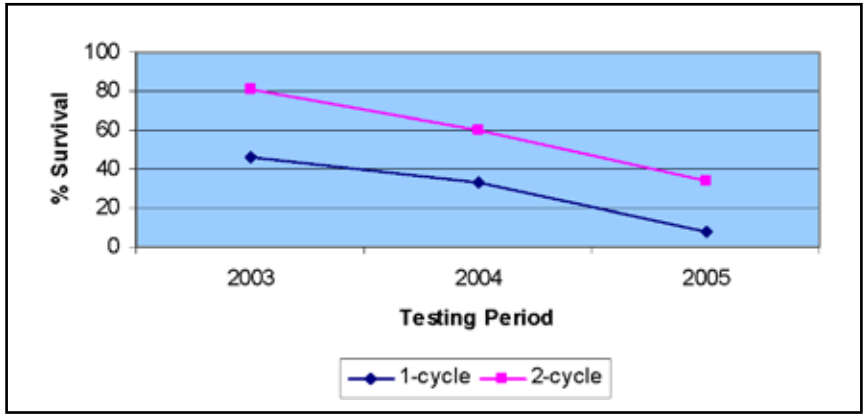

Figure 1. Percent survival of one and two forcing cycles based on number of visible plants.

then exposed to 1, 2, or 3 accelerated growth cycles. Each cycle was 182 days long and involved growth, pre-cooler conditioning, cooler, and post-cooler conditioning phases (Table 1). The best results occurred after two accelerated growth cycles. Larger-celled trays resulted in larger, more robust plants.

Many gardeners have encountered difficulties establishing western red lilies in cultivated soil. We hypothesized that the lack of natural fungal associations was limiting long-term survival. We chose to inoculate half of our plants with the vesicular-arbuscular mychorriza *Glomus intraradices* because it is commonly found in Saskatchewan soils and has been used successfully in the growth of commercial bulb crops like garlic. Root staining prior to outplanting showed hyphal growth, but no vesicle or arbuscule development. The luxury environment of the greenhouse may have limited the necessity for fungal development. In the first 2 years after outplanting, no obvious survival or performance differences were noted between the inoculated and non-inoculated plants. Mychorrizae will be more likely to play a role in long-term survival.

Samples of each trial were outplanted into 5 different locations. The biggest challenges to lily survival observed were inadequate moisture, wildlife predation, and competition from taller, more "weedy" plants. The most successful plots received regular watering and weeding. A cage made of hardware cloth was successful in excluding wildlife in one site.

In the wild, a lily grown from seed takes 3–4 seasons to bloom (Lawrence 1995–1996). In our trials blooms were seen only one season after outplanting. Blooms were most common in the two accelerated growth cycle lilies that were grown from seed. There were significant winter losses in all trials, but those plants that did survive tended to spread and produce more plant stalks (Fig. 1). Determining survival in this species can be difficult because the bulbs are able to remain dormant for one or more seasons at a time.

We propagated over 81,000 western red lilies for distribution in summer 2005. These lilies were grown from seed, given two accelerated growth cycles and inoculated with *Glomus intraradices*. In spring 2006 we had reports of beautiful blooming lilies in gardens across the province. We hope that additional trials will be able to determine the long-term effectiveness of mychorrizal inoculation in western red lily. With any luck these centennial lilies will continue as a symbol of Saskatchewan for generations to come.

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Horticulture U.K., Adapting to a Changing and Challenging Marketplace©

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INTRODUCTION

The fact is that the United Kingdom (U.K.) and European Union (E.U.) are entering very new territories which are in a rapidly changing market. The £ (Pound) and € (Euro) are becoming elusive, along with spiralling costs and no increase, only decrease, in product value. Many factors have come about to create the situation that horticulture U.K. is now facing, some of which I will try to outline.

THE MEDIA

Television. Ten years ago we were bombarded with media coverage. Television would have programmes relating to gardening on for at least 1 h per night. A show called "BBC Ground Force" was criticized by the trade for encouraging the covering of gardens in decking and just painting timber fences. However, the reality was that people were being encouraged to get out into their gardens. We had Tim Smit with the Lost Gardens of Heligan and its restoration, then the Eden Project (which incidentally is still strong in its public presence but supplements its income with rock concerts and winter ice rinks to keep the profits coming in). All of these plus regular features kept gardening "sexy."

Now, in the last 5 years we have seen a transition into fashion, house make-overs, and buying property for investments. Gardening now is lucky to get 2 h per week. Add to this the abundance of cheap flights within the E.U., and it is now a challenge to get a slice of the "leisure pound."

We still get great coverage of Royal Horticulture Society shows, especially Chelsea, but unfortunately it often coincides with poor weather.

Written Press. We still have a huge range of magazines being produced, but the articles often are either recycled from the previous year or feature products that are not supported by the industry.

Who is to blame for this? How many companies actually keep the press informed on trends, availability, and new products? It's too easy to blame; we all need to work together to ensure the public is kept up to date.

WATER AND ITS USE

Our climate is changing rapidly. For the last 5 years, we have seen drier, hotter summers, and for the last 3 years, the south and south east of England have had drought orders from April, and hose pipe bans have been enforced in the south counties. The Press, however, just got behind the fact that gardeners will not be able to water their gardens with hoses. Unfortunately, the industry just does not get working as one voice and offer help and constructive advice.

On visiting 30 garden centres this year, only three actually had displays of drought-tolerant plants and advice on how to conserve water. The rest just said, "Here's a water butt and here's a watering can, work it out for yourself!"

Growers are suffering from seasonal changes as well. Water usage is now under scrutiny, but no real action is being taken apart from the cost of water rising. What is needed is legislation on the usage of water and its efficiency. Growers know how to save water but are reluctant to invest in change.

Twenty-five years ago, HRI Efford and Margaret Scott set out the design of the true Efford sand bed, an automatic watering system that relied on nothing more than a toilet ballcock. The efficiency of these structures is superb, using less than 10% of the water of an overhead system.

Of course, initial costs are high, but the long-term payback easily outweighs this cost. Beds built 25 years ago are still working 100% with no labour input for watering and only a one-time seasonal cleaning; they never go wrong. Can this be said of the overhead sprinkler systems?

MARKETS

Our marketplace is changing rapidly. Recent surveys on behalf of the Horticultural Trade Association (HTA) have shown the public is split into three categories when it comes to buying plants:

1) Very/quite keen gardeners 34%
2) Marginal gardeners 30%
3) Hostile/not keen gardeners 36%

In 2005, the Garden Industry Monitor surveyed the public on what its perception of plants was. Some striking evidence came out; examples of findings are:

- "Most plants are from Holland." They see the huge Dutch lorries on the roads and parked at nurseries/garden centres and just assume that's from where they all come.
- Garden Centres attract keener gardeners, but marginal gardeners tend not to use nurseries. Some felt garden centres had lost their way.
- Loyalty was evident, but few respondents were driven by price.
- Spending was mainly driven by impulse.
- "Plants are cheap on average."
- When asked to value plants, they all put a higher price on the product than actually was being asked.

At this point I guess you think, "Well, why don't they brand the U.K. produce and just charge more for it?" I agree, just why don't we? However, research has shown there is no added value perceived by the plant grown on a U.K. nursery.

Nationally, we have "Plant for Life," which is an initiative spearheaded by the HTA aimed at raising the awareness of plants and the roles they can play in enhancing people's quality of life. It has linked the public to retail outlets and has provided a point to give inspiration to gardening. It provides topical updates, hints and tips, and how plants can benefit and enhance life.

If you survey a range of garden centres in Britain, whilst they all differ in their style and appearance, one thing that is quite evident is the globalization of their products. Key suppliers have been branding their products for so long and have such a stronghold on the marketplace, that when you visit a garden centre you will inevitably find the same plants, same labels, and — a fair chance — the same price. However, this is changing rapidly.

We are aware that the public browse garden centres — actually what they do is sample the coffee shop, for a garden centre is not a garden centre without a coffee shop! In many instances the coffee shop is the lifeblood of the place and certainly the most profitable, often returning a profit of around 30%.

We recently have had one garden centre get its food outlet in the Good Food Guide and mentioned in "The Sunday Times" as the "Best place to go and eat Sunday lunch," along with Time Out Award and Tatler's Award for most original restaurant. These gastro-gardeners have their coffee and cake, then browse the plant areas, they recognise the products centre to centre.

Nurseries are feeling the pinch with their product range. We have seen key nurseries dropping their propagation units because they are not cost effective. They cannot change fast enough if they are reliant on stock plants, cuttings, and liners; by the time they have changed so has the market yet again. This has often led to rationalisation of the product range due to the availability of free stock from young plant producers. Growers must create demand, not follow it.

Growers are having to study costings. Fifteen years ago we were in a situation where demand was outstripping supply. To keep up with demand growers produced more and more plants, often dropping slow-selling, low-volume lines. This has meant that 10 years later there has been an over-supply of key products. This has led to plants not selling from nurseries and to high wastage. The HTA have reported these figures as high as 30% of turnover on some sites in waste.

The DIY stores/supermarkets are pushing hard into the traditional market place. Their percentages of the market between 2001 and 2005 were 16%, 18%, 19%, 19%, and 18%, respectively. This is high volume/low price, and many growers have been in this supply chain and suffered bitter consequences in doing so. With the rapidly changing market these sheds have found they just cannot shift the proposed high volume they were expecting, and this has been dumped back at the growers. This contributes to such high wastage the market place just cannot swallow these units up anywhere whatever the price.

Garden centres have always looked upon the sheds as their biggest threat. They do sell the plants cheaper, sometimes, but the range is poor or limited. In addition, the product is often decaying because these outlets just cannot maintain quality; they do not have the systems or trained staff for advice and maintenance. The stock on offer is poor in comparison with a garden centre.

But how long will this last? The superstores can recruit and train staff if they want to, they can have enough clout in the supply chain to demand just-in-time delivery, and they can change and will. Just look at their websites to see how they tie gardening into other services.

LABOR COSTS

With nurseries and garden centres struggling to make profits they look at wages to reduce their overheads. Their first move was to reduce the volume of labour. Labour costs vary across the industry, but the range is 22%–46% of turnover. To reduce this percentage many nurseries have taken on agency labour just for the time required (this may be just 6 months or just a few weeks). Most of the labour is unskilled, but these people want to work and can often be found working 6 or 7 days per week in 12-h shifts. Recruiting British staff is nearly impossible and finding employees with critical skills such as propagation and growing, is extremely rare. This, in turn,

makes the decision whether to propagate or not mainly based on whether labour can be found. Our horticultural colleges are failing to get applicants; most courses now only have 6–10 students in commercial courses. Again, who is to blame for this? Is horticulture actually getting involved with schools and colleges? Are we really showing ourselves off to our best?

LEAN MANUFACTURING

Three years ago Manufactory Advisory Services (MAS) ran a pilot scheme with four wholesale nurseries to look at lean manufacturing.

The principles of lean manufacturing have been based on the manufacturing industry, originating from the 1950 Japanese car industry. It is a management philosophy focusing on the reduction of the seven wastes: (1) over-production, (2) waiting time, (3) transportation, (4) processing, (5) inventory, (6) motion, and (7) scrap in manufactured production.

This approach looked at all aspects of waste in the flow of decision making, planning, and production in a nursery. In the first year the average saving made by the introduction of the lean manufacturing approach into growing was £60K per annum, per site. This was made by eliminating stages in the production cycle that did not add value to the product

Examples:

- Distance travelled.
- Handling product unnecessarily.
- Not able to find tools when required.
- Paper flow in offices etc.

Now this lean manufacturing process has been implemented in excess of 100 nurseries and is now starting to be completed in garden centres. It has highlighted how massive savings can be made if the two sides of the industry would work together. Ideas about to be piloted include:

- Delivery on trust.
- Bar-coding of crates to show product at packaging to delivery.
- Automated stock control of key lines.
- Automated delivery information on e-mail.
- Product quality images via web/e-mail prior to shipment (great if the product looks excellent then maybe more can be charged for it!).

USE OF CHEMICALS

The use of chemicals on nurseries is a very emotional subject. Many growers still swear blind by a strict chemical control programme, "It's week 10 and we must spray 'X' immediately." However, with rising costs of chemicals and reduction in range this will have to change. In the U.K. an agreement with the EU was formed for the "Long-Term Arrangements for Extension of Use" (LTAEU) of chemicals. It was introduced in 1990 to overcome the problem of minor crop approvals. At that time 468 products were submitted to Pesticides Safety Directorate for inclusion. The registration of the products was free and two opportunities were given for submission. No other E.U. country developed a scheme like it.

We're going to lose the extension in 2007 and will need around 250 SOLAs (Specific Off Label Applications) to replace it! Therefore, we can say goodbye to many of our current chemicals.

Many growers are now working toward a more holistic approach to growing. Biological control is now forming the backbone of control. Identification and staff awareness has meant that careful use of predators has kept pests under control. It cannot work in total isolation, there may be a time when chemicals need to be used but using a friendly chemical to the predator is not upsetting the balance but reducing infection. Even treating perimeters such as hedgerows with lace wing larvae to control aphids is being tried. The nurseries that have been working toward these now are finding very low levels of pests, but more importantly, a significant reduction in chemicals used, in many cases up to 90%.

Compost Teas. The other big trend is the use of "compost teas." There are now in excess of 100 "tea pots" working in the U.K. These growers have seen huge reductions in the number of incidences of *Pythium*, *Botrytis*, *Diplocarpon rosae* (blackspot), and *Phytophthora*. They have seen an increase in the efficiency of their biological control and there are other spin-offs: an increase in growth/vigor, stronger rooting, and quicker establishment in containers. Many growers have now started to reduce the control-release fertilizers in their mixes up to 1.5 $kg \cdot m^{-3}$ with no reduction in growth or quality.

So what are these teas and how are they used? Compost tea provides:

Direct Nutrition. A source of foliar and soil organic nutrients. Chelated micronutrients for easy plant absorption. Nutrients in a biologically available form for both plant and microbial uptake.

Microbial Functions. Compete with disease causing microbes. Degrade toxic pesticides and other chemicals. Produce plant growth hormones. Mineralize plant-available nutrients. Fix nitrogen. Plant surfaces are occupied by beneficial microbes leaving no room for pathogens to infect the plant.

Compost tea will help to create a balanced soil food web, which will;

- Suppress disease-causing and pest organisms.
- Improve the nutritional quality of the plant.
- Produce good soil structure — improving water infiltration, oxygen diffusion, and water-holding capacity.
- Retain nitrogen and other nutrients such as calcium, iron, potassium, phosphorus, etc. Make nutrients available for plant growth at the times plants require at the rates plants require.
- Decompose plant residues rapidly.
- Reduce worker exposure to potentially harmful chemicals.
- Produce hormones that help plants grow.

The normal application is to apply every 2 weeks with the overhead spray lines or via dilution with a hose. Either way the cost benefits are enormous, £40/5 ha for teas plus 4–6 h for application. The saving on this is that nonqualified staff can apply it and work does not have to stop during application.

This is all beginning the "holistic" way of growing: understanding what the plant needs and adjusting the environment and conditions to suit it, to minimizing stress and pressure in the plant. We are now going back to the roots of growing by trying to actually grow the plants rather than boost them unnaturally with fertilizers. We are reverting to growers again!

AUTOMATION

Automation is only just beginning. With the demise of a cheap labour pool growers are finally looking at machines instead of people. We have finally gotten efficient potting systems with bale lifters, potting machines, transplanters, and motorized conveyers. The Dutch have gone one stage further with robots and full automation. One Dutch grower is turning out 4 million plants per annum, with just two growers and six on dispatch; the rest are robots. The plants arrive from another nursery; they are selected, transplanted, and graded by machine. Then, the plants are carted around the nursery by robot-driven tractors; stood down by robot arms; watered by computer-controlled gantries; lifted, pruned, and spaced as required, again by robots. When ready for sale, they are lifted at night by a robot, put on tables, brought into the packing shed, off-loaded onto conveyers, labeled and packed, then finally the human involvement, loaded onto trolleys and lorries and sent off to the customer. So where do we go from here?

THE WARNINGS

First, we are seeing increased incidence of new pests and diseases including *Phytophthora kernovii* along with *Phytophthora ramorum*. This has destroyed huge numbers of nursery stock both in the U.K. and the rest of the world. The only cure is the cut and burn policy. New pests are becoming a problem. Scale is now a major problem in the U.K., along with citrus beetles. Source plants from the Mediterranean, with the easy transport of material across international boundaries, and problems occur. No matter how strict we put border control and tests in place, it is down to the speed of action. Can we afford to wait 4 days with the plants on site before action has to be taken — how tight are our controls as growers?

PEAT AND ITS USES

In the U.K. the anti-peat lobby has been running fast and slow. Every so often they will get huge political and public support and become a threat then it dies away. We as growers are now only just learning how to use our composts with peat to grow a reasonable plant. We know we need to reduce our reliance on these substrates, but let's focus on one or two key alternatives. In the U.K. we are currently trialing: (1) Garden waste from rubbish collection, (2) bark, (3) wood chips, (4) wool waste, (5) paper, (6) carpet waste, (7) wood fibre, and (8) polystyrene.

Let's pick out the two key items and focus fully on those and develop a successful alternative together; let's not dilute our skills and research.

GLOBAL WARNING/CLIMATE CHANGE

Is it here, is it going to have an effect? Certainly in the last 10 years we have seen a change in our climate. We are getting hotter, dryer summers, not necessarily colder winters, but certainly lower light levels in the early spring. How will this affect our growing? Can we produce plants more cheaply by using outside growing space during the spring and summer? However, for this to work must we push for more plant sales in the autumn? Will the market change to the point where we have to provide plants for specific conditions and an even narrower selling window?

So, where do we see our nurseries of the future? There will always be the "back yard" nurseryman with his great range of plants, in small volumes — not always totally professional, but giving the genuine plant hunter the challenge of finding

him with that rare plant. They have their own outlets at farmer markets, gate sales, and the Internet.

The specialist propagator — where are they to go? Certainly, there will be a much greater pressure in this sector. They need to be able to react fast to changing demand whether this is utilizing micropropagated mother plants and stock or greater manipulation of mother plants to provide the volume of material required at short notice or utilizing off-shore propagation from areas such as Costa Rica or Africa or the new source of China and Japan. One thing is for sure, it has to be clean stock, free from pests and diseases, such as viruses. Co-operation is paramount; the supply chain must be secure both up and down. There has to be great communication with suppliers and customers. Growers have to innovate and create demand. We have seen great success in the past, but now it has to be focused on what the consumer needs. Waste has to be eliminated; this is just cost and eating into the bottom line profit. Growers need to be aware of what is going on around them, the focus of legislation, and environmental awareness.

We all need to be working with the environment and raising the profile of horticulture. We are great at what we do and the public should be made aware of the impact we can have on their lives to make it richer. At the end of the day we need a realistic price for our product. We need profit to develop, we need cash for security, we need skilled staff but above all what we need is a public that wants our product!

Wake up and smell the coffee!

Conifer Cone and Seed Processing©

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INTRODUCTION

The cone and seed processing of conifers is presented as a part of the Seed Handling System defined as all activities between cone collection and sowing in the nursery (Fig. 1). This presentation covers the activities of: (1) Post-collection handling of cones, (2) Cone processing, and (3) Seed processing with a general aim of increasing knowledge about conifer cone and seed biology and processing.

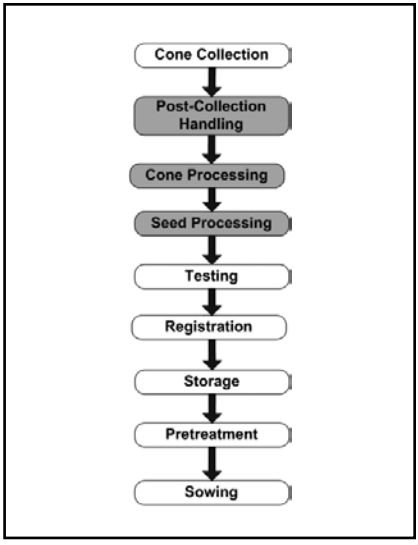

Figure 1. The seed handling system.

Conifers are a very diverse group of organisms and have been shown to be among the most heterozygous plants (Hamrick et al., 1979). This is not surprising given their long life spans and wide species distributions. This variation is important to maintain and although we continually are improving our processes it is not simply a matter of reducing variability in our product as this variability has an important role to play in our forests. There is a great deal of cone and seed biology behind cone and seed processing, but it is also subjective at times and requires highly competent and dedicated technicians to combine the art and the science into successful cone and seed processing.

There currently are three conifer cone and seed processing facilities in British Columbia (B.C.) which have averaged approximately 6000 hectoliter (hl) of cones over the past 10 years. In 2006 there was a very large increase in cone collections, primarily in response to the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) epidemic, with a total of 12,000 Hl of cones processed in B.C.

The primary descriptors of cone and seed processing are yield and germination. Yield can be thought of as a measure of efficiency measured as kilograms of seed per Hl of cones and varies from approximately 0.27 in lodgepole pine (*Pinus contorta* Dougl.) to above 2.0 in amabilis fir [*Abies amabilis* (Dougl.)Forbes]. Differences in yield are the result of many factors including; species, seed size, cone size, reproductive success of that crop, proper timing of collection, and appropriate post-collection handling of the cones. The second descriptor is germination and represents the germinable proportion of seed in a seedlot. The primary reforestation species in B.C. generally have good germination capacities: lodgepole pine (95%); interior spruce [*Picea glauca* (Moench) Voss], *P. engelmannii* Parry ex. Engelm. and hybrids (90%);

Douglas-fir [*Pseudotsuga menziesii* (Mirb.)Franco] (92%), and western red cedar (*Thuja plicata* Donn ex. D.Don) (85%). During final cleaning these two variables, yield and germination, are balanced to try and derive the greatest numbers of potential seedlings from a seedlot.

Cones are obtained from both natural stands and seed orchards for those species and seed zones in which tree improvement programs exist. An effective monitoring and pre-collection evaluation system is important in both areas to (1) determine crop size (and plan for needed resources), (2) determine if any pest problems exist, and (3) determine maturity level and try and match collection timing to full seed maturity without losing seed to natural dispersal. Sampling should become more frequent as cones and seeds are approaching full maturity (generally August to September).

POST-COLLECTION HANDLING

Post-collection handling, including temporary storage, monitoring, and transport of cones, is a key step in the production of high quality seeds. Unfortunately it is a stage that too often receives inadequate attention. Freshly picked cones are very moist, and this moisture must be removed gradually to mimic the natural maturation process and to prevent overheating and/or case hardening of the cones. Collecting immature cones or picking them during wet weather will compound moisture problems. For moist cones reduce the volume per sack to promote uniform drying.

It is generally recommended that the cones of most species should be field-stored for approximately 4 weeks prior to shipping to the extractory to reduce moisture content and risk of damage. However, exceptions to this rule include western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] and western red cedar, which have shallow seed dormancy and should be shipped to the seed processing facility directly upon picking. Store cones in sacks under shelters with exposure to freely circulating cool air to gradually remove moisture. The weave of the cone sack should not allow released seed to be lost. It is important that sacks are not stored in direct sunlight because overheating can damage cones, but they also should not be allowed to remain wet for excessively long periods since this will encourage the growth and spread of fungi. Air movement is more beneficial to drying than light or heat.

Transportation of cones from interim storage to the extractor is an important aspect of post-collection handling as seed quality can be degraded by improper transport. The keys to proper transport are to provide good circulation around the cone sacks, maintain a cool temperature, and limit the time in the transport vehicle. Proper circulation can be accomplished by using pallets to separate cone sacks. For most species cone sacks should be two-deep followed by another pallet.

Upon arrival at the extractor the cones are placed into cone storage areas until processing is initiated. An initial random sample of cones will be evaluated for basic morphological features, degree of insect or pest activity, estimates of seed yield through half-cone counts, and detailed examination of internal seed condition through cutting tests. The details of a longitudinal section of a typical conifer seed are illustrated in Fig. 2.

CONE PROCESSING

Cone processing generally involves a kilning process and a tumbling process to separate the seed from the cones. Kilning refers to drying cones in a controlled,

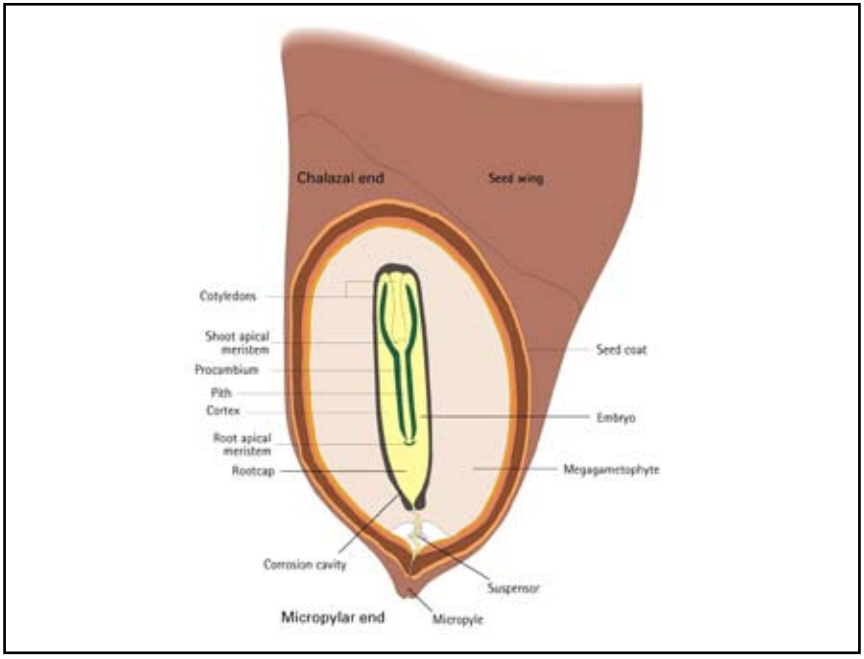

Figure 2. The anatomical details of a generalized conifer seed in longitudinal section.

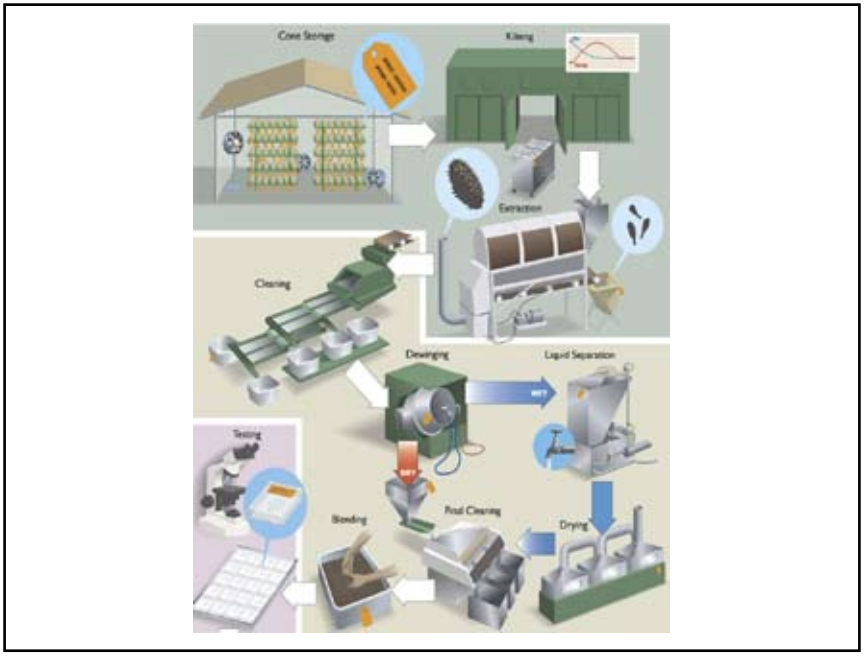

Figure 3. A generalized view of conifer cone and seed-processing steps.

warm, dry environment to flex the cone scales and allow seeds to be extracted. An overview of cone and seed processing steps are illustrated in Fig. 3. The *Abies* sp. are the exception and are usually not kilned or tumbled because their cones naturally disintegrate with additional conditioning.

Following kilning, the seeds are extracted from the cones in a large mesh cylinder referred to as a tumbler. The speed of rotation and angle of the cylinder are adjustable to allow for optimization by species. Seeds will fall through the mesh screen and onto a conveyor belt that will collect seeds and debris in a plastic bag. Spent cones traverse the length of the mesh cylinder and for small-coned species they are vacuumed out of the processing plant to an outside holding area. For large-coned species, cones are manually removed from the extraction area.

Extraction is a critical point in processing and monitoring unextracted seeds per cone is very important. If all viable seeds are not removed from the cones at this point in time it can have a large impact on yield, and there is no second chance. It is important to determine through cutting tests whether unextracted seeds are viable, since many "empty" seeds are routinely retained in the cone. If it is determined that sufficient viable seeds still remain in the cones and are extractable, the seedlot, or a portion of it, may be rekilned to improve cone opening and extraction efficiency. Excessive tumbling should also be avoided; it introduces additional debris to the seedlot, reducing processing efficiency and possibly damaging seeds.

The *Abies* taxa are not kilned or tumbled, making their cone processing unique. Upon receipt, cones are de-sacked onto plastic trays and placed into a pre-conditioning area that is maintained at a temperature of 10 to 15 °C with fan ventilation provided. The cones will remain in this area until the cones have disintegrated (generally at about 15% moisture content) and are then put over a vibrating screening machine to remove cone axis and scales and fine debris particles.

SEED PROCESSING

Seed processing involves the removal of debris, removal of nonviable seeds, and reduction of seed moisture content to prepare the seeds for long-term storage. Many different processes and pieces of equipment may be used in seed processing, and different species have different requirements. For example, all *Pinaceae* species have their seed wing removed during processing. However, the seed wing is not removed in the Cupressaceae species since it would significantly damage the seeds.

Initial cleaning is the first step in seed processing and is primarily concerned with the removal of debris from a seedlot. This debris may add moisture or pathogens or may mechanically damage the seeds, and therefore its early removal is a priority. A "scalper" or multi-screened vibrational seed cleaner uses metal screens of varying opening sizes, shapes, and arrangements to separate seed from debris. Choice and order of screens as well as vibrational speed are based on the species and type of debris in each seedlot and are important decisions for efficient and successful seed cleaning.

The seeds separated during initial cleaning will then be dewinged to remove the seed wing from its attachment to the seed coat. Dewinging generally occurs in a rotary drum or cement mixer in which rotation speed and angle can be controlled and water can be added if required. The seed wings are blown off in the dewinger and/or removed during final cleaning. Species that are wet dewinged also subsequently undergo a very brief water bath, which helps to separate particles denser than water

(i.e., rocks and pitch), which sink to the bottom of the liquid separation tank. Wet dewinging results in much "cleaner" looking seeds that will not release more debris (wing remnants) over time, but not all species respond to wet dewinging. Dewinging is a stage in which the probability of seed damage is higher, and it is important that the activity be as brief as possible to accomplish the required product.

Final cleaning is the final removal of debris particles, which should have been minimized through previous processing, and the removal of empty, immature, and nonviable seeds. Two pieces of equipment can be used for final cleaning: aspirators or the gravity table. The aspirator or pneumatic separator uses an adjustable air column to separate seeds based on terminal velocity, which is influenced, by specific gravity, size, shape, and surface texture (Edwards, 1979). Aspirators may have several, usually three, outlets for seed discharge. These are commonly referred to as light, mid, and heavy seed fractions. Cutting tests are used to calibrate airflow settings and determine if acceptable separations are occurring. The machine is set up to separate the heavy seeds considered filled and viable from the light fraction consisting of "empty" seeds and debris. The mid fraction is usually a combination and commonly has to be re-run, with adjusted settings, to separate out the viable seed. Various configurations on this central concept have been constructed and the "aspirator" is a common piece of equipment found in most seed-processing facilities.

The gravity table, originally used in the mining industry, is the primary tool used for final cleaning at the B.C. Ministry of Forests Tree Seed Centre. Seeds are separated across an inclined deck that moves in two directions — up and down, and backwards and forwards. An air current is also present from below the deck. Although it requires a great deal of dedication on the part of the technician, it can produce excellent separations. The gravity table is initially overwhelming because the operator has many variables to control.

The air current blown through the gravity table deck is strong enough to lift the light seeds slightly off the surface. These light seeds, not in contact with the deck, will run to the lower end of the deck due to the force of gravity. The heavier seeds, in contact with the deck, will be moved upwards with the reciprocating motion of the deck. The outcome of light seeds running down the deck and heavier seeds running up the deck initially seems counter-intuitive until one recognizes that different forces are used to move these fractions in their respective directions. Separations are performed on the gravity table by placing dividers on the discharge end of the deck separating the seeds into heavy, mid, and light fractions similar to the aspirators. The placement of dividers is determined through cutting tests, and it is common that more than one "run" is required for each seedlot. Separate runs on the gravity table may include changes to settings and adjustment of dividers based on additional cutting tests.

Following final cleaning the seedlot will be blended to ensure it is homogeneous prior to sampling for testing and placement in long-term storage at -18 °C.

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Small Lot Seed Handling of Species Native to British Columbia©

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INTRODUCTION

Every spring a seed need list is compiled, based on the following year's plant production schedule and the remaining seed inventory at the nursery. The list includes about 125 plant species native to British Columbia and the Pacific Northwest. The seed is collected by a number of plant collectors, including our own nursery team, from different geoclimatic zones in the region. We attempt, as much as possible, to match seed source with the eventual planting sites. This means, for example, that a species collected on the coast will not be used for planting in inland areas and vice versa.

A seed/berry order collection form is sent to each collector, who then proceeds to collect the required species and quantities, depending on availability for that particular season. Collectors take care of shipping procedures, which often means sending seed/berries in sealed pails by Greyhound or courier.

NURSERY PROCEDURE

Harvested, ripe seeds arrive from early summer through fall as berries or dry seed. All unprocessed material is inspected upon arrival and weighed. All collection data is entered on a seed collection record sheet, one for every collector in a given year. This can be done on the computer or manually on a paper document. Collection data include: name and address of the collector, species name, seedlot number, seed/berry weight, date of arrival, and any particular remarks. The seedlot number provides an easy reference to the origin of the seed. An example of a seedlot number is: JB-04-06. JB indicates the name of the collector, John Baker, 04 means this is his 4th collection of the year and 06 indicates the collection year. The seedlot number accompanies the seed through the processing stage and throughout its growing life at the nursery. Berries are stored in a cooler at 2 °C (36 °F) for a period of time until they are processed. Dry seed does not always have the low moisture content (below 10%) required for processing and storage. For this reason it is usually spread out on trays or racks for drying and curing to ensure optimum maturity of the seed.

BASIC TOOLS OF THE TRADE

Possibly the most expensive equipment required is a set of scales, mechanical or electronic, analogue or digital. Personal preference and price will determine the choice. It is important that the incoming, unprocessed seed is weighed upon arrival. For this a scale is needed that has a capacity to weigh up to 20 kg. A mechanical scale will be by far the cheapest option. After processing the seed, which may weigh up to several kilos (pounds), is weighed as well. A scale that weighs down to 1.0 g or 0.035 oz and up to 2 kg (70 oz) is the most useful. For very low seedlot weights and to make seed counts, a scale that reads down to at least 0.01 g (0.00035 oz.) is required.

Because we are dealing in most cases with small seedlot processing, the next biggest expense may be one or two food processors to process berries. We buy the cheapest ones we can find. If they wear out they can be replaced easily and cheaply. It is a good idea to have a spare one handy. We often use two machines simultaneously to speed up the processing.

For drying, freshly processed seed screens of different sizes can be used. Our stackable screens for drying measure 90 cm by 90 cm (3 ft by 3 ft) with a mesh size of 7 mm (¼ inch). We usually line the screens with a material cut out of rolls of curtain backing purchased at a fabric store. The curtain backing can be cut at different sizes and is used for many different purposes during seed processing and stratification.

For both "wet" processing of berries and "dry" processing and cleaning of dry seed, a variety of strainers, colanders, and screens are used to separate seed from pulp, husks, and debris. The larger the seed, the larger the mesh size and size of the strainer; the smaller the size of the seed, the smaller the mesh and size of the strainer. It is good to have a substantial collection of separation tools. Screens can be easily made from pieces of lath and different mesh wire screens available from hardware stores and lumberyards. Also needed for "wet" processing are a variety of pails and buckets of different sizes. Ice-cream buckets are worth collecting. White is a good color for any container because the seed and other particles stand out against the white background.

Another tool needed when processing seed is a sharp utility knife, or better yet, a one-sided razor blade (Fig. 1). It is used to perform cut tests to check for filled versus empty, partially filled, and "woody" seeds, as well as possible insect damage. Cutting seed is done at all stages of processing and assessing seed. It also helps to determine the stage of ripeness or maturity of the seed based on color of the seed coat, megagametophyte (food reserves for the embryo), and size and color of the embryo.

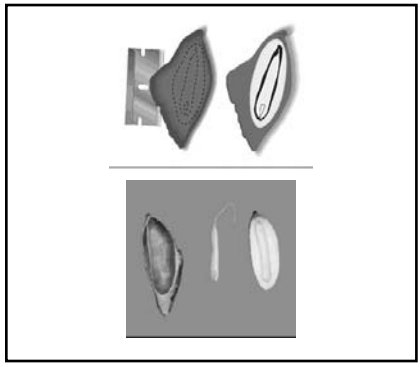

Figure 1. The use of a single-edged razor blade for seed cut tests.

Finally, there is one tool you can do without, but that is very useful if there are larger amounts of seed to be processed. It can be built from materials available from most hardware stores and PVC pipe suppliers. It is an air separator (Fig. 2), which separates empty or partially filled seeds and debris from filled seeds. It is easy to use and works by itself, leaving you time for other jobs. Its basic components are: a shop-vac at one end that draws a vacuum in a clear PVC pipe system and a PVC pipe seed container at the other end that feeds seeds into the air stream through a vibrator feeder. The vacuum can be regulated with a voltage regulator. The air stream will pick up light, empty seeds and debris and dump it into one container, while the filled, heavy seed drops through the air stream straight into another container. The air separator provides an efficient final seed cleaning method. It can be custom built fairly easily. Drawings are available from the author.

Figure 2. Air separator for cleaning seeds.

"WET" PROCESSING

All berries are macerated in the food processor (Fig. 3). The processor is filled to two-thirds from the top of the container that holds the berries. The knife in the processor should be kept sharp. When the processor is operating, water is added until the berry/water mixture flows smoothly. The processing duration varies per species; typically, it takes from 1–5 min. For most species there is no danger that the seed will be damaged by the knife. For some of the softer, larger seeds (e.g., *Mahonia* sp., *Oemleria cerasiformis*) it is necessary to keep a closer watch during the processing since they may get damaged if processed too long. In this case 1 to 3 min will be sufficient.

Once the seed is separated from the berries the mixture will become a thick slurry. Now, the processor content is dumped into a small pail under a tap (Fig. 4). A gentle flow from the tap into the pail will cause the pulp to rise to the surface while the heavy, filled seed sinks to the bottom. This process is continued until most or all of the pulp, light seeds, and debris have been floated off. The material that is floated off is caught into a strainer to prevent clogging of the drain. The contents in the strainer are dumped into another pail, which allows for checking whether any good seed may have been floated off inadvertently. It may also happen that berries have not been processed long enough, and in that case the mixture can be reprocessed. During the entire process some seeds should be cut with a razor blade to ensure that mostly filled seeds are left in the pail with the good seed and mostly empty and imperfect seed in the other. The entire process is fairly time consuming, and it cannot be hurried too much.

Finally, the good seed is run though a strainer and then dumped onto a drying rack or screen lined with curtain backing (Fig. 5). Here it is spread out evenly to ensure even drying. Often we will place a household fan to blow over the trays with the wet seed to speed the drying process.

Figure 3. Food processors used for processing seeds found in berries.

Figure 4. Seed and water slurry resulting from the food processor treatment.

The drying will take from 2–4 days depending on the temperature in the room. By then the seed should be below 10% moisture content and be ready to receive a final cleaning using screens, strainers, or the air separator. When the seed is clean and dry, the following information is recorded and entered into the inventory data sheet: seedlot weight, seed count per gram, processing yield (final clean weight : received weight = grams of clean seed per kilo of received weight), storage location, date, and processing time (Fig. 6).

Now the seed is ready to be packaged in clean, clear plastic bags (Fig. 7) and stored alphabetically by species name in plastic boxes in the cooler (Fig. 8). All our seed is stored at 2 °C (35 °F) and can be kept for a number of years, depending on species. Most seeds would store longer if frozen at -5 °C (23 °F) to -10 °C (14 °F). However, we use the cooler also for stratification purposes, and 2 °C (35 °F) is the suitable temperature in this case.

Figure 5. Seeds spread out on a screen for drying.

DRY PROCESSING

Not all seed come in berries. Many seeds are shipped more or less dry to us by the collector. These may come in a variety of seed structures in strobiles (cones) (*Alnus* sp.), in achenes (*Aster* sp.), in pods (*Lupinus* sp.), or in capsules (*Lilium* sp.). In each case they are dried and cured upon arrival in trays or on screens to ensure maximum maturity and storability (Fig. 9).

When dry, the seeds are worked, "massaged" gently by hand through miscellaneous strainers and/or screens to separate seed from chaff (Fig. 10). Sometimes pods or other seed structures are put dry through a food processor. The food processor will more or less pulverize the seed mixture, after which the seed can be easily separated with screens, strainers, and/or the air separator. When using screens and strainers, always go from a large mesh to a smaller mesh.

Figure 6. Weighing seeds on an analytical balance getting ready for packaging.

Again, upon finalizing the seed cleaning process, the seed weight and other data are recorded. Sometimes, in the case of a custom cleaned seedlot or when the seed still contains a high percentage of debris that cannot be cleaned out, we may determine the "purity percentage" of the seedlot. This is done by manually separating all impurities, including partial seeds, from a sample. The pure seed weight and the weight of the debris taken out must be weighed. The sample size we take usually

Figure 7. Seeds packaged in clear plastic bags ready for storage.

Figure 8. Seeds in individually labeled plastic boxes kept in cool storage.

consists of the final product including about 100 seeds. The following calculation is used to find the purity percentage:

$$\text{Purity (\%)} = \frac{\text{pure seed weight}}{\text{pure seed weight + debris weight}} \times 100$$

As an example, conifer tree seed in British Columbia must have a purity of 97% or better to be used in the provincial reforestation program. However, for most practical nursery purposes the purity is hypothetical, and a visual test may tell you whether the cleaning process has been adequate or not.

Figure 9. Labeled seeds are dried and cured in open trays.

Figure 10. Miscellaneous strainers and/or screens to separate seed from chaff.

Once the purity percentage is known it is possible to accurately calculate the seeds per gram using the following calculation:

$$\text{Seeds per gram} = \frac{100}{\text{weight}/100} \times \frac{\text{purity \%}}{100}$$

If the purity of the seed is not calculated it is still important to know the number of seeds per gram in order to be able to correctly calculate the number of seeds required for nursery plant production. For seedlots that have passed the visual purity

inspection, follow a simplified method of finding the number of seeds per gram. Just count the number of seeds in e.g., 0.25 g, multiply that number by 4 and you have the number of seeds/g. Or, for smaller seeds count the number of seeds/0.10 g and multiply by 10 to find the number of seeds per gram. For some of the smaller seeds counting the actual number of seeds is not practical, as you would spend a lot time counting seeds.

CONCLUSION

The processing of small amounts of seed of many of the plant species native to British Columbia and the Pacific northwest requires mainly basic equipment that can be easily found in local stores and the ability to make simple methods work effectively. It also requires patience and creativity in finding solutions to processing problems. The result can be the satisfaction in providing some of the building blocks needed to maintain and restore our natural environment.

Acknowledgement. Figure 1 was kindly provided by Dave Kolotello of the British Columbia Ministry of Forests.

ADDITIONAL READING

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SESSION I: QUESTIONS AND ANSWERS©

Evelyn Healy: How did you separate the immature from mature seeds?

Dave Kolotelo: We don't do that very well. We try to avoid it at all costs. When we get a seed lot that has a high proportion of immature seed we have to make a tough decision. Do we keep a lot of that material in and probably deal with a very low germination rate or do we separate the seed reducing viable seed yield? We don't do much physiological separation.

Evelyn Healy: How do you determine when the seed is about 10% moisture content?

Paul Vrijmoed: Having worked with tree seeds for many years you gradually learn how to get the seed to about 10% moisture content.

Mike Anderson: Do you use the same device for de-winging wet and dry seed?

Dave Kolotelo: We use a foam insert for seeds that are a little more fragile than others and let them stay in a little longer.

Mike Anderson: Have you every used that technique for de-winging maple seeds?

Dave Kolotelo: No, we've never had to do that.

Germain Boivin: Do you think the European Union (EU) has had anything to do with the decline of the nursery industry?

David Aylieff-Sansom: Yes, I believe the EU has had a major impact. They have been able to get their production costs down to such a level that product coming in from mainland Europe is 15%–25% cheaper than what would be produced in the home market. The ready supply of it is such that many UK growers are dropping some crops coming in from Europe.

Direct Sticking Through Plastic©

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INTRODUCTION

I attended my first I.P.P.S. conference in September 1994. I had recently started a small nursery specializing in native plants. Knowing successful propagation would be crucial to its growth and success, I wanted to gain some insight. The conference was held in Costa Mesa, California. The trip was entertaining for my family and very informative for me. The greatest single impression that remains to this day is how friendly and willing to share the people were. Over the years, I have benefited from the information made available by the members of the I.P.P.S. When I was asked to present, I wasn't sure I would have anything sufficiently scientific or new to offer. Upon reflection I realized that it is often tried-and-true methods and ideas that have value and have helped us continue to grow our business. This is our 15th year in business, and as is true of many small business owners, I find myself caught up in the pragmatic aspects of growing the business — staff, sales, development, and expansion. There never seems to be much time for detailed analysis or rigorous experimentation. Empirical study has its merits, though, so I decided to base my presentation on our recent trials involving field propagation of some native plants from hardwood cuttings using plastic mulch. Success of the trials would be determined by whether gains could be accomplished in the following three areas: improved ability to supply our niche market, controlling of costs, and reduction in the use of chemicals.

Our market is native plants, especially those for use in commercial landscapes, habitat and wetland restoration, stream rehabilitation, mitigation, highways, parks, and schools. The sites our plants are delivered to are often lacking irrigation and sometimes have difficult access so size and weight of plant material can be a factor, conditions can be extreme, and there is often no follow up or maintenance. Success depends on planting large, vigorous plants capable of surviving these harsh conditions. Since plantings are often government mandated, there often is no acknowledged advantage by the owner. Financial or aesthetic gratification is not gained so there is little initiative on the part of the owner to ensure success, other than to satisfy government requirements. Additionally, the budget is limited so contractors want the least expensive plant with the lowest planting cost and highest planting success.

NURSERY SITE DESCRIPTION

Peels Nurseries Ltd. is located 15 km east of Mission, British Columbia, on the north side of the Fraser Valley. Our coastal climate is characterized by warm summers, mild winters, and a long frost-free growing season. It is one of Canada's mildest, a Zone 8.

In the Spring 2002, we uncovered a sandy loam area at the edge of our container yard. The soils in this area are fluvial deposits, which are generally sands and gravels. This site has a deposit of sandy loam with some stones and is 0.5–0.75 m deep

on top of gravel. The field is generally flat with a 1.5% cross slope. The field was used for grazing prior to nursery use and consequently the weed seed load is considerable. During the summer we alternately sprayed glyphosate and tilled to gain some weed control. By the winter we planted some tree species, hoping that over the next 2-year period we could gain better control over the weeds. By the end of 2004, we were still encountering on-going weed problems. A better control was required. Short of sterilization, the next best alternative seemed to be plastic mulch.

BED PREPARATION AND CUTTINGS

In winter 2005, we went ahead with a plan to cultivate 1-m-wide raised beds and to cover these with 4-mil black polyethylene 1.5 m wide. The field was initially ploughed and disced to loosen the soil. The beds were then formed with a rototiller. The plastic was laid by hand and secured with soil at its edges. The path between the beds was mulched with 5–8 cm of sawdust.

The cuttings we chose were all easy-to-root native species, which were high-demand items for us. Species included *Salix*, *Rubus*, *Spiraea*, *Symphoricarpos*, *Ribes*, *Rosa*, *Populus*, and *Cornus*. The cutting sources were generally from our stock of potted material or stock plants, but occasionally some cuttings were wild collected. In general, we have good results with collected material provided the plants are disease free and vigorous. The cuttings are taken in January and February. The cuttings are 15–20 cm in length and 0.5–1.0 cm in a diameter. This year we had a cold snap in the latter half of February, so sticking was held off until March. The cuttings were drenched in Captan 80 WDG at 12 g per 5 L and stored under 15 cm of sawdust. When the weather warmed, two people working on opposite sides of the bed dipped and struck the cuttings directly through the plastic (Fig. 1). We used a 15-cm wide board with notches each 15 cm to provide a 15 × 15-cm spacing. Most species were dipped 1 cm in 0.4% IBA except for the willows, which received a 0.1% IBA treatment.

Figure 1. Cuttings in plastic: Spring 2006.

Figure 2. Cutting Bed: September 2006.

The only problem we encountered with the plastic mulch was with wind. In the first week after sticking, a particularly strong wind loosened several sheets of plastic and they billowed up over the cuttings. We quickly removed the cuttings, repositioned the plastic and using nails secured the sheets again. The cuttings were re-stuck, without substantial loss. Once the plants had rooted, wind was no longer an issue.

MAINTENANCE AND HARVESTING

By May, most species had rooted well. At that time we fertilized with 19N–5P–8K (9-month slow release) at a rate of 22.5 kg·1000 m^{-2}. This was broadcast by hand over the plastic.

In July and August we irrigated weekly with a moveable irrigation gun applying approximately 1–2 cm of water per setting. Both water and nutrients appeared to be evenly distributed, as all plant growth was relatively uniform in height and colour. We did not shear or top any plant material since excess height would be next year's propagation material.

Of course, the best part was the minor attention we now had to pay to weed control. The plastic and sawdust mulches were doing their job. Minor weeds in the paths were pulled out at 3–4 week intervals, and the periphery was sprayed with glyphosate.

The results from 2005 encouraged me to expand our field hardwood production to 36 beds and to experiment with some plugs through plastic as well. In 2005, I did not record plant height, but they were very similar to the 2006 (Table 2, Fig. 1). Table 1 shows the plants stuck in 2005 and our percent success with each type. Table 2 shows plant numbers and varieties for 2006 with height achieved as of the end of September.

Table 1. Hardwood cuttings 2005.

No. of Beds	Root	Species	Struck (no.)	Grown (no.)	Success (%)
3	2	*Rubus spectabilis*	3240	1991	61
4	2	*Cornus sericea*	4320	3020	69
2	1	*Salix sitchensis*	2160	1871	86
2	2	*Physocarpus capitatus*	2162	1402	64
1	2	*Spirea douglasii*	1080	882	81
1	2	*Symphoricarpos albus*	1080	512	47
1	2	*Lonicera involucrata*	1080	795	75

Table 2. Field hardwood cuttings 2006.

Bed No.	Species	Date	Sept. height (inches)	Cuttings (no.)
1–5	*Cornus sericea*	13 Feb	30–36	5400
6–7	*Rosa nutkana*	13 Feb	18–24	2160
8–9	*Salix sitchensis*	13 Feb	48–60	2160
10	*Salix hookeriana*	14 Feb	48–60	1080
11–12	*Ribes sanguineum*	14 Feb	18–24	2160
13–19	*Rubus spectabilis*	1 Mar	18–24	6480
20–22	*Salix scouleriana*	2 Mar	60–72	2160
23	*Lonicera involucrata*	2 Mar	48–60	1080
24–26	*Physocarpus capitatus*	3 Mar	36–48	3240
27–29	*Spirea douglasii*	3 Mar	24–36	3240
30–32	*Symphoricarpos albus*	3 Mar	18–24	3240
33	*Populus tricocarpa*	6 Mar	60–90	1080
34–36	*Rubus parviflorus*	6 Mar	18–30	3240

Harvesting the 2005 crop occurred in January 2006. The process of digging, grading, and bundling was done by hand in the field. The plastic by that time had be-

come brittle and came away from the plants easily without damaging the plants. The result was very large, sturdy plants, which were sold to projects in progress at the time and potted to #2 pot or #3 pot for spring sales. Root development was good, and when the plants were topped at grading, these tops were trimmed to be used as propagation material in the new beds for 2006.

RESULTS AND COMPARISONS

We are now at the end of the 2006 growing season. For both years the top growth exceeded my expectations. As Table 2 shows we saw up to 8 ft of growth on some species. Color was good, branching was adequate, and height was excellent. Our success rate with each plant type appears to be acceptable, ranging from 47% to 86% in 2005. In 2006 we appear to have approximately the same success level, except for the *Rubus parviflorus*, which is extremely low at approximately 25% rooting. We probably won't repeat this item, relying rather on seed production.

We took the balance of our hardwood cuttings that were not used in the field and stuck all of the 2006 species in 38s. We also stuck *R. spectabilis*, *Salix sitchensis*, *S. hookeriana*, and *S. scouleriana* in #1 pots. These items all rooted at approximately the same rate as the field cuttings. The plug trays, though, quickly outgrew their root volume and required shearing in mid-summer to 20–25 cm tall, as did the #1 pot material, which was sheared at 0.4–0.5 m tall. The field material, on the other hand, continued to grow.

CONCLUSION

The driving force behind these trials was threefold: first, to boost our hardwood production utilizing a resource we had; second, to produce cheaper and quicker the products our customers require; third, to do this in an environmentally sustainable manner.

Utilizing this corner of the nursery for bare-root production has had a number of positive results. Primarily, it has boosted our production of some high-demand products. The 1525 m^2 area produced approximately 27,500 large plants. Space utilization is comparable to a #2 pot growing system, which would use 1630 m^2 to grow the equivalent number of plants, yet we gain many #5 pot size plants from this system. Additionally, it produces enough vegetative material to re-stick all beds for the next year. In conjunction with our plug production, we now have a better range of plant sizes and better flexibility to deal with accommodating new projects as they come on line.

The second concern was cost. When we total all our costs for labor, machinery, and materials to till, prepare, make cuttings, stick them, and maintain the field, the cost is equal to market value for an equivalent bare-root plant. Consequently, I am anticipating that with practice and automation, we can reduce the cost.

The third concern was environmental. As a company involved in environmental enhancement, I would like to believe that not only can we profit from environmental efforts, but also we can walk the walk. Our use of weed control chemicals has dropped dramatically, replaced by mulches and minimal hand weeding. In the spring, the plastic appears to reduce evaporation and improves heat retention and allows the plants to accelerate growth. In the summer, the plastic is shaded by

the plants and has less influence on soil temperature. So far, it does not appear to inhibit nutrient or moisture flow. I believe compared to container systems, we use less fertilizer, water, fungicides, and herbicides.

Overall I am very pleased with the system, because it appears to achieve each of our goals. The trial was a success since we made use of a fallow piece of property and produced some high-demand plants. In the future we can further develop and improve the system by introducing some automation and expanding the taxa propagated, while also hopefully improving environmentally by finding a facility that can recycle the plastic.

Propagating Ornamental Grasses at Small Nurseries©

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BY SEED

We try to grow anything that comes true from seed by seeding, because we tend to get more compact and fuller plants that way. One exception is *Helictotrichon sempervirens*, since seeds are hard to find and germination is not good.

I prefer to have seeds sown in small-celled plug trays (e.g., 288s, 252s, or 128s) since they establish very quickly when transplanted into a 4-inch pot.

I have most of our seeding done by propagators that specialize in seeding and have efficient seeding machines. We get better consistency, and it works out to be more cost effective.

In most cases we multi-seed, putting up to five seeds per cell (see Table 1).

Most of our seeds come from regular seed companies. However, we do collect some of our own seed when seed is either too hard to find or too expensive.

COOL-SEASON GRASSES BY DIVISION (WINTER)

We have found that several cool-season grasses can be propagated quite nicely during the winter in our climate (U.S.D.A. Zone 7), with no heating required.

They are *Arrhenatherum elatius* var. *bulbosum* 'Variegatum', all *Festuca* taxa, and *H. sempervirens*.

We use either 4-inch or 1-gal stock plants that are short and compact and plant them into 50- or 72-cell plug trays. Care should be taken not to plant too deeply; this is probably the most common error when propagating these taxa. They do not do well in a heated greenhouse (above 15 °C).

COOL-SEASON GRASSES BY DIVISION (SPRING)

This group of cool-season grasses responds well to warmer temperatures (15–18 °C) and longer days. They are *Calamagrostis*, *Carex*, *Deschampsia*, *Juncus*, and *Molinia*. We try to use short and compact stock plants. The *Calamagrostis* and *Molinia* species can be field-grown once again using relatively young plants (no more than a year old). Most of these will be put into a 50-cell tray. The *Calamagrostis* species work well put directly into 4-inch liners. Care should be taken not to plant too deep.

WARM-SEASON GRASSES BY DIVISION

As their name implies, these taxa respond very well to high temperatures (18–25 °C) and light. They are perennial so they die back to dormant buds after the first hard frost in the fall. I find it best to propagate them when dormant during the winter (with heat and light) or just before they start to grow in the spring. They do not take well if propagated during the first flush of new growth in the spring, but will take well again mid-summer. I find it best to grow *Imperata* in containers (1- or 2-gal pots). The others divide better from in-ground stock not more than 1 year old. This group includes *Hakonechloa*, *Imperata*, *Miscanthus*, *Panicum*, and *Pennisetum*.

Table 1. The number of seeds per cell for various grass species.

Species	Number of seeds per cell
Andropogon gerardii	3
Anemanthele lessoniana	3–5
Bouteloua gracilis	3–5
Briza media	3
Carex comans 'Frosty Curls' (syn. *C. albula* 'Frosty Curls')	3–5
Carex buchananii	3–5 usually slower to germinate
Carex comans 'Bronze Perfection'	3–5
Carex dipsacea	3–5
Carex flagellifera	3–5
Carex grayi	1
Carex tenuiculmis	3–5 slow to germinate; try cold treatment
Carex testacea	3–5 slow to germinate; try cold treatment
Chasmanthium latifolium	1
Cortaderia selloana 'Pumila'	3
Cortaderia richardii	3
Cortaderia sellaona White	3
Cortaderia sellaona Pink	3
Elymus magellanicus	1
Festuca amethystina	3–5
Helictotrichon sempervirens	1 usually germinates poorly
Koeleria glauca	3–5
Milium effusum 'Aureum'	3–5
Pennisetum alopecuroides	3
Pennisetum orientale	3
Pennisetum glaucum 'Purple Majesty'	1
Saccharum ravennae	3
Schizachyrium scoparium	3
Sorghastrum nutans 'Indian Steel'	3
Sporobolus heterolepis	3–5
Stipa gigantea	3
Stipa tenuissima	3–5
Uncinia rubra	3–5

Mycorrhizal Fungi: Impact of Commercial Products in Nursery Propagation©

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INTRODUCTION

Mycorrhizal fungi are specialized organisms that live on plant roots in a relationship that is mutually beneficial. The host plant supplies the fungus with carbohydrates produced during photosynthesis. In return, the fungus grows an extensive network into the soil, transferring water and nutrients to the roots and providing a protective environment.

Mycorrhizal fungi are very common in natural soils. They are less common in nursery growing media or in urban soils. From 2001 to 2005, our company tested commercial formulations of mycorrhizal products in nursery production and urban plantings. This article reviews trial results in plant propagation at Byland's Nurseries Ltd., Kelowna, British Columbia.

ABOUT MYCORRHIZAL FUNGI

Types of Mycorrhizal Fungi. "Mycorrhiza," or fungus roots, describes the association between a plant root and a specialized soil fungus. Mycorrhizal associations are prevalent in nature and found on 90% to 95% of land plants (Marx, 1999).

Endomycorrhizal fungi are the most widely distributed. "Endo" refers to the fungi penetrating into the root. It cannot be seen except for some hyphae growing near feeder roots. Vesicular-arbuscular mycorrhizae (or VAM) are the most abundant and commonly associated with turf grasses, vegetables, flowers, fruit trees, and many ornamental shrubs and trees. Over 80% of all plant species associate with a few genera such as *Glomus*. Specialized endomycorrhizal fungi are found on Ericaceous plants (such as *Rhododendron* and *Vaccinium*) and *Viburnum* or on orchidaceous plants (Peterson et al., 2004).

Ectomycorrhizal fungi occur on about 10% of the world's plants. They are found on conifer trees (*Picea* and *Pinus*) and hardwoods such as *Betula*, *Carya*, *Fagus*, and *Quercus*. "Ecto" refers to the fungal growth forming a thick sheath around feeder roots. The structures of many ectomycorrhizal fungi can be seen with the naked eye, and some species produce mushrooms or puffballs, including gourmet truffles and edible mushrooms such as chanterelles (Maronek et al., 1981).

Some plants are capable of forming both endo and ectomycorrhizal associations, for example, *Chamaecyparis*, *Juglans*, *Juniperus*, *Salix*, and *Tilia*.

No mycorrhizal association is a situation found on a few plants typical of early ecological succession, including weeds such as Shepherd's purse, stinkweed, bittercress, bindweed, and buckwheat (Maronek et al., 1981).

BENEFITS OF MYCORRHIZAL FUNGI

Nutrient Uptake. Mycorrhizal roots usually grow faster, are larger, and are more physiologically active than nonmycorrhizal roots. The improved nutrient uptake is more obvious in low fertility soils, "tired" land, and disturbed landscape sites (Maronek et al., 1981).

Mycorrhizal association improves phosphorus uptake by plant roots. The impact is greater for organic nutrient sources than for synthetic sources, indicating mycorrhizal roots can out-compete soil microorganisms for phosphorus liberated from decomposing organic matter. Mycorrhizal roots also stimulate the activities of naturally occurring phosphorus-solubilizing bacteria such as *Pseudomonas putida* and *Erwinia herbicola* (syn. *Enterobacter agglomerans*). Similar comments can be made to explain improved nitrogen uptake by mycorrhizal roots (Hamel, 2004).

Disease Tolerance. Mycorrhizal roots have an increased tolerance to infection by soil-borne diseases caused by *Pythium*, *Phytophthora*, *Rhizoctonia*, and *Fusarium*. One level of protection comes from the secretion of antibiotics by some fungi. Another level of protection comes from the stimulation of beneficial soil microorganisms in the rhizosphere (the region in the soil around the root). Finally, there is a physical barrier on the outside of the root created by the mantle of ectomycorrhizal fungi. In all cases, prior root colonization by mycorrhizal fungi is necessary to obtain protection from soil-borne diseases (Quarles, 1999).

Stress Tolerance. Mycorrhizal plants exhibit higher survival in cold temperatures and more tolerance of soil problems such as low pH or high salt content. Specific mycorrhizal fungi provide the host plant with competitive advantage in these stress situations (Trappe, 1977).

Drought tolerance is of particular interest. Mycorrhizal plants generally perform better than nonmycorrhizal plants during drought conditions. Host plants colonized by drought-adapted mycorrhizal fungi exhibit improved growth and survival during drought and more rapid recovery after re-watering when compared to nonmycorrhizal plants (Mudge et al., 1987). For example, in a study with the endomycorrhizal fungi *G. intraradices*, maize seeds were exposed to 3 weeks of drought 45 to 65 days after sowing, followed by 3 weeks of water recovery. Mycorrhizal plants maintained higher leaf water potential during the 3 weeks of drought and took 50% less time than nonmycorrhizal plants to recover to the level of well-watered plants (Subramanian et al., 1997). Similar observations were made in another study with the fungus *G. deserticola* and pepper plants subjected to drought cycles (Davies et al., 1992).

A number of mechanisms help mycorrhizal plants overcome drought conditions. The most obvious explanation is the larger root system and increased phosphorus uptake in mycorrhizal plants, contributing to higher water uptake. However, a more important mechanism is the impact on leaf activities by maintaining stomatal opening and carbon fixation during drought periods. Finally, mycorrhizal roots are better at extracting soil water because of improved soil structure and more soil surface explored by fungi hyphae (Augé, 2004).

RECENT RESEARCH IN NURSERY PROPAGATION

Rooting of *Taxus*. A team from the U.S. Department of Agriculture in Oregon placed propagules of *G. intraradices* into a rooting substrate of coarse perlite, peat moss, and sand. Hardwood cuttings of *Taxus* × *media* 'Hicksii' were collected from previous year's growth on field-grown plants, trimmed to 15 cm in length, disinfected, then dipped into 1.03% IBA.

At 108 days after sticking, root mycorrhizal colonization was higher when cuttings were placed in a rooting substrate containing mycorrhizal inoculum from root frag-

ments or fungal hyphae. At 108 and 152 days after sticking, the number of roots per cutting was significantly higher in the presence of mycorrhizal fungi when compared to control, with a similar observation for total root dry weight. For both measures, results were equal or better than using only a rooting hormone (Scagel et al., 2003).

Rooting of *Rosa*. The same team in Oregon placed 3 ml of *G. intraradices* inoculum into 10-cm (4-inch) pots filled with perlite and peat (4 : 1, v/v) medium. Two-node cuttings of different *Rosa* cultivars were bleach-disinfected then stuck into pots with or without the inoculum. Cuttings were harvested 28 days later for measurements.

Untreated controls showed no sign of mycorrhizal colonization whereas results varied from cultivar to cultivar for cuttings rooted in inoculated media. Where root colonization did occur, results were as good or better than using a rooting hormone for percentage of rooted cuttings, number of roots per cutting and root weight per cutting. Where only rooting hormone was used, there were also plant cultivar differences in root weight per cutting (Scagel, 2001).

Flowering of *Freesia*. At the time of planting, the U.S.D.A. team in Oregon placed mycorrhizal inoculum under corms of *Freesia* × *hybrida* cultivars. The inoculum was made of *G. intraradices*-inoculated soil, hyphae and spores, and colonized *Allium* root segments. The control was a sterilized inoculum.

Results indicate that addition of mycorrhizal inoculum increased root colonization, decreased the number of days to shoot emergence, and increased the number of flowers produced. Mycorrhizal plants also had larger daughter corms than non-inoculated plants. The beneficial effects were generally increased when mycorrhizal inoculum was applied in pasteurized soil (Scagel, 2003).

Rooting of Junipers. A team at Laval University, Québec, placed a commercial formulation of *G. intraradices* into rooting media for hardwood cuttings of *Juniperus sabina* 'Blaue Donau' (syn.'Blue Danube'). Presence of inoculum in the rooting media had no significant effect during the rooting stage. However, when rooted cuttings were potted into 6-L containers, growth after one season was 50% greater for mycorrhizal plants (Trépanier and Rioux, 1997).

TRIAL RESULTS AT BYLAND'S NURSERIES

Impact on Shrub Growth. In July 2001, rooted liners of *Cornus alba* 'Bailhalo', Ivory Halo™ Tatarian dogwood; *Spiraea japonica* 'Froebelii' (syn. *S. bumaldi* 'Froebeli'); and *Juniperus sabina* 'Monna' were potted in standard 1-gal containers filled with regular growing medium [composted conifer wood plus composted plant residue (3 : 1, v/v)], amended with standard rates of slow-release Osmocote 19N–5P–8K fertilizer, lime, gypsum, and micronutrients) (B.C. Ministry of Agriculture, 2002). The trial examined variations in the growing media compared to the standard recipe. One treatment (20 plants over 4 replications) was the addition at label rate of the commercial product "Mycorise Pro Endo" containing *G. intraradices*. In Sept. 2002, 15 months after potting, root samples were collected and analyzed for mycorrhizal colonization by an outside laboratory. Each sample was approximately 200 g of younger roots manually removed from random locations inside the root ball of one plant.

For *Cornus*, there was a significant increase in number of roots colonized and root surface colonized when plants were grown in growing media amended with the commercial mycorrhizae product. Plants grown in the absence of inoculant had very low root colonization (Table 1).

Table 1. Mycorrhizal root colonization[1] and impact on top growth 15 months after potting of *Cornus alba* 'Bailhalo', Ivory Halo™ Tatarian dogwood (8 root samples and 20 top samples per treatment).

Treatment	Root colonization[3]	Surface colonized[4]	Top dry weight
Regular media (control)	0.13	0.13	39.59 grams
Regular + Pro Endo[2]	2.13	1.88	41.20 grams
Standard error	0.324	0.227	2.165
Significance[5]	$p < 0.01$	$p < 0.001$	not significant $p < 0.05$

[1]Analysis at Premier Horticulture, Québec, <www.premiertech.com>.

[2]Granular Mycorise Pro Endo, 1 propagule *Glomus intraradices*/g (Premier Tech Biotechnologies, Québec).

[3]Percent of sub-sample roots showing colonization, 1-unit increment scale from 0 (none) to 5 (100% of roots).

[4]Percent space occupied by mycorrizal fungi, incremental scale from 0 (none) to 4 (100% of space).

[5]For mean root colonization: $F(1,14) = 19$, MSE = 0.84. For mean root surface occupied: $F(1,14) = 30$, MSE = 0.41.

The plants were cut at the soil line, oven-dried for 24 h, and measured for top dry weight. The growth difference was not significant between control plants (40 g/plant) and plants colonized with mycorrhizal fungi (41 g/plant). Similar results were obtained for *Spiraea* and *Juniperus* (data not shown). Likely, there was no difference in top growth because the plants were grown under optimum fertilizer and water conditions.

Thus, mycorrhizal fungi successfully colonized the roots, yet there was no impact on top growth. So why add mycorrhizal products during nursery plant propagation? As most growers already know, top growth is only one of many factors that are important for plant health.

Impact on Rooting of Juniper Cuttings. In Sept. 2001, unrooted softwood cuttings of *J. squamata* 'Blue Star' and *J. sabina* 'Monna' were planted in 36-cell trays with a standard rooting medium [composted Douglas-fir, perlite, pumice, and composted plant residue (4 : 3 : 2 : 1, by volume)]. Commercial mycorrhizal products were applied at label rate, with treatments replicated four times. At intervals, 36 plants were lifted in each treatment and a count made of cuttings showing root emergence.

For 'Blue Star', after 10 and 20 weeks when compared to control, using Premier's 'Pro Endo' and Root's water soluble endoRoots® resulted in more cuttings with roots emerging from the stem, but using Root's granular endoRoots resulted in fewer cuttings with root emergence (Table 2). Results were generally similar for 'Calgary Carpet'.

After 20 weeks, results indicate a significant impact on number of root breaks per rooted cutting at $p < 0.001$, with more roots on cuttings grown in a media amended with Premier's 'Pro Endo' and Root's water-soluble endoRoots (Table 3). Average dry weight per root was significantly higher for the same treatments at $p < 0.01$.

Table 2. Number of cuttings showing roots for *Juniperus squamata* 'Blue Star' cuttings grown in media with various commercial formulations of mycorrhizal fungi (36 samples per treatment).

Treatment	Application rate	10 weeks	20 weeks
Regular rooting mix (control)	–	67%	75%
Regular + Pro Endo at planting on media[1]	3.75 ml/cell	75%	89%
Regular + endoRoots 14 days post-plant[2]	0.2 g/50 ml/cell	72%	92%
Regular + endoRoots mixed into media[3]	10 lbs/yd^3	33%	78%
Standard + endoRoots at planting on media[3]	3.75 ml/cell	19%	31%

[1]Granular Mycorise Pro Endo, 1 propagule *Glomus intraradices*/gram (Premier Tech Biotechnologies, Québec).

[2]Water-soluble endoRoots Inoculant, six *Glomus* species, 44 dry spores and hyphae/gram (Roots Inc., Missouri).

[3]Granular endoRoots, six *Glomus* species, eight spores and propagules/gram, also 3-3-4 nutrients (Roots Inc., Missouri).

Table 3. Impact on root growth of *Juniperus squamata* 'Blue Star' cuttings grown 20 weeks in media with various commercial formulations of mycorrhizal fungi

Treatment	Application rate	Roots per cutting[1]	Weight per root[2]
Regular rooting mix (control)	–	5.29 b	2.94 grams b
Regular + Pro Endo at planting on media	3.75 ml/cell	15.00 a	4.17 a
Regular + endoRoots 14 days post-plant	0.2g/50 ml/cell	12.71 a	4.11 a
Regular + endoRoots mixed into media	10 lbs/yd^3	4.43 b	2.35 b
Regular + endoRoots at planting on media	3.75 ml/cell	0.71 b	1.23 c
Standard error		1.813	0.286

[1]Means followed by the same letter are not significantly different at $p < 0.001$, ANOVA [F (4,30) = 10.9, MSE = 23].

[2]Means followed by the same letter are not significantly different at $p < 0.01$, ANOVA [F (4,30) = 18.7, MSE = 0.57].

Thus, two commercial mycorrhizal products improved root emergence and root growth from unrooted cuttings, while another product resulted in poor root growth. Further trials with the same products helped clarify possibly reasons for the different results.

Impact on Rooting of Shrub Cuttings. In July 2002, unrooted softwood cuttings of *Aronia meloncarpa* 'Autumn Magic', *Cornus alba* 'Elegantissima' (syn. 'Argenteomarginata'), and *Euonymus alatus* 'Compactus' were planted in 36-cell trays with a standard rooting medium as described above. Treatments were the same commercial products described above for juniper cuttings, with one important difference:

Table 4. Impact after 12 months of commercial products applied 4 weeks after sticking unrooted *Aronia meloncarpa* cuttings (36 plant samples and one soil sample per treatment).

Treatment	Rate of application	Top dry weight (g)	E.C.[5] (dS/m)
Regular rooting mix (control)	–	0.344 b[1]	0.36
Regular + Pro Endo spread on media[2]	3.75 ml/cell	0.321 b	0.29
Regular + endoRoots drenched on media[3]	0.1 g/25 ml/cell	0.375 ab	0.32
Regular + endoRoots spread on media[4]	3.75 ml/cell	0.409 a	0.40
Standard error		0.011	

[1]Within treated column, means followed by the same letter are not significantly different at $p < 0.05$, ANOVA

[2]Granular Mycorise Pro Endo, 1 propagule *Glomus intraradices*/gram (Premier Tech Biotechnologies, Québec).

[3]Water-soluble endoRoots Inoculant, 44 dry spores and hyphae of six *Glomus* species/gram (Roots Inc., Missouri)

[4]Granular endoRoots, eight spores and propagules of six *Glomus* species/gram, 3-3-4 nutrients (Roots Inc., Missouri).

[5]Analysis at Norwest Labs, Alberta, <www.norwestlabs.com>, NWL samples ID 987239 to 987242.

the application was made 4 weeks after sticking, thus on newly rooted cuttings. In June 2003, 1 year after treatments, plants were harvested to measure root colonization and dry weight.

For all plants combined, there was a significant treatment impact on top dry weigh ($p < 0.001$) but not on root dry weight ($p < 0.001$ [F (3,385) = 38, MSE = 0.005)]. For *A. meloncarpa*, there was significantly more top growth for cuttings grown with Root's granular endoRoots (Table 4). Similar results were obtained with *Cornus* and *Euonymus* (data not shown).

A composite sample of growing media was prepared for each treatment and analyzed for nutrient content by an outside laboratory. Results indicate nutrient content was modified by addition of Root's granular endoRoots but not for the other products. The addition of Root's granular endoRoots resulted in higher electrical conductivity (see E.C. in Table 4), nitrate (1.09 $mg \cdot L^{-1}$ vs. 0.37 for control), phosphate-P (5.94 $mg \cdot L^{-1}$ vs. 4.28 for control), sulphate-S (10.6 $mg \cdot L^{-1}$ vs. 7.5 for control), and calcium (35.4 $mg \cdot L^{-1}$ vs. 29.1 for control).

Thus, when comparing the trials with juniper cuttings and shrub cuttings, the commercial products that helped root initiation of unrooted juniper cuttings had no impact on root growth of rooted shrub cuttings. A third commercial product, Root's granular endoRoots, had a negative impact when applied to unrooted juniper cuttings but a positive impact on rooted shrub cuttings. This product contains a nutrient charge of 3N–3P–4K derived from composted poultry manure, ferrous sulfate, and potassium sulfate. Possibly, the salinity charge had a negative impact on initial root emergence but a positive impact on later root growth.

Impact on Growth of Hosta. In October 2001, rooted cuttings of *Hosta* 'Royal Standard' were potted in standard 1-gal containers filled with a growing medium as described above, but with a different package of slow-release nutrients (13N–13P–13K). There were five treatments comparing commercial products at label rates, each replicated over 24 containers. Plants were over wintered, grown under normal conditions in the spring, and cut at the soil line on 26 June for oven drying.

Results indicate a significant treatment impact for top dry weight at $p < 0.01$ but no significant difference for root dry weight at $p > 0.05$. Plants grown with Root's granular endoRoots at label rate had higher root mycorrhizal colonization (86% vs. 0% for control) and significantly more top weight (4.03 g/plant vs. 1.68 g for control) (Table 5).

Table 5. Impact of commercial mycorrhizal products on root colonization, root dry weight and top dry weight of *Hosta* 'Royal Standard' after 8 months of growth (23 plants per treatment)

Treatment	Rate in 1-gal container	Mycorrhizal colonization[1]	Root dry weight (g)	Top dry weight (g)
Regular growing media (control)	–	10%	5.83 a[2]	1.68 c[3]
Regular + Pro Endo in media[4]	30 ml	0%	6.25 a	1.70 c
Regular + endoRoots drench[5]	0.6 g/500ml	12%	4.98 a	1.36 c
Regular + endoRoots in media[6]	15 ml	0%	6.23 a	3.16 b
Regular + endoRoots in media[6]	30 ml	86%	6.86 a	4.03 a
Standard error			0.596	0.209

[1]Percent endomycorrhizal colonization of sub-sample roots, Mycorrhizal Applications Inc., Oregon

[2]Means followed by the same letter are not significantly different at $p < 0.05$, ANOVA [$F(4,107) = 31.3$, MSE = 7.8]

[3]Means followed by the same letter are not significantly different at $p < 0.01$, ANOVA [$F(4,107) = 31.3$, MSE = 0.96]

[4]Granular Mycorise Pro Endo, 1 propagule *Glomus intraradices*/gram (Premier Tech Biotechnologies, Québec)

[5]Water-soluble endoRoots Inoculant, 44 dry spores and hyphae of six *Glomus* species/gram (Roots Inc., MO)

[6]Granular endoRoots, 8 spores and propagules of six *Glomus* species/gram, 3-3-4 nutrients (Roots Inc., MO)

Thus, the three different commercial products increased root mycorrhizal colonization, but only one product impacted top growth. The addition of a low nutrient charge at the time of mycorrhizal inoculation may have favored root colonization and subsequent plant growth.

Impact on Branching. On 4 July, 2001, rooted cuttings of *Linum pernenne* 'Saphyr' were potted into standard 6-inch containers. There were five treatments of growing media amendments replicated over 21 containers. One potting mix was augmented with the commercial product Mycorise Pro Endo described above.

Table 6. Number of branches breaking from the central stem on *Linum pernenne* at 1-month intervals after potting rooted cuttings into different growing media (21 samples per treatment).

Treatment	At 4 weeks	At 9 weeks	At 13 weeks
Regular perennial mix (control)	13.2 c[1]	15.9 c	21.5 c
Regular mix but no 34-0-0 no 0-45-0	7.4 c	15.2 c	22.0 c
Propagation mix with fertilizers	10.4 bc	18.3 bc	26.5 bc
Byland's regular mix with fertilizers	11.5 b	20.7 b	30.3 b
Byland's regular mix no 34-0-0 no 0-45-0 plus Pro Endo in media at label rate[2, 1]	18.2 a	30.6 a	44.9 a

[1]Means followed by the same letter are not significantly different at $p < 0.001$, ANOVA [$F(8,190) = 10.85$, MSE = 21].

[2]Granular Mycorise Pro Endo, one propagule *Glomus intraradices*/gram (Premier Tech Biotechnologies, Québec).

Results indicate a significant difference between treatments at $p < 0.001$. Plants grown with mycorrhizal fungi produced more branches breaking from the main stem than any of the other treatments. The impact was significant 4 weeks after potting and continued until the last rating 13 weeks after potting (Table 6). The improved branching was likely because of improved nutrition in the root zone.

Impact on Post-planting Survival. In April 2002, over 5000 bare-root trees were potted in 10-, 15-, 20-, and 25-gal standard containers with the regular potting mix, as described above. The two treatments were no inoculation (control) or manual application of a commercial product directly on the root system at the time of potting (inoculated). In July, the trees were visually rated for quality of top growth.

For all plants combined, there was no treatment impact on plant growth at $p > 0.05$. Many plant genera grew well after replanting and showed no impact from mycorrhizal inoculation (*Acer*, *Gleditsia*, *Juglans*, *Malus*, and *Syringa*, data not shown). For other genera that regularly suffer losses after replanting, addition of mycorrhizal fungi generally improved survival and growth (Table 7).

Impact of Rates Used. In September 2002, rooted liners of *J. sabina* 'Broadmoor', *Physocarpus opulifolius* 'Diabolo', and *Yucca filamentosa* (Adam's needle) were potted in standard 1-gal containers with regular growing media as described above. There were four treatments, replicated into 20 containers each, with variations in application rate of the commercial product Mycorise Pro Endo. Plants were grown for 1 year, then harvested for measurements.

Results indicate a significant difference between treatments for top dry weight at $p < 0.05$ but not for root dry weight. Plants grown in a mix amended with twice the label rate had significantly more top dry weight than other mycorrhizal treatments (Table 8).

Root samples were analyzed at two outside laboratories to assess mycorrhizal colonization. The laboratories use different reporting methods but results are similar (Table 9).

Thus, the 50% label rate was as effective as label rate for root colonization, but only the 2× rate resulted in improved plant growth.

Table 7. Impact of mycorrhizal inoculation at the time of tree potting evaluated 3 months later as "growing" (shoot extension), "alive" (green leaves, no growth), or "dead" (wilting, did not grow).

Tree type	Treatment[1]	Number of trees	Growing (%)	Alive (%)	Dead (%)
Celtis occidentalis	Control	40	60	18	23
	Inoculated	148	86	5	9
Crataegus monogyna 'Snowbird'	Control	29	41	59	0
	Inoculated	122	53	47	0
Quercus ellipsoidalis	Control	19	42	42	16
	Inoculated	81	43	35	25
Sorbus aucuparia 'Skinner'	Control	70	56	1	32
	Inoculated	92	85	1	15
Tilia cordata 'Greenspire'	Control	57	60	11	30
	Inoculated	215	75	6	19
Tilia mongolica 'Harvest Gold'	Control	40	43	18	40
	Inoculated	243	58	18	24
All trees	Control	1630	63 a[2]	15 a	23 a
	Inoculated	4062	65 a	12 a	23 a

[1]'Inoculated' was 125 ml applied on roots at the time of planting of Mycorise Pro Endo (*Glomus i.*) or Mycorise Pro Ecto (*Pisolithus tinctorius, Rhizopogon* sp., *Laccaria* sp., and *Scleroderma* sp.), Premier Tech Biotechnologies, Riviere-du-Loup, Canada.

[2]Means followed by the same letter are not significantly different at $p > 0.05$, ANOVA [$F(1,2) < 1.0$, MSE > 39]

SUGGESTED APPROACHES FOR NURSERY PROPAGATION

1) Commit to In-House Testing. There are many factors to consider with commercial use of mycorrhizal fungi. The benefits are mostly underground and often not obvious above ground. Differences in growing media can impact plant root colonization. Different commercial formulations work best at different plant production stages.

Researchers at the University of California tested four commercial products at recommended application rates. They found significant differences between products on the growth of *Liquidambar styraciflua* rooted seedlings. They concluded that "nurseries test both the infectivity and effectiveness of mycorrhizal inoculants for the successful application of mycorrhizal technology in horticultural practices" (Corkidi et al., 2005).

2) Select the Mycorrhizal Association Appropriate for the Crop. Mycorrhizal associations tend to be host-specific. Conifers and many hardwood trees associate with ectomycorrhizal fungi. Most flowers and shrubs associate with endomycorrhizal fungi. Propagators must select a commercial product matching the crop to obtain measurable benefits.

Table 8. Impact after 1 year of different rates of a commercial mycorrhizal product on combined growth of container-grown *Juniperus*, *Physocarpus*, and *Yucca*.

Treatment	Rate per 1-gal container	Root dry weight (g)[1]	Top dry weight (g)[2]
Regular media (control)	–	26.99 (SE 1.896) a	34.10 (SE 1.449) ab
Regular +Pro Endo ½× rate	15 ml	21.96 (SE 2.040) a	30.16 (SE 1.559) b
Regular +Pro Endo 1× rate	30 ml	24.55 (SE 2.037) a	33.08 (SE 1.557) b
Regular +Pro Endo 2× rate	60 ml	26.87 (SE 2.187) a	37.73 (SE 1.672) a

[1]Means followed by the same letter are not significantly different at $p < 0.05$, ANOVA [F (3,109) = 1.3, MSE=119].

[2]Means followed by the same letter are not significantly different at $p < 0.05$, ANOVA [F (3,109) = 3.7, MSE=69].

Table 9. Root mycorrhizal colonization reported by two laboratories for samples of *Yucca filamentosa* 'Adam's Needle' (samples from four plants per treatment).

Treatment	Rate per 1-gal container	Root colonization at lab #1[1]	Root colonization at lab #2[2]
Regular media (control)	–	0 %	0
Regular +Pro Endo ½× rate	15 ml	41 %	2.75
Regular +Pro Endo 1× rate	30 ml	42 %	2.75
Regular +Pro Endo 2× rate	60 ml	52 %	2.50

[1]Percent endomycorrhizal colonization of sampled roots, Soil Foodweb Inc., Oregon, <www.soilfoodweb.com>.

[2]Mean of four sub-samples for percent space occupied by fungi, incremental scale from 0 (none) to 4 (100%), Premier Horticulture, Québec, <www.premiertech.com>.

Researchers with the U.S. Department of Agriculture in Oregon examined different fungi for rooting of *Arctostaphylos uva-ursi* cuttings. They found significantly higher number of cuttings with roots and increased root growth per rooted plant where the inoculum was made of the ectomycorrhizal fungi *Laccaria laccata*. There was no measurable impact from using the endomycorrhizal fungi *G. intraradices* (Scagel, 2004b).

3) Use a Mixture of Mycorrhizal Fungi. Different species of mycorrhizal fungi have different competitive abilities. Propagators increase their chances of success by using commercial products that contain a variety of fungus species.

Researchers in Spain examined different mycorrhizal species for their impact on drought tolerance of *Lactuca sativa* (lettuce). They concluded that *G. deserticola* was the most efficient during drought to colonize roots, maintain plant growth, and allow efficient use of water, followed by *G. fasciculatum* and *G. mosseae* (Ruiz-Lozano et al., 1995).

4) Use early in Plant Production. Mycorrhizal associations will last as long as growing conditions allow. Using commercial products early in propagation reduces

the amount of product required per soil surface and increases the time of exposure for successful root colonization.

Researchers at The Pennsylvania State University inoculated annual bedding plants [*Solenostemon* (syn. *Coleus*), *Impatiens*, *Petunia*, *Salvia*, *Tagetes*, and *Viola*] with *G. intraradices*. Inoculation at sowing required less inoculum and was generally as effective in promoting colonization as inoculation at transplanting. The best results came from inoculation at sowing and again at transplanting (Koide et al., 1999).

5) Do Not Use on Stressed or Sick Plants. Successful mycorrhizal colonization requires a transfer of photosynthesis materials from the plant to the fungus. Healthy plants can sustain the loss of photosynthates. For sick or dying plants, transferring resources to the mycorrhizal fungi may be enough to trigger further plant decline.

Researchers with the U.S. Department of Agriculture in Oregon placed mycorrhizal inoculum under corms of *Triteleia laxa* 'Koningin Fabiola' (syn. *Brodiaea laxa* 'Queen Fabiola') at the time of planting. Inoculation altered aspects of plant morphology and biomass partitioning. Many reports describe an initial lag-phase after inoculation where non-inoculated plants are larger than inoculated plants (Scagel, 2004a).

6) Use Other Approaches for Ericaceous and Orchidaceous. There is currently no commercial product containing specialized mycorrhizal fungi for Ericaceous plants (such as *Rhododendron* and *Vaccinium*), *Viburnum*, or for orchids. Stimulation of root growth and biocontrol of root diseases must be obtained by other methods.

Researchers at the University of Vermont colonized the roots of *Pieris floribunda* by growing seeds in peat moss. Effective root colonization with ericoid mycorrhizal fungi was obtained in 10 of the 13 commercial peat products tested. The authors conclude that peat moss harvested from regions with native ericaceous plants can be used to colonize nursery plants, provided the peat contains colonized root debris or is harvested in late summer to fall (Gorman and Starret, 2003).

7) Avoid Detrimental Practices. Propagators using mycorrhizal fungi must avoid over-fertilization. Mycorrhizal association is encouraged where soil phosphorus supply is adequate or low, because the fungus can mobilize soil phosphorus that is chemically bound with calcium or iron. However, when phosphorus concentration is high in plant tissue, mycorrhizal association tends to decline (Grant et al., 2005).

Propagators using mycorrhizal fungi must be careful with pesticide applications. Negative impact from various products depends on the type of mycorrhizal fungi. Possible inhibitory (negative) effect is greatest for pesticides applied in a soil drench rather than on the foliage, and during the first 3 weeks of root mycorrhizal colonization (Davies, 2000).

Propagators using mycorrhizal fungi must be careful with growing media composition. Different peat moss products can suppress or enhance root colonization, depending on the type of mycorrhizal fungi (Linderman and Davis, 2003).

8) Expect Most Benefits to Occur in the Hand of the Customer. The benefits of mycorrhizal fungi seldom include increased plant growth. The benefits include improved plant nutrition in poor quality soils, reduction of root diseases in poorly-drained soils, and higher tolerance to stress situations such as transplanting,

high salts, high pH, or drought. Few of these conditions exist in a greenhouse or a nursery. Most of these conditions exist in landscapes and street plantings, where nursery plants are destined.

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SESSION III: QUESTIONS AND ANSWERS©

Patrick Peterson: Did you say you applied a granular material after the plants were rooted?

Mario Lanthier: Yes. There are different commercial products on the market that contain mycorrhizal fungi. They all have strengths and weaknesses in terms of their effectiveness with various plant species. There is one that is a granular formulation, and you apply it like you would a fertilizer topdressing.

Randy Murphy: You told us you want to apply mycorrhizae after the cuttings have rooted. Have you noticed temperature having any effect on application timing?

Mario Lanthier: No. However, I haven't looked at that specifically. If the temperature is appropriate for root development, it would be appropriate for these microbes. Two things are important in the use of mycorrhizae: (1) you have to put the microbe in the soil and (2) you have to feed the microbe. Mycorrhizae don't grow well in sterile soil; they do well in soils that have high organic matter levels like container media.

Evelyn Healy: What species of vesicular arbuscular mycorrhiza were you working with, and did all the products you worked with have the same species?

Mario Lanthier: No, different products come with different species. A group from Switzerland took one spore of *Glomus intraradices*, a species that is found all over the world, and in the lab, went through 200 generations from that one spore. At the end of 200 generations they found around 50 different biotypes of mycorrhizal fungi. The question was this: are we looking at a small number of species all over the world or are we looking at a large diversity and we then have to be careful what we introduce where? That question has not been resolved. There are some species that are found all over the place, and scientists have identified some that are better at some things than others. In general, products with a mixture perform better because they cover more bases. However, products with a low number of species may be appropriate in specific situations.

Steve McCulloch: Are mycorrhizal fungi susceptible to fungicides, and how does that enter into experimental design?

Mario Lanthier: Once the mycorrhizal fungus is established on the root system it has a fairly high tolerance to most fungicides we would use in greenhouse propagation. There are exceptions. We have looked at the impact of fungicides on root development during propagation. Some fungicides are extremely rough on root elongation during propagation. Those fungicides are also very rough on mycorrhizal fungi.

Steve McCulloch: In contrast to graft incompatibilities we see in propagation, why don't plants reject the association with a mycorrhizal fungus?

Mario Lanthier: It's a symbiotic relationship; they both benefit from it. It's not that one gains more than the other. The plant gains a whole lot from this relationship, such as improved water uptake, nutrients, and protection from various root diseases.

Val Cobrian: Do you have a nematode for slug or snail control in Canada?

Jim Matteoni: No.

Anonymous: What would you recommend for slug and snail control around containers in poly houses?

Jim Matteoni: There are a couple ways of dealing with this ranging from metaldehyde baits to sprays that can be fairly nasty so are probably best avoided. On a bench you can use a copper strip on the perimeter of the bench. Snails have a difficult time crossing the copper strip because it has an electrical charge to it. It may need to be "recharged" periodically, and that can be done with salt. That won't work in large nursery settings.

Kevin Kubeck: For specialty propagators, who have small numbers of plants, is it possible we don't have the number of plants necessary to keep biological control agents alive?

Jim Matteoni: You might consider using some banker plants that will provide biological control agents on a regular basis that are predators, which have a voracious appetite and a more diverse appetite. Good banker plants include eggplant, beans, and melons.

Kevin Kubeck: We are doing some hybridization work and are concerned with the potential for biological control agents to consume pollen.

Jim Matteoni: Thrips consume much more pollen than any biological control insect.

Propagation of Difficult-to-Root Shade Trees: *Parrotia* and *Carpinus*©

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INTRODUCTION

Parrotia persica 'Inge's Ruby Vase' and *Carpinus betulus* 'Fastigiata' are both upright plants with small leaves and good pest resistance, making them good street trees for urban areas. With the ongoing problems in North America such as emerald ash borer and *Acer platanoides* cultivars joining the invasive species list in New England and eastern Canada, the need for other species or taxa to take over is increasing. Grafting compatibility is always a consideration when dealing with large, mature specimens in the urban setting. Putting these two types of trees plus other difficult-to-root taxa onto their own roots can be very challenging.

Specimen Trees Wholesale Nurseries Ltd. is located in Pitt Meadows, part of the greater Vancouver area in southwestern British Columbia. The nursery is compromised of 480 acres; 20 acres of containers, 6 acres under polyethylene greenhouses, and 450 acres of field-grown conifer and deciduous trees and shrubs.

The greatest hurdle we have overcome is the successful propagation of hard-to-root deciduous trees making them a viable crop for our business. *Parrotia persica* and cultivars of *C. betulus* 'Fastigiata' comprise about 10% of our production.

MATERIALS AND METHODS

Cutting Stock Parameters. Without exception, juvenile plants produce the best cutting material. We have found that cuttings from 3- to 4-year-old trees produce the most viable cutting material. The timing of taking the cuttings is important. In most years mid-July is the best time. The cutting wood should be actively growing. Each piece of cutting material should be around 24 inches long. We harvest in the morning and bring them into the propagation house where they are kept under micro-spinners until processed. Any wilting or stressing at this stage is very detrimental to later rooting percentage and over-wintering longevity.

Processing of Cuttings. Cuttings are made from the current year's growth that has matured. Tip cuttings are typically not used, because material is usually too soft. Soft material is susceptible to bruising in handling, burning at point of hormone contact, poor bud maturity, and leaf scald under misting.

Cuttings are usually 6 to 9 nodes in length with the basal 2 to 3 leaves stripped off. Cuttings are not wounded as this leads to an unbalanced root system when older. We have tried some of the newer rooting hormones such as Gro-root Xtra, but still fall back on the brand Stimroot. This material is an ethanol-based IBA solution. Through trial and error a concentration of 5000 ppm has been found to be the best on *Carpinus* while a concentration of 8000 ppm is needed for *Parrotia*, *Cercidiphyllum*, *Acer*, and many others. The basal end of the cutting is dipped to a depth of about 1/4 inch.

The basal cut is always made just below a bud, the closer to the bud the better. Longer stem material left below the bud nearly always dies, usually causing total necrosis of the cutting.

Rooting Substrate. In the case of both *Parrotia* and *C. betulus* 'Fastigiata' we have had the best success with a product made by Oasis. We use the $1^{1}/_{4}$-inch square cubes, which come in a form like a large bar of chocolate. This product comes with pre-drilled holes; however the width of the hole is usually too great to allow the cuttings to have total contact with the material. Cuttings when stuck are placed slightly away from the manufacturer's hole.

Plug sheets are placed in flats and pre-soaked before use. Pre-soaking is imperative to stop the drying out of the cuttings before the misting system can soak the cubes. As long as the cuttings are placed in the same location in the cubes, even spacing is achieved. For larger-leaved species and taxa a larger cube is used.

There are two important features of these cubes. First, they are sterile, and second, they hold the cutting securely with no root disturbance.

Once the plug trays are filled with cuttings they are placed on the mist benches. A 1% Captan solution is applied at this time. The cuttings receive a bottom heat temperature of 75 °F (25 °C). Misting cycles are set at 10 sec on and 5 min off. Even though the cuttings are sitting in a totally moist environment rooting is fast. *Acer rubrum* cultivars are on and off the benches in 3 weeks. Full rooting of both *C. betulus* 'Fastigiata' and *Parrotia* is usually around 10 weeks, as is *Cercidiphyllum* and *Magnolia* cuttings.

Winter Husbandry. As the days start to shorten, the misting cycle is cut back. Leaf drop is a constant clean up job, but very important in keeping things clean. The early-to-root species such as the *A. rubrum* and *Prunus* cultivars are long ago off the benches and transplanted.

Carpinus, *Cercidiphyllum*, *Magnolia*, and *Parrotia* are handled differently. Even though rooting is strong, transplanting at this time will create very large winter losses. We have found that keeping them on the bottom heat until spring keeps the rooting and transplant percentages very high.

By the first of November all leaves are removed. Rooting percentages are high, 85% or better. Even though the tops are dormant, the bottom heat continues to promote root growth.

The misting frequency is decreased every third day until there's only one 15-min cycle at mid-day to prevent the plugs from drying out. The root zone temperature is dropped to 55 °F (13 °C). The propagation house area is not heated; as a result the tops of the cuttings are kept cool.

Bud Break. Around the first week in March the buds start to swell. The rooted plugs are removed from the mist benches and put into a hardening-off area. The area is not heated, which allows the root system to harden and the buds to break slowly, making the flush less susceptible to fungal attacks.

The rooted plugs sit in the hardening-off area for about 1 month, then are transplanted into a mix of peat and green sawdust mix (6 : 4, v/v), Nutricote 17N–7P–9K mini-prill and micronutrients.

The transplanting is done easily as the flats of Oasis cubes are broken apart. If rooting is not evident then the cutting and cube is discarded. Grading is important because a uniform root system is desired. *Parrotia*, *Carpinus*, *Cercidiphyllum*, and

especially *Magnolia*, do not like root disturbance at time of transplanting and are slow to recover. The use of the Oasis cube totally alleviates this problem since the complete package is transplanted.

Things to Touch On. Since we are a caliper tree grower, the development of the root system is hugely important. Early rooting techniques using oasis cubes and the possibility of the coconut fiber plugs are the beginning of the process. The use of the Anderson pot, whether it is the bands pot or the band pot, is important to developing a downward root system at time of transplanting. A circular root system becomes a liability to the tree as it grows older.

CONCLUSION

I would like to say in closing that the key to successful propagating of difficult-to-root deciduous trees is in how far you are willing to stretch and bend your methodology. There is no one best method. It has taken Specimen Trees Wholesale Nurseries Ltd. 15 years to get to this stage, and yet we still modify our practices.

Greenhouse Automation and Plant Propagation's Global Connection©

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Plant propagation has been approached in different ways in different growing operations. Unrooted cuttings are usually collected either from the shade house or greenhouse or even from plants grown in landscaped areas in order to produce rooted vegetative liners in a nursery set up. Therefore, the seasonal changes in all the environmental parameters influence the quality of cuttings and rooting ability of cuttings throughout the year.

There is, however, a new approach to propagation in certain greenhouse operations. The global connection between cutting production facilities around the world and some of the very sophisticated greenhouse operations here in the United States of America is a fascinating phenomenon.

New introductions of ornamental plants are developed constantly by plant breeders around the world. Once produced, these plants are nurtured through tissue culture to maintain the true genetics and then mass-produced in perfect greenhouse conditions. The nuclear/mother stock plants, the foundation stocks, and unrooted cutting material are tested constantly for virus and other diseases by plant scientists and agronomists to ensure disease-free cutting materials. The regular pathogen testing and true-to-type testing of stock plants and cutting material is done regularly in their on-site laboratories.

The propagation nurseries around the world export unrooted cuttings throughout the year. Their emphasis is both on year-round quality assurance and on attentiveness to customer needs. Certified cuttings (E cuttings) are produced with a special quality certificate. The pathogen testing and true-to-type testing is performed on nuclear stock, foundation stock, and the cuttings. The unrooted cuttings are then distributed by U.S.A. brokers and rooted at the designated rooting stations in the U.S.A. After proper import permit processes, custom clearance, and agriculture inspection clearance, cuttings are delivered by air and Fed-Ex™ to the rooting station/propagation greenhouses. Many suppliers are including temperature-recording devices in shipments in order to verify temperature records during the transit. The unrooted cuttings and tissue-cultured plants are stored at 40 °F humidity chambers and are either planted in substrate on the same day or stored for few days before transplanting.

Most of the rooting stations have state-of-the-art automated greenhouse facilities. Unrooted cutting production facilities are spread throughout the world, including Israel, Africa, China, Costa Rica, Guatemala, Australia, Brazil, Netherlands, Columbia, and Spain. Tissue culture factories are established in New Zealand, Australia, Denmark, and Netherlands. One of the largest unrooted cutting producers (Carmel) is located in Israel, where they produce excellent quality cutting materials. Throughout the world, Israel Carmel brand name stands for selected fresh produce delivered on time and in perfect condition. Carmel has excelled in produc-

ing greenhouse cuttings for over 25 years. With headquarters in Tel Aviv, Israel, and branches throughout the world, Agresco (Carmel) worldwide network provides marketing, delivery, and sales services all over the globe.

Greenhouse automation is a very important part of producing high-quality rooted liners and seedling plugs. Automation of cutting material facility first produces unrooted cuttings of optimum physiological status year-round. Then, automation in the propagation greenhouses produces high-quality plants with consistent results. In addition, purchasing high-quality seeds for maximum germination and diseases-free plants is also important. Applying strict chemical and environmental protocols in combination with the perfect optimum conditions results in very successful growing operation.

Use of efficient and automatic seeders minimizes labor and produces uniform seedlings and can potentially save time and money for growers. Tranplanters, which automate the task of picking plugs from plug trays and inserting them into pots, provide many benefits to growers. The most complex transplanters can plant from 10,000 to 35,000 plugs per h depending on the configuration of the machine (Bolus, 2005).

In addition, stepping up greenhouse sanitation plays a very important role in propagation. Disease can cause severe economical damage to nursery crops. Installing foot-baths and hand sanitizers at each greenhouse entrance for prevention of viral and bacterial diseases have proven to be very useful tools (Hall, 2005). All employees handling the plant material in the production cycle must use aprons and gloves. Preventative and curative use of fungicide management is the most critical component of a sanitation program.

The greenhouse automation includes irrigation booms, computer-controlled greenhouse environments, proper and strict management of light levels, photoperiod, humidity levels, day- and night-temperature regimes. The irrigation booms are useful for applying fertilizers, fungicides, and plant growth retardants. The training and management of greenhouse staff at all levels of growing in combination with greenhouse automation results in the creation of mathematical growing formulas for each plant taxon. Use of strict growing protocols and use of strict chemical protocols is necessary for year-round success in any plant propagation environment.

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SESSION V: QUESTIONS AND ANSWERS©

David Hannings: I understand you root cuttings in the fall and they stay on the mist beds all winter. Are the mist beds in the greenhouse or outdoors? Also, what do you do about nutrition during that period?

Sandy Howkins: The mist benches are indoors. The bottom heat is turned down to 50 °F. They do not receive any nutrition.

Devin Cooper: When do you change the misting frequency from 5 sec every 5 min to something else?

Sandy Howkins: The misting frequency follows light duration changes. Once the cuttings are well-rooted in the fall, the bottom heat is turned down by the first of November. Then, they receive one 5-min misting cycle around noon. We watch the cuttings through the winter months, during which they receive one irrigation per week through December or January. Once it starts to warm up in February they will get two irrigations per week.

Daphne Research at the University of British Columbia: The Search for Fungal Resistance©

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A *Daphne* research program was initiated in 2000 at the University of British Columbia (UBC) designed to develop cultivars with improved commercial and garden performance. The overall appeal of daphne is based on many desirable characteristics, including its attractive foliage, variable plant habits, and flower colors, but most of all, its sweet fragrance or perfume. The most "popular" species among nursery producers and home gardeners is *Daphne cneorum* L. (rose daphne or garland flower). Both total sales of *D. cneorum*, as well as the number of nurseries producing stock, are increasing rapidly. In British Columbia, Canada, over 23 commercial growers are currently selling *D. cneorum* compared to only seven growers in 1992 (British Columbia Landscape and Nursery Association Buyer's Guide and Directory, 1992 and 2005).

Despite this increase in production and inherent appeal, daphne has acquired a poor reputation for long-term performance because of disease problems reported by both producers and consumers. Although reports on daphne disease in Canada are lacking, anecdotal evidence suggest significant losses are occurring and that these losses are primarily due to root pathogens. However, disease susceptibility appears to be species-specific, with some species highly susceptible while other species appear to be immune. Previously, pathology reports identified *Fusarium* Link ex Gray (Pataky, 1988), *Phytophthora cactorum* (Lebert & Cohn) Schröter (Linderman and Zeitoun, 1977), *P. nicotianae* var. *parasitica* (Breda de Haan), Tucker (Tompkins, 1951), and *Pythium* Pringsh. (Grand, 1985), plus several unidentified fungi, as possible causal agents of this problem. In 2001, symptoms of an undescribed daphne disease were reported in Vancouver, British Columbia. Typical symptoms were somewhat inconsistent with those in previous pathology reports on daphne in that these plants all had black lesions on the roots and died within 2 weeks following appearance of the first foliar symptoms. This disease, coined "Daphne Sudden Death Syndrome" (DSDS) or "Mad Daphne Disease" by gardening enthusiasts, kills plants quickly following the first foliar symptoms. Observations of DSDS-infected plants indicate the following progression of symptoms: (1) brown to black necrotic lesions on the roots, (2) leaf chlorosis leading to abscission, (3) whole plant stunting, and (4) stem collapse and plant death.

To identify the causal agent of DSDS, root tissue samples were collected from diseased and healthy plants (paired samples of diseased and healthy plants acquired from individual nurseries throughout the greater Vancouver region) of *D. cneorum* 'Ruby Glow' and included roots of various diameters, discoloration, and degrees of degradation. From diseased plants, the following fungi were isolated: *F. roseum* (Snyder & Hansen), *F. oxysporum* (Snyder & Hansen), *Trichoderma* sp. (Persoon ex Gray), *Aspergillus* sp. (Micheli ex Link), and *Thielaviopsis basicola* (syn. *Chalara elegans* Nag Raj et Kendrick) (Berk. et Br.) Ferr. However, only *T. basicola* was isolated from all diseased plants but was absent from healthy plants.

Thielaviopsis basicola is a widespread pathogen of several economically important plant species (Nag Raj and Kendrick, 1975). In Canada, this pathogen causes the disease "black root-rot" on crops such as carrot (*Daucus carota* L.) (Punja et al. 1992) and tobacco (*Nicotiana tabacum* L.) (Gayed, 1972; Stover, 1950a, 1950b), while also found on several ornamental species such as poinsettia [*Euphorbia pulcherrima* (Willd. ex Klotzsch) Graham] and petunia (*Petunia* hybrid Vilm.) (Punja et al., 1992). In all of these plant species, *Thielaviopsis*-infected plants produced shoots that were stunted and chlorotic, with roots having black lesions containing the characteristic spores of the fungus (Punja et al., 1992). These symptoms are consistent with those reported for DSDS. To test pathogenicity, a conidial suspension was applied to healthy roots of both 2-year-old nursery-grown and rooted in vitro-produced plantlets of *D. cneorum*. The following 0–5 rating for disease progression was used: 0 = healthy plant, no symptoms; 1 = less than five lesions on lateral roots, no lesions on tap root, no foliar symptoms; 2 = greater than five lesions on lateral roots, less than five lesions on tap root, no foliar symptoms; 3 = most lateral roots with lesions and some necrosis, greater than five lesions on tap root, five to ten chlorotic leaves; 4 = most lateral roots necrotic, greater than five lesions on tap root, most leaves chlorotic with some leaf abscission; 5 = plant is dead. These data were then used to create a composite value for Plant Disease Index (PDI).

Four weeks post-treatment, all nursery-grown plants inoculated with *T. basicola* developed symptoms consistent with DSDS (PDI = 3.5), while all other plants, either inoculated with the other isolates or the control plants, remained symptomless and healthy (PDI = 0). In vitro inoculated plants displayed the same pattern of disease occurrence among the isolates as expressed on the nursery-grown plants. However, *T. basicola* induced symptoms in significantly less time (< 2 weeks) on these plantlets than on the nursery plants. *Thielaviopsis basicola* was successfully re-isolated and re-identified from all inoculated plants confirming its ability to induce DSDS (Noshad, et al., 2006).

Once the causal agent for the disease was identified, we initiated a germplasm screen to assess individual species' resistance to DSDS. Terminal cuttings from 32 *Daphne* taxa (container-grown) were harvested at two time periods (mid-July and mid-August) and treated as follows: flower buds and lower leaves were removed to give a clear stem to stick; cuttings were given a single shallow wound and soaked in a solution of Physan 20™ (1 teaspoon per U.S.A. gal) for 60 sec and allowed to dry; cuttings were dipped in Stim Root #2 Rooting Powder™ (0.4% IBA) and then direct stuck in $2^{1}/_{4}$ inch Premo™ pots filled with propagation grade perlite, peat, granite grit #2, and pumice (double screened to remove fine particles) (10 : 8 : 6 : 1, by volume) and amended with dolomite lime (65AG at 900 g/yd^3) and Micromax™ (400 g/yd^3). The flats were placed under mist with bottom heat set at 22 °C. The cuttings were checked weekly for rooting and removed from mist on an individual basis as they rooted. Rooted cuttings were placed under Vispore™ (a synthetic shade material) and misted twice daily by hand for 1 week, following which they were transferred to an open bench in the greenhouse and fed with Excel Cal-Mag™ 15N–5P–15K at 100 ppm total nitrogen. The rooted cuttings were transferred to a polyhouse in the fall where they were allowed to go dormant but kept frost-free. They were repotted in the spring with medium composed of peat, Turface™ MVP, granite grit #2, soil (screened and pasteurized), and pumice (8 : 8 : 6 : 4 : 1, by volume) amended with dolomite lime (65AG at 670 g·m^{-3}), Osmocote™ 18N–6P–12K (2150 g·m^{-3}), and

Psi Matric™ (wetting agent). Four months following potting, plants were subjected to the pathogen challenge as described above.

Rooting percentages varied by species and cutting time, with some species rooting easily regardless of time [*D. collina*, *D.* × *eschmannii*, *D. genkwa* (large flowered form), *D. laureola*, *D.* 'Lawrence Crocker', *D.* × *manteniana*, and *D.* × *rollsdorfii* 'Wilhelm Schacht'], some species rooting best in early summer [*D. bholua*, *D. cneorum*, *D. genkwa* (Hackenberry Group) *D. tangutica* Retusa Group, (syn. *D. retusa*), *D. tangutica*, and *D.* × *thauma*], some species rooting best in later summer (*D. circassica* and *D. odora*), and some species that were difficult to root regardless of time (*D. longilobata* and *D.* × *napolitana*).

Following the pathenogenicity test protocols described above, all propagated species were screened for disease resistance using *T. basicola*. The pathogen challenge revealed significant differences among the species for resistance. In general, the three most susceptible species were *D. cneorum* (PDI = 64), *D. pontica* (PDI=60), and *D.* × *antensiana* (PDI = 57) while the three most resistant species were *D. mezereum* (PDI = 10), *D. caucasica* (PDI = 9), and *D. tangutica* Retusa Group/*D. tangutica* (PDI = 0).

Future research will characterize disease development in both susceptible and resistant species, with special attention paid to the very early infection events. Once characterized, anatomical, morphological, and biochemical traits associated with disease resistance will be identified and their underlying mechanism(s) described. Ultimately, these "resistance" mechanisms will be manipulated so they can be incorporated into commercial cultivars.

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Propagating *Rhododendron* Species by Cutting and Seed©

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The Rhododendron Species Foundation (RSF) is a nonprofit organization dedicated to the conservation, research, acquisition, evaluation, cultivation, public display, and distribution of *Rhododendron* species. The Foundation provides education relating to the genus and serves as a unique resource for scientific, horticultural, and general gardening communities worldwide.

The RSF will use the following means to achieve this mission:

- Acquire and maintain as comprehensive a collection of *Rhododendron* species as possible.
- Conserve *Rhododendron* species through the cultivation and distribution of selected forms and documented wild-collected material as obtained in the field and by other means.
- Support the Rhododendron Species Botanical Garden — a living plant museum and effectively designed garden for the display and cultivation of rhododendron species along with other plants with which they associate.
- Provide information, education, and support of research for persons interested in the genus *Rhododendron*.

The Rhododendron Species Foundation was established in 1964 by a small group of *Rhododendron* enthusiasts who were interested in growing and learning about species rhododendrons. They began by obtaining scions from collections existing in the United Kingdom from the early collectors of Asian plants. These were grown in a private garden in Salem, Oregon, but by 1974 the collection had grown too large and needed to be moved. The group approached George Weyerhaeuser, and he agreed to lease land to them for the purpose of establishing the botanical garden on the Weyerhaeuser Corporate headquarters campus, where the collection resides today in Federal Way, Washington.

As a growing number of people became interested in species rhododendrons the Foundation established a membership. As a member, one could purchase cuttings rooted from the collection of "wild" rhododendrons to grow in one's home garden, thus the propagation program was begun and a nursery operation necessary.

In the early days it was difficult to get plants that were the real species because there were a great number of open-pollinated seedlings in cultivation masquerading as species plants. As a result, most of our propagation took place from a limited pool of verified plant material as cuttings. In recent years, access to unexplored and under-explored regions in Asia, mainly China, has been expanded, and RSF has sponsored and been a participant in many expeditions in search of new plant material and has met with great success. As a result of this success our propagation program has grown to include seed growing as well as cutting propagation, and I will give a brief overview of the methods we use to accomplish our plant production goals.

Nursery production provides material to replenish the collection and provides backup plants to be kept in reserve in case of losses in the garden. The nursery also supplies plants for sales through our twice-yearly catalog as well as for our

on-site sales area. About 40% of our production is from cuttings and 60% from seed, mostly collected in the wild, but a small percentage is hand-pollinated seed from our garden.

Cutting production is used for selected plants, especially good forms or good sellers that can be easily produced by this method. We also use cuttings to produce clonal material for collection backup plants. Because the genus *Rhododendron* encompasses everything from tropical epiphytes to alpine tundra plants and because our mandate is to grow them all, propagation is not entirely straightforward. We do, however, use fairly standard equipment and cutting methods, and our main variables are timing and scion treatment.

Our facility is a 35-ft × 48-ft Nexus greenhouse with concrete floor, active cooling, and a computer-controlled climate, including shade. Cuttings are rooted on bottom heat and mist in 6-inch-deep plastic mesh-bottom flats filled with a coarse peat and perlite mix. Our cutting year begins with deciduous azalea softwood in early April and ends with semi-ripe cuttings in October or November. We have 25 years of cutting records, the last 10 of which are in Microsoft Access database and are easily looked up to help me remember what should happen when and to aid in experimentation. Many rhododendrons have a very narrow window of opportunity for rooting, so our propagation record keeping is a vital tool for optimizing production.

We do up to 20,000 cuttings per year with a success rate ranging from 100% all the way to 0%. We propagate approximately 500 species of *Rhododendron*, many of which have dozens of cultivars, so we do small numbers of many different plants. This complicates production slightly and means that we must keep meticulous records in order to keep track of propagation results and production inventory. Cutting methods and treatments are quite ordinary, although I insist on the use of sharp knives instead of pruners for making end cuts and wounding to minimize tissue crushing on the more difficult-to-root species. We use liquid rooting hormone on the soft azalea and tropical cuttings, because the powdered form seems to encourage rotting on these types. I begin a weak liquid feed as soon as rooting begins and continue until they are ready for transplant. The rooted cuttings are removed from propagation flats and moved into $2^{7}/_{8}$ inch square by $5^{1}/_{2}$ inch deep band pots. They are weaned from heat and mist, then moved outside to hoop houses to grow and wait potting into 1-gal containers the following spring.

A more recent addition to our propagation scheme is growing wild-collected seed. Our curator, Steve Hootman, has led many seed collection trips to Southwest China and Northeast India in the past 10 years and has brought back several new introductions as well as some reintroductions of plants that have not been collected in the past 50 to 100 years. This has increased the genetic diversity of rhododendrons in cultivation and will help in developing better garden plants through breeding programs, which many people in the Northwest are involved in.

Early on, we suffered a few miserable failures mostly related to the medium we were using for germination. Now that we figured a few things out (and built a new and better greenhouse) we are having very good success with seed growing.

We begin by sowing in $2^{1}/_{2}$ inch-square shallow pots in mesh flats so they can be bottom watered and drained by dunking in a water tray and then lifting them out to drain. These pots are filled with live sphagnum that has been run through a $^{3}/_{8}$ -inch screen and then seeded directly on top. All are placed in closed flats with clear lids on bottom heat, and most germinate within 2–3 weeks. As the first true

leaves appear we begin treating them to liquid fertilizer, soaked up from the bottom of the flats every week. We begin pricking out 8–12 weeks after germination and line the seedlings out into shallow flats and let them continue on bottom heat. By late spring many of the species are ready to move into the same band pots we use for the rooted cuttings, and they are transplanted, taken off heat, and hardened off for a few weeks and moved to hoop houses outside for spring potting the following year. Using live sphagnum has solved our main problems with germination, which were a medium that stayed too wet and fungus gnat larvae. It has created a couple of other problems that are easier to live with: the seedlings must be grown fast enough to prick out before the sphagnum dies and turns to muck and there are always weed seeds in it. The weeds consist mainly of *Drosera rotundifolia*, *Carex* sp., and an occasional *Ledum*, all of which are easily distinguished from the *Rhododendron* seedlings. Overall, the benefits of live sphagnum moss have outweighed the problems.

In the past few years with this method we have been able to produce plenty of plant material to supply the demands of our catalog sales and the other outlets thorough which we sell our rhododendrons.

Simple Successful Propagation at Classical Farms©

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Classical Farms LLC is a wholesale grower of annual color crops in Rainier, Washington, which is slightly southeast of Olympia in western Washington State. My wife and I started the business in 1985. Jill Cross is our production supervisor. Our primary crops are pansies and a large selection of annuals including hanging baskets, color planters, and gallons. Fall crops include garden mums, perennial asters, ornamental cabbage and kale, pansies, and cyclamen. Plants in 4-inch pots are the most common size, with over 1.6 million produced in 2006.

The majority of the 4-inch crops are purchased as plugs. However, in-house propagation plays an important role with many crops. Our propagation facilities work well and are not particularly sophisticated. Annual premium cuttings, basket stuffers, cordyline, fuchsias, perennial asters, garden mums, and chocolate cosmos are rooted by cutting propagation. Ornamental grasses, cabbage, and kale are propagated by seed, along with other selected annual crops. Mums, fuchsias, ornamental cabbage and kale, chocolate cosmos, and cordyline will be mentioned in more detail.

Chrysanthemum. Unrooted chrysanthemum cuttings are purchased in bags of 50 cuttings each and are stuck in either 50-cell trays or directly into the final 4-inch pot. The 50-cell trays will be transplanted to 1-gal containers. We don't use any hormone with the garden mums. However, cutting suppliers sometimes use a liquid or powder dip before shipping. Bottom heat at 75 °F is used with the 50-cell trays because the facility has bottom heat; however, mum plants root readily with no supplemental bottom heat. Roots are often seen in 6 days. Misting is done about 13 or 14 h/day and can be as frequent as every 1–2 min with a 10-sec burst. On cloudy days, misting intervals are lengthened. As with most intermittent mist, the smaller the amount of water used the better. We use Sterling 8 mist clocks or the Davis Solar-6 clock. Mist needs to reach the edges of the propagation areas, and the facility has to have high humidity. Painting of our plastic Quonset houses with shade paint, or covering with shade cloth, was helpful this year. Cuttings can scorch on the very hottest days even at short misting delays, and temperatures can reach well over 100 °F. As soon as rooting occurs, we roll up one side of the rooting pipe houses. Waves of mum cuttings are done mid-May through mid-July. Cuttings (in 4-inch pots) are planted outside their respective rooting houses and pushed inside on carts and set down in the mist. Plants in 4-inch pots are variety tagged at this time, too. The 4-inch pots are slower to stick, but there is no transplant time later. Some side notes:

- If any cuttings have *Botrytis*, this can be detected in the bags of cuttings, and the cuttings should not be planted.
- Don't leave bags of cuttings in the sun at lunchtime.
- Cutting medium is a peat and pumice blend (13:7, v/v)
- All our mum cultivars are patented, so taking cuttings is prohibited.
- We do some night interruption in August with HID lights or incandescent bulbs for October garden mum sales.

Fuchsia. Fuchsia softwood cuttings are taken in August or early September, depending on the crew workload. These easy-to-root plants will be sold as hanging baskets in May, or as 4-inch pots in April. Short, 2 or 3-inch two-node cuttings are taken, flowers removed, dipped in Hormex #1 (0.1% IBA), or Hormex #3 (0.3% IBA) on tough to root cultivars, and stuck in 50-cell trays. Bottom heat at 75 °F is used along with mist intervals that will ensure a light film of water on the leaves during daylight hours. White plastic tents over the benches are used for sun protection. Clean cuttings are important, or *Botrytis* can occur in the trays. Cuttings callused in 7 days and rooted in 3 weeks. They are then transplanted to baskets in November or December. Care in labeling of cuttings must occur. Record keeping is important.

Ornamental Cabbage and Kale. Ornamental cabbage and kale are simple seed-produced crops that are extremely popular in the Northwest, with the plants looking good in the landscape as late as the new year. We produced 30,000 this fall in two sizes, 4-inch and 1-gal.

Seed is relatively inexpensive and readily available, although certain seed can be hard to find and seed crop failures can also happen. The seed is hand sown in 50-cell trays. No special medium is used, just our straight peat and pumice (13 : 7, v/v) container mix. The flats are laid out on the bench; no heat is required because they are sown in July or August. Multiple waves of seed are sown, and the seed is covered lightly with the soil medium. Germination is fast, 4–5 days, and care must be taken so that mice don't damage the plants! Seedlings are removed from the greenhouse as soon as possible to prevent stretched stems. Varieties for 4-inch pot production are different than those for 1-gal production. For example, Nagoya should not be used in 4-inch pots, as it grows too large. Varieties for 4-inch production include Chidori, Kamome, and Pigeon.

Chocolate Cosmos and *Cordyline*. Chocolate cosmos and *Cordyline australis* 'Red Sensation' are two of the few perennial plants Classical Farms grows. Both are purchased from Steve McCulloch of I.P.P.S. fame, at his tissue culture business—Mountain Shadow Nursery. We buy chocolate cosmos unrooted and cordyline rooted.

We arrange to receive these microcuttings in June or July when we have propagation space available. In the case of chocolate cosmos, we have stuck multiple cuttings (12) in a 4-inch pot, and have also tried them in 72-cell trays, one per cell. Generally, transplant loss is greater when using the multiple cuttings method. Roots can readily be broken in transplanting.

We have used two hormone treatments: a Woods liquid dip (1 : 10, 1.03% IBA and 0.66% NAA) and Hormex #3. No significant difference was detected, so this year we simplified the procedure and used only the Hormex #3.

Rooting time can range from 15 to 30 days, and water management is key. Short, nonfrequent bursts of mist have been best (6 sec per 5–20 min). We have found our standard greenhouse mix to be better for these two crops than a specialized fine propagation mix. It is important to leach the trays prior to planting to reduce the E.C. to negligible levels. Bottom heat for rooting is 75 °F. Cuttings are misted by hand using a squeeze bottle during planting. Media is dibbled because the cuttings are soft. Work is done right at the propagation bench and can be slow. The planting crew rejected tweezers because they slowed the planting speed.

We try to grow tuberous roots by winter. We don't prune tops much to help in tuberous root development. No tuberous roots mean death. We transplant to 4-inch pots in mid-May and sell in July. It is a one-year crop for us.

Cordyline australis 'Red Sensation' is much simpler. It is planted in 72-cell trays. The rooted microcuttings are misted continually the first day only. After that, they are misted only in the afternoons. Establishment and growth remain slow for the first 30 days, after which they are transplanted into larger cells. Bottom heat at 75 °F is used. We sell these plants in 4-inch pots or in combination planters.

SESSION VI: QUESTIONS AND ANSWERS©

Verl Holden: Have you found a mycorrhizal fungus that colonizes *Daphne*?

Andrew Riseman: We haven't looked.

Dave Adamson: How do you fill the long, inflated polyhouses we saw in the pictures? Do you walk them in from the ends or use conveyors?

Ross Merker: For propagation we fill from the ends. Weather permitting, we'll plant inside the house so it's a short distance to push the plants.

Nevin Smith: We've noticed virus-like symptoms on the plants we grow, and I wondered whether anyone has done research on virus elimination in *Daphne*?

Andrew Riseman: None that I know of. Are you working from stock plants, taking cuttings?

Nevin Smith: Yes, we are, and we've made a rigorous effort to maintain "clean" plants by segregation. However, in the nursery setting, with routine, constant pruning, reinfection occurs.

Andrew Riseman: I don't know of anyone who's doing virus indexing on *Daphne*. Seed propagation can be used to rid plants of viruses.

Steve McCulloch: I know of *Daphne* virus research that's been conducted in New Zealand and published in the Proceedings. My question is regarding *Daphne* Sudden Death Syndrome (DSDS). Have you looked at the many different interspecific hybrids of *Daphne* or considered using some of the more resilient species and crossings to see what kind of heritability there might be for resistance?

Andrew Riseman: I would love to. The problem with that is first, associated with a botanical garden, I was primarily interested in species, and that's where I started out trying to understand species differences. And, if possible, understand how the resistance is evolving in the different lineages of the species. That is where I would ultimately like my personal research to go. Certainly, once we have the screen system in place we will be collecting the hybrids and evaluating them to see how certain species contribute susceptibility or resistance into the hybrids.

Paulus Vrijmoed: Where do you find the sphagnum peat moss for your germinating medium and do you do anything to it (e.g., grinding)? Would it be useful for other native species?

Dennis Bottemiller: It comes from a runway construction site at the SeaTac airport. We grind it up lightly by passing it through a 3/8-inch screen (hardware cloth), put it in a container, and seed directly into it.

Paulus Vrijmoed: When do you transplant the germinants?

Dennis Bottemiller: As soon as they get their first set of true leaves we start taking them out. We like to remove them quickly before the sphagnum begins to deteriorate.

Chemical and Physical Properties of Douglas Fir Bark Relevant to the Production of Container Plants©

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A one-year survey on the chemical and physical properties of Douglas fir [*Pseudotsuga menziesii* (Mirbel) Franco] bark was conducted with the following objectives: (1) document baseline chemical properties of Douglas fir bark (DFB) that have relevance to production of container plants, (2) determine the effect of screen size and age on DFB chemical properties, and (3) document the consistency of those properties throughout the year. In June, Aug., Oct., and Dec. 2005, and Feb. and May 2006, fresh and aged DFB samples were collected from two Oregon bark suppliers. One supplier offering a bark screened to 2.2 cm (coarse), and the other a bark screened to 0.95 cm (fine). Samples were analyzed for pH, electrical conductivity, and essential plant macro- and micronutrients. Native fresh and aged DFB contains significant extractable amounts of all essential plant macro- and micronutrients, except N. In general, the aging process reduced pH and increased extractability of phosphorous, potassium, calcium, magnesium, boron, and iron. Uniformity of DFB chemical properties throughout the year was affected by bark screen size and less so by age, with the coarse grade being more consistent.

Seed Germination and Viability of *Bursera* Species of Morelos, Mexico©

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Tropical dry forest restoration in Mexico is hindered by poor germination of *Bursera copallifera* and other common *Bursera*. Fungal infections of the seeds are common. Preliminary work on *B. copallifera* found that the stony endocarp was water-permeable. One germination experiment on a mixed collection of *B. copallifera* seed tested treatments with (1) deionized water, (2) 4-h soak in 3% hydrogen peroxide, (3) mechanical scarification by cracking, and (4) 4-h soak in 3% hydrogen peroxide plus mechanical scarification. There was no statistical difference between the treatments, although mechanical scarification alone appeared to encourage fungal infection. A second experiment with individual seed collections of several *B. copallifera* trees tested: (1) deionized water (control), (2) moist pre-chill for 6 days at 4 °C preceded by a 48-h imbibition period at room temperature, (3) 250 µM GA_3, (4) 600 µM benzyladenine (BA), and (5) 125 µM GA_3 plus 300 µM BA. Logistic regression analysis found that the most important effects on germination were the variation between the seed collections of each tree ($p = 0.05 < 0.0001$) and the tree-by-treatment interaction ($p = 0.0005$). Treatment effect was minimal ($p = 0.0432$). While the seeds of each tree responded differentially to the treatments, none of the treatments improved germination to a statistically significant extent. Pre-chilling decreased germination of the seeds of one tree. Most of the remaining seeds were dead at the end of the test period. The proportion of viable seeds varied widely among the trees. Low viability and vigor appeared to be the most important factors limiting germination in *B. copallifera*. The results suggested a possible relationship between tree density and seed viability that should be examined more closely.

BACKGROUND

Of the approximately 100 *Bursera* (Burseraceae) species, 80 occur in Mexico; 70 are endemic. Several *Bursera* are common dominant tropical dry-forest trees. Poor germination is common.

Preliminary Observations.

- Many filled seeds don't germinate.
- Stony endocarp was water-permeable.
- Endocarp was usually infected with various fungi.
- Germination was poor in most preliminary tests.
- Six-day pre-chill treatments and GA_3 looked promising.
- Between 10%–20% of nongerminated embryos stained weakly with tetrazolium chloride.
- Excised embryos germinated within 3–5 days.

Research Questions Focused on *Bursera copallifera*.

- Does some type of dormancy inhibit germination?
- What treatments, if any, promote germination?

EXPERIMENT I

Seeds, dry-stored for 8 months, were treated as below and incubated under 16 h of fluorescent light. Daily temperature fluctuation was 21–26 °C.

Treatments include: (1) Mechanical scarification (cracked endocarp); (2) 3% H_2O_2, 4-h soak; (3) 3% H_2O_2, 4-h soak + mechanical scarification; and (4) Control: DI water.

Results. One-way ANOVA ($p = 0.089$) found no significant difference between treatments.

EXPERIMENT II

Treatment response vs. variation between seed collections from nine *B. copallifera* trees of two localities was studied.

Treatments included: (1) Control (DI water), (2) Pre-chill, 6 days, 4 °C, (3) 250 µM GA_3, (4) 600 µM BA, and (5) 125 µM GA_3 + 300 µM BA.

Treatment conditions: 16-h fluorescent light/daily temperature fluctuation 21–26 °C.

Results of Regression Analysis.

- Variations between seed collections of the different trees ($p < 0.0001$) and the tree-by-treatment interaction ($p = 0.0005$) were most important.
- Treatment effect was minimal ($p = 0.0432$).
- No single treatment increased germination for all of the seed collections.

Viability and Vigor of Seeds.

- Estimated viability varied among seed collections.
- Most nongerminated seeds were dead by Day 45.
- Late germinating embryos often exhibited signs of low vigor.
- Estimated difference in the proportion of viable seeds for the two locations, Quilmula and Teocalco, was about 0.2 (Fig. 1).

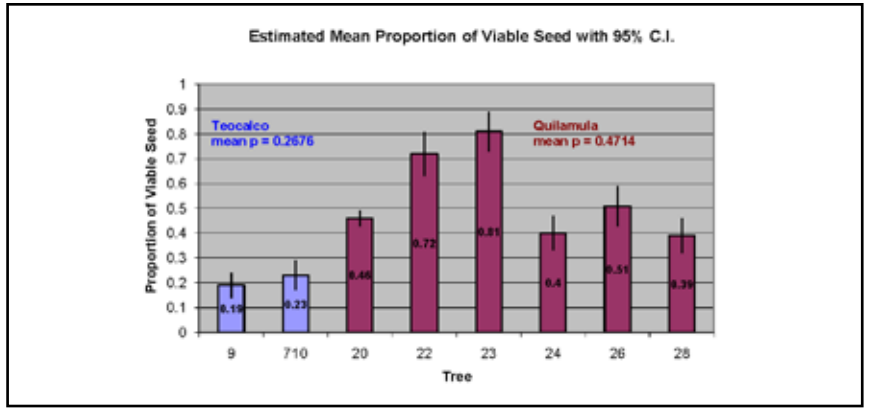

Figure 1. Estimated mean proportion of viable seed from two locations (Teocalco and Qualamula).

DISCUSSION

- No strong dormancy mechanism was detected for *B. copallifera.*
- None of the treatments tested could be recommended to improve seed propagation of this species.
- Mechanical dormancy did not inhibit germination of strong embryos; scarification promoted fungal attack; warm stratification on moist sand (results not shown) did not improve germination over the control.
- Seeds may have a mild degree of physiological dormancy, but for these collections, any after-ripening requirement was met by 6 weeks or more of dry storage between harvest and treatments.
- Seedlings of seeds treated with GA_3, BA, and especially GA_3 + BA had statistically lower rates of survival after potting compared to the control and pre-chill seedlings (results not shown).
- Low vigor and viability appeared to be the greatest inhibitors of germination in *B. copallifera.*

FOR FURTHER STUDY

- The trees sampled at Teocalco were fairly isolated, in a more disturbed habitat, and produced a lower proportion of viable seeds compared to the trees sampled at Quilamula. Is this location effect real or an artifact of limited sampling?
- How do samples from other locations compare? The *Bursera* are generally dioecious and outcrossing, and most species are conspicuously absent from secondary forests.
- Is inbreeding depression a problem in disturbed, fragmented forests?

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TECHNICAL SESSIONS

MONDAY MORNING, 9 October, 2006

The 31st Annual Meeting of the International Plant Propagators' Society – Southern Region of North America convened at 7:45 AM at the Hilton Charlotte University Place, Charlotte, North Carolina, with President Bob Smart presiding.

PRESIDENT BOB SMART. President Smart welcomed everyone to Charlotte, North Carolina, for the 31st Annual Meeting of the International Plant Propagators' Society – Southern Region of North America. He thanked Local Site Committee Chair David Threatt and his committee for the long hours in arranging the excellent tours, hotel, and other planning activities and all their attention to detail. He encouraged all students, new members, and perspective new members to attend the 2nd annual reception prior to the banquet and auction, so they could catch the uniqueness and sprit of the I.P.P.S. that makes it special — "To Seek And Share." Smart also encouraged all members to make new members and attendees feel welcome — share with them and seek from them. He also thanked Program Chair and 1st Vice-President Kay Phelps for the excellent program and slate of speakers she assembled.

LOCAL SITE COMMITTEE CHAIRMAN DAVID THREATT. Chairman Threatt welcomed everyone to Charlotte. He mentioned that he and his committee had been planning for this meeting for the past 5 years and that it was an honor to have the I.P.P.S. – SRNA come to Charlotte, North Carolina and to meet and tour local nurseries. He thanked his local site committee for all of their help: David Hyatt, Marla Townsend, Rick Crowder, Mike Roberson, and Kevin Gantt.

He talked about the tours, banquet, and auction in the evening, with special guest: NASCAR legend, Richard Petty.

PROGRAM CHAIR KAY PHELPS: Chairman Phelps welcomed all members, guests, and students. She thanked the membership for the opportunity to serve them and then reviewed the scheduled program. The Question Box was scheduled for Tuesday evening to be co-chaired by Blake Jones and Richard May. She thanked Dr. Glenn Fain for his audio and video efforts. Phelps then introduced Stewart Chandler to moderate the 1st session.

The Principles and Practices of Breeding Hydrangeas©

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INTRODUCTION

Hydrangea includes approximately 23 species with a disjunct distribution in temperate and tropical regions of eastern Asia, Eastern North America, and South America (McClintock, 1957). Of these 23 species, *Hydrangea anomala* subsp. *petiolaris, H. arborescens, H. macrophylla, H. paniculata, H. quercifolia,* and *H. serrata* are the most common in cultivation. *Hydrangea macrophylla*, with over 500 extant cultivars, is one of the most important flowering shrubs, and its popularity is due to its versatility as a garden shrub, florists' pot plant, and cut flower (Griffiths, 1994).

HISTORY OF HYDRANGEA BREEDING

Historically, hydrangea breeding has involved intraspecific crosses within *H. macrophylla, H. paniculata,* or *H. serrata*. Interspecific crosses within the genus have resulted in minimal success. Intraspecific crosses involve two plants from the same species, while interspecific crosses involve plants from two different species in the same genus. Of the three above-mentioned species, the primary focus has been improvement of *H. macrophylla*; which was first bred by the French in the early 1900s. Dutch, Belgian, Swiss, English, German, and Japanese breeders followed. Most of the early breeding focused on the production of cultivars with improved flower size and color for the pot plant or florist market (Lawson-Hall and Rothera, 2005). In recent years, the popularity of hydrangeas as garden shrubs has increased due to the introduction of new cultivars such as 'Bailmer' (Endless Summer™ hydrangea). Breeders should strive to develop plants that are adapted to garden culture and provide multiple seasons of interest. Traits of interest for *H. macrophylla* breeding include: the ability to rebloom (remontancy), inflorescence type, improved flower colors, fragrance, showy fruits, improved foliage, fall color, pigmented stems, strong stems, compact habit, cold hardiness, drought tolerance, disease resistance, and pest resistance.

TOOLS AND CRITERIA TO CONSIDER

New sources of genetic diversity and unique characteristics are needed in future cultivars to sustain the current enthusiasm and excitement, thus enhancing sales. Interspecific crosses may prove important sources of genetic diversity and unique characteristics. Recently, Rinehart et al. (2006) developed simple sequence repeat or microsatellite (SSR) markers for hydrangeas. These markers may reveal genetic relationships among species, assess genetic diversity among and within species, verify hybridity of progeny from intraspecific and interspecific crosses, and analyze parentage. Research is ongoing to identify markers linked to traits of interest, such as remontancy and disease resistance, for use in marker-assisted selection (MAS).

Several researchers have determined chromosome number, genome size, and ploidy level for many different species and cultivars of *Hydrangea*. See Cerbah et

al. (2001), Demilly et al. (2000), and Zonneveld (in van Gelderen and van Gelderen, 2004) for more information. Consult Reed (2004 and 2005) for excellent discussions on self-incompatibility, stigma receptivity, and pollination biology in hydrangeas and Dirr (2004), Lawson-Hall and Rothera (2005), and van Gelderen and van Gelderen (2004) for detailed information on species and cultivars of hydrangeas. Dirr (2004) presents a detailed summary of recent hydrangea breeding programs.

SO YOU WANT TO BREED HYDRANGEAS!

A comprehensive breeding strategy should be developed that includes the goals, a plan to achieve those goals, a list of supplies, equipment, and facilities that will be required, and protocols for selection, evaluation, and introduction of new cultivars.

Determine Goals. Two general types of goals are improvement of existing traits and introduction of new traits. Existing traits, such as remontancy and disease resistance, are already present in the species of interest. New traits, such as fragrance and showy fruits are not present in the species of interest and are often introduced through interspecific crosses. How the trait is inherited (quantitative vs. qualitative, dominant vs. recessive) must also be considered. Quantitatively inherited traits are controlled by multiple genes and are difficult to breed for. Qualitatively inherited traits are controlled by one or two major genes and are easier to breed for.

Select Parents. The genotypes that are selected for use as parents depend on the goals and should be based on a review of the literature and field observations. Field evaluations in Athens, Georgia (Dirr, 2004) and Fletcher, North Carolina (Bir, 2000a; Bir, 2000b) have identified taxa that are disease resistant and cold hardy and that flower consistently. When selecting genotypes for use as parents, remember that superior parents yield superior progeny and inferior parents yield inferior progeny.

Facilities Required. A typical nursery setup is needed for growing seedlings to flowering plants. Required facilities include a heated house, overwintering structures, breeding cages, and a mist system. While crosses can be made outside, it is easier to make controlled crosses inside a greenhouse where the plants can be isolated from insects and where water and temperature can be controlled. If using interspecific crosses, it is necessary to synchronize flowering of the different species or to collect and store pollen. A walk-in cooler may be useful for synchronizing flowering of different species. Pollen can be successfully stored for up to 11 months (Kudo and Niimi, 1999), which will eliminate the need for a walk-in cooler. A shade area will be necessary, especially in the South, for growing most species of *Hydrangea*, with *H. paniculata* being the most obvious exception.

Perform Crosses. Plants are brought into a heated greenhouse [±24 °C (75 °F) / ±18 °C (65 °F) day/night temperature] in early January. This will prevent late spring freezes from damaging inflorescences, allow complete control of temperature and water availability, and prevent pollen contamination by excluding insects from the breeding environment. Flowers are fully expressed in 10 to 12 weeks. Three to five inflorescences per plant are pollinated by hand. Reciprocal pollinations, using each parent as a male and female, are made in the morning using fresh pollen if available. If mophead cultivars are used, the sterile flowers with showy sepals must be

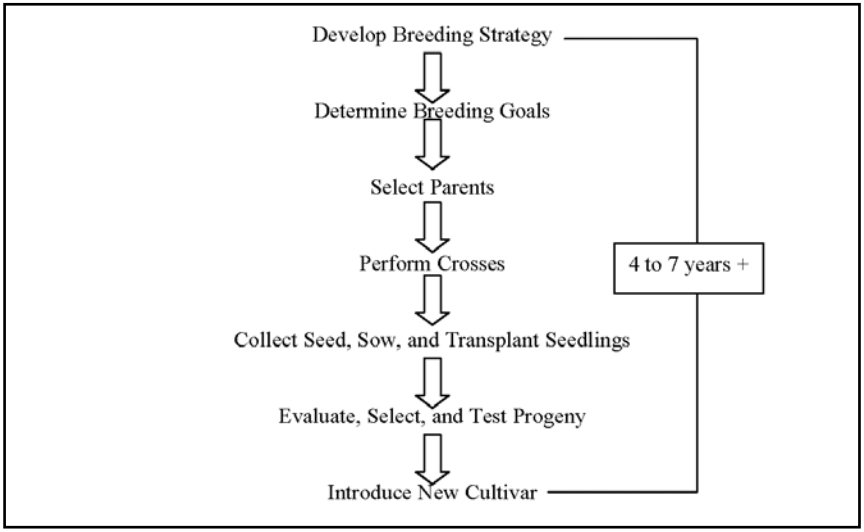

Figure 1. Flow chart and timeline for a typical hydrangea breeding program.

removed to allow easier access to the underlying fertile flowers. If lacecap cultivars are used, removal of one-third to two-thirds of the fertile flowers will reduce the number of pollinations that will be required. A lacecap inflorescence contains hundreds of fertile flowers, each capable of producing 100 or more seeds. Flowers used as the maternal parent should be emasculated to prevent self-pollination. Pollen is transferred to the stigma of the maternal parent using a small paint brush or by brushing an anther from the pollen parent directly onto the stigma of the maternal parent. *Hydrangea macrophylla* possesses a gametophytic self-incompatibility system. Therefore, emasculation may not be necessary, but a small percentage of self-pollinations may result. All inflorescences used for pollinations are labeled with the maternal parent, pollen parent, and date. Keep a logbook that details each cross and includes the parentage, date, and number of flowers for each cross. Plants are moved outside in May, and the infructescences are allowed to mature.

Collect Seed, Sow, and Transplant Seedlings. Collect the capsules in fall as they turn from green to brown. Dry them indoors in small paper bags. Crush the capsules and separate the seeds from the chaff using a small screen. Surface-sow the seeds in flats filled with soilless medium. Do not cover the seeds. Place the flats under mist or keep them moist until germination occurs. Once the seedlings have developed two or more pairs of true leaves, transplant them into individual cells and grow in a greenhouse. After the danger of frost has passed, move the seedlings outside and pot into 11-L (3-gal) containers under shade.

Evaluate and Select Progeny. Evaluate and select superior progeny according to the goals of the program. Seedlings can be screened for traits such as foliage characteristics and disease resistance during the first growing season. Flowering characteristics such as color, inflorescence type, and remontancy usually cannot be screened until the second growing season, because the plants must reach maturity before they will flower. Seedlings will flower when approximately 16 to 18 months

old. Superior and/or unique progeny that have been selected should be propagated and evaluated in multiple locations and/or for multiple years to ensure that they will remain true-to-type. During evaluation, superior seedlings may be bulked up through asexual propagation to ensure that enough plant material is available to speed the introduction of a new cultivar.

HYDRANGEA BREEDING TIMELINE

It takes approximately 12 to 14 months from the time crosses are made in the greenhouse until the seedlings are potted outside the following spring. Evaluation, selection, testing, and bulking-up of a seedling may take an additional 3 to 5 years or more. From the time an initial cross is made until a new cultivar is released may take 4 to 7 years or more (Fig. 1).

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The IR-4 Ornamental Horticulture Program: What, How, and Why©

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WHAT IS IR-4?

The IR-4 Project works with growers, researchers, registrants, and regulatory agencies to develop research data so that new products can be registered and new crops, diseases, insects, and weeds can be added to existing product labels. The IR-4 Ornamental Horticulture Program, one of several programs under the IR-4 project, develops information for non-edible specialty crops grown in greenhouses, nurseries, landscapes, Christmas tree farms, and forestry production nurseries.

The IR-4 Ornamental Horticulture Program is supported by two major funding sources: the USDA Agricultural Research Service (ARS) and the USDA Cooperative State Research, Education, and Extension Service (CSREES). The ARS research staff conducts research trials across all pest disciplines and is critical in the effort to provide pest solutions to the green industry. The funding provided by CSREES typically supports research through the state university and State Experiment Station systems.

The CSREES has four regions utilized by IR-4 to coordinate its research efforts — Northeast, North Central, Southern, and Western. The IR-4 headquarters operation is located at Rutgers University in New Jersey. All of these units operate independently under the umbrella of the Project Management Committee (PMC), which has members from each of the units, ARS, and CREES (Fig. 1). Each regional coordinator is based at one of the land-grant universities: Cornell University, Michigan State University, University of California-Davis, and University of Florida. These regional coordinators place research trials with experts in entomology, plant pathology, weed science, and plant growth regulators.

HOW DOES IR-4 WORK?

Identify Grower Needs. The first step for IR-4 to select research projects is to determine the most pressing disease, insect, and weed problems facing growers and landscape professionals. IR-4 solicits input on these issues in several ways. Growers, researchers, and extension personnel can fill out project request forms and submit them to either their regional coordinator or State Liaison Representative, or to the ornamental horticulture program manager via a web-based form. Growers, researchers, and extension personnel can also complete an annual survey to determine which diseases, insects, and weeds are the most problematic, meaning they may not be easily or economically managed with current products.

The 2006 grower/extension survey started 2 June and ended 1 Sept. There were 337 participants this year: 236 growers, 20 landscape care professionals, 70 researchers and extension agents, and 11 allied-industry professionals. People who took the survey ranked 13 different research needs on a scale of 0 (no importance) to 5 (very high importance) and then listed the top three disease, insect, and weed problems

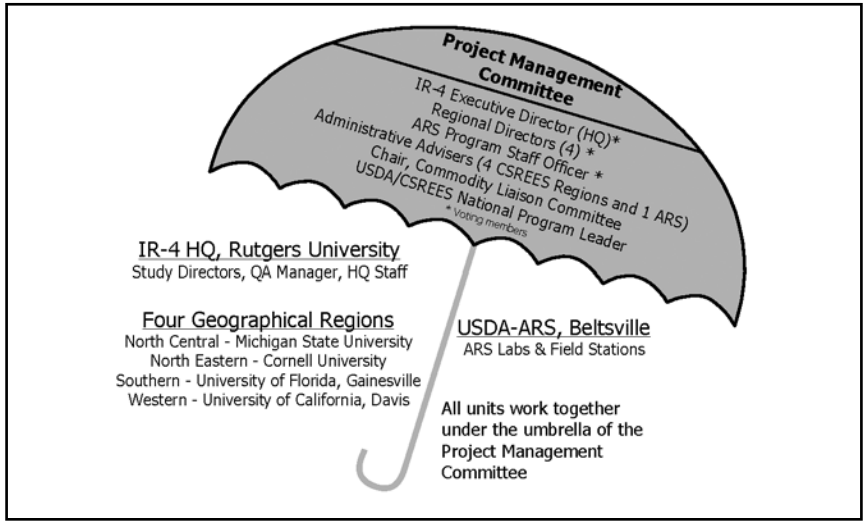

Figure 1. The structure of IR-4.

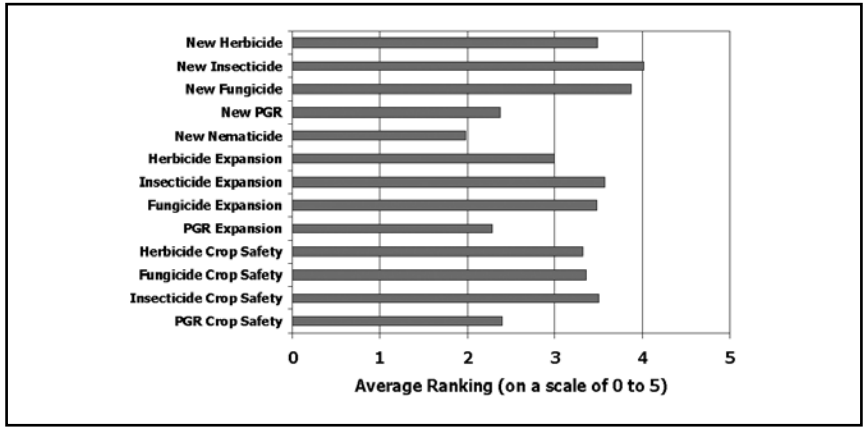

Figure 2. Growers and landscape care professionals rank research needs.

where product choices are limited. The research need with the highest average was new insecticide products followed closely by new fungicides (Fig. 2). The top 5 diseases mentioned were *Phytophthora*, *Botrytis*, powdery mildew, *Rhizoctonia*, and downy mildew. The top 5 insects listed were thrips, whiteflies, scales, mealybugs, and spider mites. The top five weed problems were *Euphorbia* sp. and *Chamaesyce* sp. (spurge), *Cardamine* (bittercress), *Cyperus* (nutsedge), *Oxalis*, and *Eclipta.*

Annual Workshop. At the annual workshop, attendees discuss the major pest issues and assign each a priority for research within the IR-4 Program during the following year. The survey results and submitted project requests have the most

influence in establishing the research direction. In general, those diseases, insects, and weeds without registered products are ranked higher than those that can be controlled with commercially available products. There may be situations where the survey and project requests point to a certain research direction, but workshop participants select other diseases, insects, or weeds as the high priority projects. For example, there may be a great need for new products to control a certain disease or pest, but at the time of the workshop there are no new, unregistered products to put into a testing program. Another example where the research direction may be different from the annual survey is a situation where IR-4 has sponsored research into a product not yet registered for ornamental horticulture uses and additional data would not greatly increase the speed of registration or breadth of the product label. Finally, sometimes there can be a lengthy gap between when research is conducted and when the resulting information is used either for extension presentations, technical updates, or label registrations for grower-identified needs.

Research Priorities for 2007. Attendees at the 2006 IR-4 Ornamental Horticulture Program Workshop selected several high priority projects for research in 2007. The two entomological projects were thrips and anything coleopteran (borers, beetles, white grubs, and root weevils), a continuation of the 2006 research priorities. For plant pathology, the ongoing *Phytophthora* and *Pythium* efficacy projects were continued. Workshop attendees committed to two new projects dealing with sedge efficacy and crop safety of products for sedge control along with finishing the 2006 project on crop safety of Sedgehammer, Sulfentrazone, SureGuard, and V-10142 on select ornamental horticulture plants.

Establishing the Research Program. After the high priority projects have been established, the regional coordinators place trials with university researchers and private contractors. These researchers help write the protocols so that the resulting data are meaningful for both growers and the manufacturers registering the products.

Data Summaries and Distribution to Manufacturers. After the researchers have completed their trials, they send the data to their regional coordinators who in turn send it to the ornamental horticulture program manager. The data for each high priority project are summarized into a single report, which is sent to each manufacturer with products in the testing program. These reports can be submitted to federal or state registration officials. The summary report is also posted to the IR-4 website where it is available to anyone interested in reading the results.

WHY IR-4 IS IMPORTANT FOR GROWERS?

The IR-4 program is the only government-sponsored organization that has a mission to listen to and address growers' needs by collecting data, which will lead to registered products with state and federal agencies. In fact, IR-4 has worked to obtain product registrations for growers of food crops for more than 40 years and has facilitated collection of data important to ornamentals growers for almost 30 years. The IR-4 project can serve as an advocate for growers with manufacturers so that products can be tested and then labeled for certain diseases, insects, and weeds. Finally, the IR-4 ornamental horticulture program website can become a source of comparative efficacy and crop safety information so that growers and landscape care professionals can more effectively make decisions about which products to use.

WHO TO CONTACT AT IR-4.

For more information about the IR-4 Ornamental Horticulture Program, contact Cristi Palmer at 732-932-9575 extension 4629 or visit the website at <www.ir4.rutgers.edu>. A Regional Coordinator can also help those who wish to learn more about studies in a particular region. Regional Coordinators can be contacted at: Northeast Region – Edith Lurvey, 315-787-2308, Email: ell10@cornell.edu; North Central Region – Satoru Miyazaki, 517-336-4611, email: ncrir4@msu.edu; Southern Region – Charles Meister, 352-392-2399, email: cmeister@ifas.ufl.edu; Western Region – Rebecca Sisco, 530-752-7634, email: rsisco@ucdavis.edu; and USDA-ARS Office of Minor Use Pesticides – Paul Schwartz, 301-504-8256, email: schwartz@ba.ars.usda.gov.

Propagation of Deciduous Azaleas©

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INTRODUCTION

There are 15 deciduous azalea species native to the Eastern United States, but they are relatively rare in our gardens. In 1791, plant explorer William Bartram said of *Rhododendron calendulaceum*, the Flame Azalea (Fig. 1), "This is certainly the most gay and brilliant flowering shrub yet known." (Slaughter, 1996). Our native azaleas have been greatly admired for hundreds of years, but partially due to propagation difficulties, these species are still not widely available in the trade.

Native deciduous azaleas come in a wide range of colors, and many are delightfully fragrant. Species bloom at various times of year, from early spring to late summer. Most native azaleas are not bothered by mildew, a major problem with the deciduous Knap Hill and Exbury azalea hybrids. Adapted to local environments, native azaleas require less care than many garden shrubs. Their delicate flowers, which usually bloom over a long time period, are also less susceptible to weather. Many plants have very attractive foliage. Unfortunately, due to loss of habitat, theft, deer browsing, and competition from invasive alien species, many wild azaleas are threatened.

EAST COAST NATIVE AZALEA SPECIES

Native azaleas are quite variable, and rare forms still exist in the wild that should be preserved and propagated. Some species are better suited to southeastern gardens, but the author briefly comments about all 15 native species, grouping them by color and order of bloom (Kron, 1993).

Figure 1. Picture of flame azalea in flower.

White Group.

Rhododendron alabamense – White with a yellow blotch; fragrant; sometimes difficult in containers.

Rhododendron atlanticum – White to pale pink; very fragrant with attractive blue-green foliage.

Rhododendron eastmanii – First identified as a species in 1995; flowers white with a yellow blotch.

Rhododendron arborescens – Very fragrant; white with red stamens; excellent heat tolerance, and roots fairly easily.

Rhododendron viscosum [Includes the *R. serrulatum* (see *viscosum*), *R. oblongifolium* (see *viscosum*), and *R. coryanum* (syn. *coryi*)] – Fragrant white flowers.

Pink Group.

Rhododendron vaseyi – Delicate pink to white flowers; adaptable plant but often difficult to root.

Rhododendron canadense (formerly *R. rhodora*) – Small purple flowers; does not like heat or drought.

Rhododendron canescens – Pink to white; mildly fragrant; good heat tolerance.

Rhododendron perclymenoides (formerly *R. nudiflorum*) – Similar to *R. canescens* but more difficult to root.

Rhododendron prinophyllum (formerly *R. roseum*) – Deep pink; fragrant; not very heat tolerant.

Orange Group.

Rhododendron austrinum – Yellow to gold; fragrant; heat tolerant and excellent in the southeast.

Rhododendron flammeum (formerly *R. speciosum*) – Yellow, orange, or red; heat tolerant; hard to root.

Rhododendron calendulaceum – Yellow, orange, or red; not as heat tolerant and often difficult to root.

Rhododendron cumberlandense – Similar to *R. calendulaceum*, but blooms slightly later; difficult to root.

Rhododendron prunifolium – Red to coral; blooms in mid- to late summer; heat tolerant; easy to root.

Natural Hybrids.

Gregory Bald Azaleas – Blends of white, yellow, pink, orange, and red; blooms in June.

CUTTING PROPAGATION

Stem cuttings are often preferred for vegetative propagation, but rooting deciduous azaleas can often be problematic. One major difficulty is that after cuttings root, they often refuse to break dormancy the following year. Since the plants drop their

leaves in the fall, cuttings with dormancy problems fail to send out new growth the next spring and eventually die.

Timing is the key to success when taking deciduous azalea cuttings. The best time is late May to early June while in active growth. By taking cuttings early, there is often adequate time to form roots and to send out additional growth before autumn. Plants begin going into dormancy when the days get shorter and nights turn cool. Some propagators force plants into growth in late winter so cuttings can be taken even earlier, thus increasing the chance of success.

The author suggests the following procedure for rooting deciduous azalea cuttings on a modest scale. He roots his cuttings under fluorescent lights in containers enclosed in plastic bags.

Procedure.

- ***Cutting Selection.*** Preferred cutting material is strong new growth that is getting firm, but is not hardened-off. Cuttings need not be very long; segments of 5 to 8 cm (2 to 3 inches) are ample.
- ***Preparation.*** Pinch out soft new growth and any developing flower buds. Remove lower leaves. To eliminate insects and fungal spores that could eventually cause problems, soak cuttings in a 5% Clorox solution for about 5 min and then rinse thoroughly. Cuttings can also be sprayed with a systemic insecticide/ fungicide mixture (Isotox / Funginex).
- ***Auxins.*** Dip the end of the cutting in a rooting hormone like Dip 'N Grow®. The strength should be relatively low, 1 part hormone to 10 parts water. Some propagators suspect that higher hormone concentrations may inhibit cuttings from breaking dormancy. Some growers are successful without using any rooting hormone at all.
- ***Rooting Medium.*** Stick cuttings in a rooting medium of equal parts peat and perlite. The medium should be damp but not too wet. Azaleas are shallow rooted so cuttings do not need to be inserted deeply, only the bottom inch or so, up to the first leaf on the cutting.
- ***Care.*** Enclose containers in clear plastic bags to maintain high humidity. Keep containers under fluorescent lights with "long-day" conditions, 18 to 24 h of light per day, to maintain vegetative state for at least 8 weeks, or until cuttings root. Since plants are used to high humidity, before removing the plastic, open bags slowly over several days to gradually harden plants off. Otherwise leaves wilt very quickly, since they are unable to adjust to abrupt change.
- ***Dormancy Concerns.*** Rooted cuttings that have sent out a flush of new growth can be moved to a cool greenhouse or cold frame in the fall to go through the normal dormancy process. Cuttings that did not break are best kept under fluorescent lights until spring to avoid dormancy problems. The author prefers to wait until early spring before repotting cuttings.
- ***Growing Medium.*** For cuttings or young plants, peat and perlite (1 : 1, v/v) is suggested; sometimes mixed with a bit of coarse sand. In larger pot sizes, excellent drainage is important so the author

uses a mix of equal parts of the peat and perlite rooting medium used for cuttings, combined with an equal amount of pine bark fines. Some growers prefer 100% pine bark fines for larger containers, especially when growing in full sun with heavy irrigation.

- ***Potting.*** Pot sizes of 8 to 11 cm (3 to 4.5 inches) are usually adequate for the first season. Transplant to 4- or 11-L (1- or 3-gal) pots the following year, and pinch or shear back early to encourage branching. Grow in full sun for best bud set. Plants can reach marketable size in 1 to 2 more years.
- ***Care.*** Plants appreciate ample water, but the amount of fertilizer deciduous azaleas need is related to light intensity. The stronger the sun, the more fertilizer plants can tolerate. Beware of high fertilizer with low light intensity, since it encourages disease problems. The author uses Nutricote Total, Slow Release 13N–13P–13K with micronutrients-Type 100, applied in spring after blooming. Supplement with dilute liquid fertilizer such as Schultz 15N–30P–15K, as cuttings leaf-out in spring, and as needed through the season. Avoid fertilizer late in the summer, since plants must go dormant before winter so as to avoid bark split and related winter injury. Since plants are deciduous, they can be overwintered with minimal protection if pots are clustered together and mulched well to protect root systems. Root systems are not as hardy as stems, so pots should not be allowed to freeze too hard, even with mature plants.

SEED PROPAGATION

Raising plants from seed is an excellent method for propagating native azaleas, especially for those species that are difficult to propagate by other methods. A single seedpod can have a hundred or more seeds, so a large number of plants can be raised from limited stock. In the wild, few seedlings make it to maturity because tiny plants are susceptible to drought and competition. However, once past that first year, plants are more adaptable to extremes. Seed-grown plants will show genetic diversity, but almost every one will make an attractive landscape plant.

During the late fall or winter, sow seed indoors thinly on the surface of peat and perlite potting medium, the same mix used for cutting propagation. Enclose containers in clear plastic bags and place them under fluorescent lights with long day conditions at 15.6 °C (60 °F). Seedlings germinate in a few weeks, but grow slowly at first. Crowded seedlings can be transplanted to fresh medium when they show their first true leaves. Never let small seedlings dry out, for if that happens once, they usually die. Keep seedlings growing inside clear plastic bags until spring.

As with cuttings, allow seedlings to harden off by gradually opening the plastic bags over several days before moving them outside. Get seedlings used to increased light levels and then transplant to individual pots, 6 to 8 cm (2.5 to 3 inches) in diameter depending upon seedling size. Avoid over-potting. Eventually move to moderate light, 30% to 50% shade cloth for at least the first season. Pinch plants or prune back to encourage branching. The next year, move plants up to 11-cm or 4-L (4.5-inch or 1-gal) containers and eventually to a 11-L (3-gal) size. At that time, they should be grown in full sun, with ample fertilizer and regular irrigation to encour-

age bud set. Under good growing conditions, a well-budded landscape plant can be produced from seed in about 3 years.

There are various approaches for seed-grown deciduous azaleas. The former Arneson Nursery in Canby, Oregon, U.S.A., developed crosses that produced deciduous azalea hybrids that were quite uniform in color and plant habit. Vivian Abney of East Fork Nursery, Sevierville, Tennessee, U.S.A., raises many native azalea species from the wild, and each plant is labeled with the seed source. At the Tennessee Rose Nursery in Trade, Tennessee, J. Jackson and wife, Lindy Johnson, raise open-pollinated descendents of the "Zo" hybrids. These are multicolored native azaleas similar to June-flowering Gregory Bald hybrids, using stock plants from late Ohio nurseryman, Zophar Warner. The Lazy K Nursery of Pine Mountain, Georgia, U.S.A., is famous for its seed-grown natives, especially *R. prunifolium*.

OTHER PROPAGATION TECHNIQUES

- **Dormant Cuttings.** Mike Creel, retired extension agent from Lexington, South Carolina, is having success rooting dormant cuttings of deciduous azaleas. Woody twigs, preferably with branched segments, are placed under clear plastic domes. These domes remain outside in open shade, and cuttings are allowed to go through normal cold treatments. As the woody cuttings break dormancy, they send out new growth while forming roots at the same time. The plants started from dormant cuttings apparently avoid dormancy problems common with cuttings taken in early summer. Mike does not use any auxins for rooting.
- **Basal Shoot Cuttings.** Many deciduous azaleas are stoloniferous, so Allen Cantrell of Fern Gully Nursery, Chesnee, South Carolina, has been propagating plants by taking a portion of a shoot or root from the base of a mature plant. Segments are potted up and kept in a humid, shady area. Roots form below ground level, and adventitious buds break above where exposed to light.
- **Micropropagation.** Tissue culture has become one of the best methods for rapidly increasing cloned forms of deciduous azaleas (Briggs et al., 1988). The first stage is to isolate plant tissue in a sterile culture medium. Various chemicals are used to get shoots to elongate, after which they are cut into segments and rooted. After rooting, care is essentially the same as with raising small seedling plants. Through Virginia's Beautiful Gardens™ program, Barry Flinn and Rumen Conev, Institute for Sustainable and Renewable Resources at IALR, Danville, Virginia, are experimenting with tissue culture protocols using some of the author's native azalea selections. We hope to make quantities of those plants available in the future.

CONCLUSIONS

Our native deciduous azaleas of the Southeastern U.S. make excellent landscape plants and deserve wider distribution. Selected clones can be propagated by methods such as softwood cuttings, dormant cuttings, and basal shoot cuttings. Most of the difficulty related to vegetative propagation centers around dormancy problems where cuttings root but fail to grow. In vitro tissue culture propagation is proving to be a valuable method for rapid increase of cloned forms. Quality plants can also be raised from seed to blooming size in a few years with relative ease.

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Propagation at the U.S. National Arboretum, an Overview©

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INTRODUCTION

Established in 1927 by an Act of Congress, the U.S. National Arboretum is administered by the U.S. Department of Agriculture's Agricultural Research Service. The mission of the National Arboretum is to serve the public need for scientific research, education, and gardens that conserve and showcase plants to enhance the environment.

This presentation will discuss two divisions at the National Arboretum: the Tree and Shrub Breeding Program of the Research Unit and the Gardens Unit. These units focus on plant propagation for distribution, breeding, and display. Our breeding program encompasses a wide range: from basic and developmental research on trees, shrubs, turf, and floral plants to the development of plants with superior characteristics through a program of testing and genetic improvement. We develop new methods of pest and disease detection and control, improve our understanding of the taxonomy and nomenclature of ornamental plants and their wild relatives, and collect and preserve plant germplasm with ornamental potential.

The Gardens Unit works with a wide range of single-genus groupings in display gardens including azalea (my specialty), boxwood, daffodil, daylily, dogwood, holly, magnolia, maple, and peony. Major garden features include aquatic plants, the Asian collections, the Fern Valley native plant collections, the flowering-tree walk, the Friendship Garden, The Gotelli Dwarf and Slow-Growing conifer collection, the Introduction Garden, the National Bonsai & Penjing Museum, the National Capitol Columns, the National Grove of State Trees, and the National Herb Garden.

PROPAGATION FACILITIES

The mist system is housed in one of the glass-covered greenhouses, which have been in service since about 1961. While plans are in place to demolish our greenhouses and rebuild brand new modern facilities in the near future, these older glass houses still serve our propagation and growing needs for the time being.

Conventional mist benches with evenly placed emitters are utilized for propagation. The Mist-o-matic Electronic Leaf system regulates mist cycle by a balance system. The weight of water from the mist emitters lowers the electronic leaf, which in turn shuts off the mist. Then through evaporation, the leaf eventually rises again, triggering the mist to cycle on, wetting the leaf, and then shutting off the mist. This system works well for most of the horticulturists I interviewed for this article, since numerous activities prevent us from monitoring the mist system closely. In addition we also use timer-operated mist controllers that rely on photocells to help prevent the timed mist from over-watering new propagules.

David Kidwell-Slak, support scientist and propagator for the shrub breeding research program, has set up a fog chamber inside one of the glass houses in order to achieve 100% humidity, which is beneficial for some *Prunus* and *Cercis* cuttings.

The structure was built with a PVC pipe frame and covered with plastic and some shadecloth. A humidifier from a department store was attached. The jury is still on to how well this is working, but with cooler temperatures in the winter and spring, it should work well. The shrub-breeding program also operates a tissue culture lab.

GROWING MEDIA

Most of the horticulturists at the National Arboretum use three main ingredients to create rooting or seed-starting media with coarse sand, milled sphagnum, and perlite (1 : 1 : 1, by volume) most often used. Variations on this might be two parts coarse sand to one part milled sphagnum, which I currently use for azalea cuttings. For seed propagation, our horticulturist for the Asian collections uses milled sphagnum, coarse sand, and perlite (2 : 1 : 1, by volume); and the native plants horticulturist uses milled sphagnum and coarse sand (1 : 1, v/v) for general seed propagation.

RATIONALE FOR PROPAGATING

Each unit, garden, or display propagates for different reasons. The National Arboretum also serves as a back-up collection for other institutions. If a natural disaster occurs, we can ship replacement cuttings to help replace lost or stolen plants. This happened to the salvia collection at the Baton Rouge Botanical Garden after Hurricane Katrina. Our plant records department maintains an extensive database of information for all plants brought to the National Arboretum. The database (BG BASE) was developed specifically for use in botanic gardens, and most of us can input data directly into the database from our computers. All shipments of plant material are tracked in our database.

For the herb garden, more variety can be obtained through the raising of seed from specialty nurseries, and it's more economical. The horticulturist, Christine Moore, tells me that 80% of their propagation is done from seed (chili peppers and basil are the largest collections). Most seed is sown from late February through the end of May. The salvia (over 60 taxa) and pelargonium (about 75 taxa) collections are maintained only through propagation by cuttings.

For the native plants collection, curator Joan Feely uses wild-collected material from a known provenance whenever possible. This is important for research purposes if the plant is ever used for breeding. Joan raises most of her plants from seed but, last year, raised cuttings of our locally native *Viburnum dentatum* and *Lonicera sempervirens* for restoration purposes using rediscovered indigenous species.

For the azalea collection, I obtain cuttings from plants that are as near to the original source of that cultivar as is possible. For example, I collected cuttings of the North Tisbury azaleas from Ms. Polly Hill on Martha's Vineyard in Massachusetts. Polly Hill is responsible for introducing the North Tisbury azaleas to the nursery trade. Most of what I grow is from cuttings, but lately about 5% of what I grow has come from seed of native azalea species collected from the wild.

Susan Martin, horticulturist for the conifer collection, mainly propagates through cuttings from plants that revert or "misbehave," such as many of the selections of *Chamaecyparis*. She may repropagate selections from collectors such as William Gotelli who donated a sizeable collection of dwarf and slow-growing conifers to the National Arboretum in 1962. Cuttings are taken after three hard frosts, usually

between Thanksgiving and Christmas. Cuttings typically root in 3 months. Some pines and other species are grown from seed but it is only about 5% of her total.

Carole Bordelon, the horticulturist for the Asian collections, and Martin Scanlon, horticulturist at our Glenn Dale facility in Maryland, have traveled to China with NACPEC (North American China Plant Exploration Consortium) and brought back seed from many genera. The goals of these collection trips are to collect germplasm that increases the genetic diversity of the targeted genera, provide material for researchers to utilize in breeding for heat or cold hardiness, disease resistance, and drought tolerance, as well as conservation of germplasm. Many areas in China are not protected, and so material is collected for reasons of conservation. For many years, all *Acer griseum* in North America came from one location in China. Before a collecting trip, the participants create a target list of genera to collect based on many factors including research program needs and collection gaps. Documentation of propagation techniques for some of the seed they collect is limited; therefore, there is a need to try several different techniques to get optimal germination.

In accord with its mission "to develop new and improved cultivars of woody ornamental plants," the tree and shrub breeding program breeds plants for tolerance to pollution, disease, and pests. *Lagerstroemia* 'Natchez' is a successful National Arboretum introduction. With its warm, cinnamon brown bark, lovely white flowers throughout the summer, field tolerance to powdery mildew, and stately tree-like stature, 'Natchez' epitomizes elegance in the plant world. Margaret Pooler, head of the shrub-breeding program, said propagation is done for two major reasons: for distribution and to grow out seedlings from hybridizations. About 50% of what they propagate comes from seed and 50% comes from cuttings.

PRE-TREATMENTS AND SOWING PRACTICES

Fresh seed is stored in a cooler at 4 °C (40 °F) until planted. Some seed must be cold stratified for 2 to 3 months before germination, and some seed might even have double dormancy, which means it needs two cold seasons to germinate. Dr. Pooler uses a hot water treatment, rather than acid, to scarify *Cercis*. Many of the herb garden's larger seed need to be removed from husks (such as peanuts) or have the fuzz removed (cotton). Sweet peas are pre-soaked before being sown.

Pitcher plants (*Sarracenia leucophylla, S. alata,* and *S. purpurea*) can be temperamental in greenhouse conditions, but curator Joan Feely has found a way to raise them from seed using rain water collected in buckets outside or collecting water from air conditioners and dehumidifiers in order to avoid any chemicals that are found in our city water. In the future, Joan plans to construct a germination unit outside where seed can be exposed to natural temperature fluctuations and germinate naturally when the time is right in a rodent-free outdoor space.

SPECIAL PROJECTS

The herb garden has 10 specialty gardens: old-fashioned and David Austin rose gardens; the holly border; basil bed (25–30 varieties); chili pepper bed (60–80 varieties); salvia bed (60 or more varieties, most from cuttings); ornamentals; and containers. Acting curator Christine Moore depends on volunteers to sow and transplant the many hundreds of varieties of herbs raised from seed or cuttings.

Currently, the National Arboretum's woody ornamental breeding programs are focused on developing improved cultivars of *Lagerstroemia*, *Cercis*, *Prunus*, *Hydrangea*, *Clethra*, *Tsuga*, and ×*Chitalpa*, as well as other genera. In addition, the tree-breeding program is breeding trees for shorter stature for use under power lines. The program also includes breeding for sterility for ornamentals that tend to be invasive in some situations such as *Berberis* sp., *Ulmus parvifolia*, and *Ligustrum sinense* (Chinese privet). Cuttings are also taken for distribution of our USNA introductions in order to keep those introductions available to the consumer. We also propagate to save valuable germplasm that may be difficult or impossible to re-collect. Tissue culture is also used in the shrub-breeding program.

Tissue culture facilitates biotech applications, such as genetic engineering, and could be useful in the breeding program to introduce genes that might assist with disease and pest resistance, sterility, or ornamental traits. For example, studying the regulation of anthocyanin genes may make it possible to create plants with novel flower or leaf color by controlling the expression of this gene in various plant parts such as a red-leaved *Prunus laurocerasus* (common cherry laurel) or a purple-flowered crape myrtle.

Some difficulties are encountered in growing plants from cuttings or seed for display at the National Arboretum. We have problems with damping-off diseases on seedlings. Sometimes cuttings must be taken multiple times in order to obtain the desired number of plants for the collection because they don't always root for various reasons, including improper handling technique. With the limited staff available to work on projects, our dependence on volunteer help is becoming more and more important for our success. Volunteers are not always propagation experts, so training is very important. Periodically the mist nozzles can clog with calcium deposits and create inadequate coverage of a flat of seeds or cuttings. Genera like sundew and shortia present difficulties in germinating and may not make it into the display some years. Some junipers are extremely difficult to root and take several tries. *Prunus* 'First Lady', a National Arboretum introduction, must be rooted from juvenile shoots or suckers prompted from an older tree.

CONCLUSION

The Gardens Unit and the Tree and Shrub Breeding Programs of the Research Unit at the U.S. National Arboretum work together to make the arboretum the top quality research and educational facility that it is. Our researchers use the germplasm collected by horticulturalists from the U.S. and abroad for the work they are doing in breeding new and improved cultivars. Plants brought back from collecting trips, once determined to be of garden merit, are displayed in our gardens, with the new and unusual where they can be observed by the public and preserved for future generations. Our gardens feature plants that our research team has successfully bred and introduced to the nursery trade as well as other plants our researchers might utilize in future breeding work. All of this is accomplished by using the methods and principles of propagation, trying various techniques, using proper handling, and maintaining a clean growing environment.

Throughout the 446 acres of the National Arboretum, one can learn the values of design, variety, and nature. The herb garden features plants of industrial or

culinary use, the conifer collection features beautiful displays of evergreen plants that need full sun to prosper, while the azalea collection features a wide variety of azaleas for use in partial shade. The Asian collection features many plants that have become popular in our gardens, and the Introduction Garden features reliably good new plants and innovative ways to use the tried and true. Finally a visit to the native plants in Fern Valley introduces the public to concepts of conservation, invasive species, and the beauty of the natural environment. Propagation of plants helps us keep the gardens of the U.S. National Arboretum alive and healthy.

A New Substrate for Container-Grown Plants: Clean Chip Residual©

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Clean Chip Residual (CCR) is a potential new nursery substrate that is a forestry by-product composed of approximately 50% wood, 40% bark, and 10% needles. This study evaluated CCR as a growth substrate for container-grown nursery crops. Two perennial species were grown in one of eight substrates (100% bark from two sources, two screen sizes of CCR, and the same treatments combined with 20% peat) along with standard nursery amendments. Species tested included *Buddleja* 'Pink Delight' and *Verbena* 'Homestead Purple'. Growth of these species in CCR was, in general, similar to plants grown in typical pine bark substrates. These results indicate that CCR has the potential to be a viable substrate option for the nursery industry.

INTRODUCTION

Aged pine bark with the addition of a percentage of sand and peat moss make up the majority of container substrates used in nurseries throughout the Southern U.S.A. Unfortunately, the future availability of pine bark is declining due to reduced forestry production, increased importation of logs (no bark), and use of pine bark as a fuel source (Lu et al., 2006). It is important to explore alternatives to traditional pine bark substrates; potential substrates must be readily available, sustainable, economical, pest-free, and easily processed.

A new trend in harvesting pine trees occurs with mobile in-field chip operations. This equipment is used to process trees into "clean chips" to be sent to pulp mills. This process produces a residual product composed of about 50% wood, 40% bark, and 10% needles (about 25% of the biomass). This product, "clean chip residual" (CCR), is either sold for boiler fuel or, more commonly, spread across the harvested area. If the processed product is sold for boiler fuel the approximate cost is $3–4/yd^3. In-field harvesting operations are occurring across the Southeast. Several million acres in the Southeast are currently in forestry production, and CCR has potential to provide a sustainable media resource to meet the continuing needs of the nursery industry.

[1]Graduate Student Research Paper Winner; 1st Place.

One concern among nursery producers is the increased wood content compared to the traditionally used pine-bark substrate. A recent study by Wright and Browder (2005) showed that a 100% wood-fiber substrate could be used successfully for nursery crop production with proper nutrition and irrigation. Studies by Fain and Gilliam (2006), Fain et al. (2006), and Boyer et al. (2006a) successfully used substrates composed of whole pine trees to produce container-grown nursery crops. The percentage of wood in whole tree substrates ranges from 75%–85%. The CCR was tested as a growth substrate for greenhouse-grown annuals (Boyer et al., 2006b). It was reported that use of these substrates resulted in plants that were similar in size to plants grown in pine bark alone. In addition, several 100% wood-fiber products have been introduced in Europe (Worral, 1978; Gruda and Schnitzler, 2003) for use in vegetable production. These studies show that having a larger portion of wood in the substrate may be acceptable for producing nursery crops.

The objective of this work was to evaluate fresh CCR as a substrate for production of container-grown nursery crops.

MATERIALS AND METHODS

The CCR used in this study was obtained from a 10-year-old pine plantation near Evergreen, Alabama. Loblolly pine (*Pinus taeda*) were thinned and processed for clean chips using a total tree harvester. The CCR used in this study was further processed through a horizontal grinder with 4-inch screens. The sample was then run through a hammer mill to pass a 1.9- or 1.3-cm (0.75- or 0.95-inch) screen. These two CCR sizes were used alone or blended 4 : 1 (v/v) with peat and compared with pine bark from suppliers in Mississippi and Alabama. Treatments are listed in Table 1.

This study was initiated at the USDA-ARS Southern Horticultural Laboratory, Poplarville, Mississippi, on 30 March 2006. It was repeated at Auburn University, Alabama; however, due to space restrictions only the Mississippi data is presented. Each substrate was amended per yd^3 with 14 lb 18N–6P–12K (Polyon 9 month), 5 lb dolomitic limestone, and 1.5 lb Micromax (Scotts Co.). Two perennial species, *Buddleja* 'Pink Delight' and *Verbena* 'Homestead Purple', were transplanted from standard 72-cell flats and grown in trade-gallon containers, placed outside in full sun, and overhead irrigated as needed. Plants were arranged by species in a randomized complete block with eight single plant replications. Pour-through extractions were conducted at 15, 32, and 63 days after planting (DAP) to test media pH and electrical conductivity (EC). Leaf chlorophyll content was quantified using a SPAD-502 Chlorophyll Meter (Minolta, Inc.) at 30, 60, and 100 DAP. Growth indices ([height + width1 + width2] / 3) were recorded at 32, 64, and 105 DAP. Flower numbers were counted at 64 and 102 DAP. Media shrinkage was recorded at 7 and 146 DAP. Shoot dry weight was recorded at the conclusion of the study (105 DAP).

RESULTS

With *Buddleja* initial growth differences occurred (Table 1); however, these differences were minor and were likely due to varying irrigation needs among plants in the different substrates. By 64 DAP all *Buddleja* were similar in growth and had similar flower counts and similar color (leaf chlorophyll; data not presented). This trend continued at 102 DAP when all plants were again similar in size. Also, from a visual standpoint, all plants were commercially acceptable for marketing regard-

Table 1. Effects of various substrates on growth of *Buddleja* 'Pink Delight'.

Treatment[y]	Growth indices[z]			Flower number		Shoot dry weight
	32 DAP[x]	64 DAP	102 DAP	64 DAP	102 DAP	105 DAP
100% PB (MS)	19.0[w] c	61.2 a	66.4 a	7.1 a	9.1 cd	50.7 b
100% PB (AL)	31.5 a	55.7 a	66.4 a	7.1 a	14.3 b	49.6 b
100% ¾" CCR	24.5 b	57.4 a	65.1 a	7.5 a	8.6 d	42.7 c
100% ½" CCR	24.6 b	59.9 a	68.3 a	9.1 a	9.6 bcd	42.6 c
4:1 PB:PEAT (MS)	25.4 b	60.3 a	66.5 a	7.1 a	10.1 bcd	49.3 b
4:1 PB:PEAT (AL)	31.3 a	55.2 a	68.9 a	6.1 a	18.8 a	58.1 a
4:1 ¾" CCR:PEAT	30.7 a	56.7 a	69.5 a	7.0 a	13.5 bc	47.7 bc
4:1 ½" CCR:PEAT	26.8 b	63.0 a	67.4 a	7.4 a	10.3 bcd	45.0 bc

[z]Growth indices [(height + width1 + width2)/3] presented in centimeters and shoot dry weight presented in grams.

[y]Treatments were: PB = pine bark (MS = Mississippi source, AL = Alabama source), CCR = clean chip residual, PEAT = sphagnum peat moss.

[x]DAP = days after planting.

[w]Values within column followed by a different letter are significant using Duncan's Multiple Range Test (α =0.05).

less of the substrate source. There were slight differences in flower numbers and shoot dry weights at 102 DAP. The pine bark (Alabama) and peat (4 : 1, v/v) treatment had more flowers at the end of the study than most treatments, which likely contributed to the larger shoot dry weight. Interestingly, plants in treatments with the Alabama pine bark tended to exhibit excellent growth either alone or in combination with peat. In contrast, plants grown in the Mississippi pine bark tended to have the least growth. These results with two different sources of pine bark indicate the variability in physical characteristics that often occurs among pine-bark sources in the industry. Also, these results show that CCR treatments grow plants as well as or better than some pine-bark substrates that are currently used.

Results with *Verbena* were similar to those of *Buddleja* (Table 2). At 32 DAP the greatest growth occurred with plants grown in the Alabama pine bark, either alone or with peat, however, by 64 DAP, all plants were similar in size. At 64 DAP slightly more flowers occurred on plants grown with the Alabama-based pine bark substrate. In general, the CCR-grown *Verbena* had the least flower numbers at 103 DAP, however, the flower numbers were acceptable for commercial sale. All plants were visually rated to be commercially acceptable. Shoot dry weights were similar among all treatments at 105 DAP.

Substrate pH measurements were within acceptable ranges (5.5 to 6.5) for the duration of the study (Table 3). For EC all treatments at 15 DAP were above the recommended range (0.2 to 0.5 mS cm^{-1}) (SNA, 1997). Only two substrates were within the recommended EC levels at 32 DAP: pine bark (4 : 1, v/v) and peat (both Mississippi and Alabama). All other treatments at 32 DAP and all treatments at 63 DAP were below the recommended range.

Shrinkage data showed slight differences in the height of the media surface (cm below the top of the pot) at 7 DAP (data not shown). However, at the conclusion of the study all treatments had the same substrate level, indicating that use of CCR alone or in combination with peat does not significantly increase media settling due to decomposition of the wood in 105 days.

DISCUSSION

Similarities among treatments in this study indicate that CCR is a viable substrate option for containerized plant production in nurseries. Species included in this test showed little or no differences compared to control treatments, indicating that growth in CCR can produce crops that are as marketable as those grown in pine bark. More studies need to be conducted in order to determine appropriate irrigation and fertilizer regimes as well as document the growth responses of other plant species grown in CCR. Adoption of CCR as a substrate for nursery crop production could significantly lower substrate costs for nursery producers.

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Table 2. Effects of various substrates on growth of *Verbena* 'Homestead Purple'.

Treatment[y]	Growth indices[z]			Flower number		Shoot dry weight
	32 DAP[x]	64 DAP	103 DAP	64 DAP	103 DAP	105 DAP
100% PB (MS)	18.4[w] c	50.7 a	83.6 a	15.1 c	20.3 bc	67.5 a
100% PB (AL)	31.1 a	45.7 bc	82.3 a	20.8 ab	19.5 bc	70.8 a
100% ¾" CCR	24.0 b	45.8 bc	85.3 a	15.0 c	16.4 c	63.3 a
100% ½" CCR	24.5 b	42.1 c	86.8 a	12.9 c	19.4 bc	63.7 a
4:1 PB:PEAT (MS)	21.5 bc	48.0 ab	90.8 a	15.9 bc	26.6 a	72.4 a
4:1 PB:PEAT (AL)	33.2 a	46.3 abc	84.8 a	22.1 a	24.5 ab	74.2 a
4:1 ¾" CCR:PEAT	24.6 b	46.6 abc	84.1 a	13.4 c	15.5 c	64.7 a
4:1 ½" CCR:PEAT	26.1 b	49.1 ab	86.8 a	12.5 c	16.9 c	64.8 a

[z]Growth indices [(height + width1 + width2)/3] presented in centimeters and shoot dry weight presented in grams.

[y]Treatments were: PB = pine bark (MS = Mississippi source, AL = Alabama source), CCR = clean chip residual, PEAT = sphagnum peat moss.

[x]DAP = days after planting.

[w]Values within column followed by a different letter are significant using Duncan's Multiple Range Test (α =0.05).

Table 3. Substrate electrical conductivity (EC) and pH for substrate blends in a container-grown perennial study of *Buddleja* 'Pink Delight' and *Verbena* 'Homestead Purple'.

Treatment[z]	15 DAP[y]		32 DAP		63 DAP	
	EC[x]	pH	EC	pH	EC	pH
100% PB (MS)	0.80[w] a	6.4 ab	0.19 b	6.6 a	0.11 a	6.5 ab
100% PB (AL)	1.01 a	6.2 c	0.13 b	6.4 a	0.15 a	6.2 b
100% ¾" CCR	0.88 a	6.5 a	0.18 b	6.6 a	0.15 a	6.6 a
100% ½" CCR	1.03 a	6.5 a	0.19 b	6.7 a	0.12 a	6.6 a
4:1 PB:PEAT (MS)	1.11 a	6.3 bc	0.20 b	6.6 a	0.09 a	6.2 b
4:1 PB:PEAT (AL)	1.07 a	5.9 d	0.32 a	6.2 a	0.09 a	5.7 c
4:1 ¾" CCR:PEAT	1.20 a	6.3 c	0.17 b	6.5 a	0.13 a	6.1 b
4:1 ½" CCR:PEAT	1.04 a	6.4 ab	0.19 b	6.6 a	0.09 a	6.3 ab

[z]Treatments were: PB = pine bark (MS = Mississippi source, AL = Alabama source), CCR = clean chip residual, PEAT = sphagnum peat moss.

[y]DAP = days after planting.

[x]EC = mS/cm.

[w]Values within column followed by a different letter are significant using Duncan's Multiple Range Test (α =0.05).

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Pre-Emergent Herbicide Use in Propagation of *Loropetalum chinense* 'Ruby'©

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Three herbicides were evaluated during propagation of *Loropetalum chinense* 'Ruby' to determine the effects on rooting and subsequent plant growth. Herbicides evaluated were: Gallery (isoxaben), Ronstar 2G (oxadiazon), and Regal O-O (oxyfluorfen + oxadiazon). Herbicides were applied at three separate times during the propagation process: before sticking, lightly rooted, or fully rooted. Before sticking treatments were applied to flats filled with standard medium prior to the cuttings being stuck. About 1 month later when roots had just begun to emerge [3 to 5 cm (1 to 2 inches) long], a separate group of cuttings (lightly rooted) were treated. Finally, the third application occurred to a separate group of cuttings (not previously treated) once the cuttings were fully rooted. Data was collected at 65, 248, and 342 days after sticking (DAS). One year after sticking, growth indices of 'Ruby' loropetalum were similar regardless of when Gallery was applied. At that time there was no effect on root coverage except when Gallery was applied before sticking, which had 58% root coverage compared to 69% for nontreated plants. With Ronstar and Regal O-O shoot growth was similar about 1 year later; however, root coverage was suppressed with Ronstar applied before sticking and at lightly rooted, while Regal O-O suppressed root coverage on all dates of application.

INTRODUCTION

Cuttings are often propagated in small containers, and previous research suggests weeds are better competitors for water, light, and nutrients in smaller containers than in larger containers (Berchielli-Robertson et al., 1990). With herbicide restrictions, hand weeding is the major form of weed control in propagation but can suppress growth of cuttings through mechanical disruption (Johnson and Meade, 1987). Another restriction with hand weeding is cost of labor. Estimated labor costs ranged from $246–$567/acre based on an average hourly wage of $3.53–$3.97 (Gilliam et al., 1990). North Carolina's annual weeding labor costs ranged from $967–$2,228/acre based on an hourly wage of $14.75 (Judge et al., 2004).

There is a need for weed control options beyond hand weeding during propagation of nursery crops, especially with rising labor costs and potential labor shortages. Most herbicides available for the nursery industry contain DNA herbicides, which are root inhibiting (Altland et al., 2003; Thetford et al., 1991). In previous research, Ronstar has been shown to cause no reduction in root growth or quality when ap-

[1]Graduate Student Research Paper Winner; 1st Place.

plied during propagation of boxwood (Thetford and Gilliam, 1991). In other work, Ronstar and Regal O-O were reported to cause no reduction in root quality of azalea or hollies during propagation (Cook and Neal, 2001). In more recent work, Altland et al. (2000) showed Gallery to have post-emergent control of bittercress, which is one of the major weeds in propagation. A post-emergent option for bittercress control in propagation would provide a needed option for nursery producers.

Evergreen nursery crops are frequently propagated in outside beds during the summer. Conditions are ideal for germination and growth of many weed species. Eliminating these weed species during propagation will reduce future weed pressure in production areas and promote better crop growth. The objective of our study was to compare Ronstar and Regal O-O with Gallery for effects on rooting of 'Ruby' loropetalum when applied at different times during the propagation process.

MATERIALS AND METHODS

In this study three preemergence herbicides were applied to cuttings of *Loropetalum chinense* 'Ruby' at three different times in the rooting process. Gallery at 1 lb/aia, Ronstar at 4 lb/aia, and Regal O-O at 3 lb/aia were applied either before sticking (2 Aug. 2005), when cuttings were lightly rooted (18 Sept. 2005), or when cuttings were fully rooted (4 Nov. 2005). Terminal cuttings 7 to 9 cm (2.8 to 3.5 inches) were stuck on 2 Aug. 2005, in 9-cm (3.5-inch) containers utilizing a pinebark : sand 6 : 1 (v:v) medium amended with Polyon 17–6–12 @ 9 lbs/yd^3, Micromax @ 1.5 lbs/yd^3, and dolomitic lime @ 5.0 lbs/yd^3. Each cutting was dipped in Dip 'N Grow 1 part : 5 parts water (2000 ppm IBA) for 4 sec prior to sticking. This study was a 3×3 factorial with 9 replications of 9 containers per replication in a completely randomized design. All treatments were hand weeded throughout the study to eliminate weed competition effects.

With the before sticking treatment, propagation flats were treated 1 h before cuttings were stuck and watered in with 0.6 cm (0.25 inch) of water. All pots were placed in outdoor cold frames under 47% shade with overhead mist every 5 min for 5 sec from 8:00 AM to 7:00 PM. Thirty-eight days after sticking (DAS), 8 Sept. 2005, a separate group of lightly rooted cuttings not previously treated were pulled from the mist beds prior to mist starting at 8:00 AM, to allow treatment to dry foliage. Thereafter the foliage was lightly brushed off and plants were watered in [0.6 cm (0.25 inch)] and returned to mist. On 4 Nov. 2005 (94 DAS), the final treatment (fully rooted) was applied the same as the second treatment, and plants were left under mist for one additional week before being moved to a retractable shade house for overwintering.

Data were collected 65, 248, and 342 DAS. At 65 DAS, shoot number per cutting and average length of the three longest shoots were recorded for cuttings treated before sticking and lightly rooted. Four plants from each replication were randomly selected to determine number of primary roots, average length of the three longest roots, and root fresh weight. After overwintering, 7 April 2006 (248 DAS), growth indices (height + width at widest point + width perpendicular ÷ 3) and percent root coverage of the propagation container (0–100 scale) were taken prior to potting in full gallon containers. Growth indices and percent root coverage of containers were taken again on 10 July 2006 (342 DAS).

RESULTS

65 DAS Before Sticking. Gallery had no effect on shoot growth or root growth on cuttings of 'Ruby' loropetalum (Table 1). Ronstar and Regal O-O suppressed shoot length by 44% and 37%, and root length by 30% and 16% compared to the nontreated control.

Lightly rooted. Compared to the nontreated control plants there were no herbicide effects on new shoot number, shoot length, or root fresh weight (Table 1). Gallery and Ronstar had slightly less root numbers compared to Regal O-O and nontreated plants. Slight suppression in root length (less than 10%) occurred with Gallery and Regal O-O compared to the nontreated control with the exception of Ronstar.

248 DAS Before Sticking. Gallery- and Ronstar-treated cuttings were similar but were smaller and had less root coverage than the nontreated control plants while Regal O-O caused severe reduction in growth indices (73%) and root coverage (74%) (Table 2).

Lightly Rooted. 'Ruby' loropetalum stem cuttings treated when roots were 2.5 to 5 cm (1–2 inches) long were similar in growth indices regardless of herbicide treatment (Table 2). Root ratings were slightly less for Ronstar and Regal O-O compared to the nontreated control; however, Gallery-treated plants had similar rootball coverage to the nontreated control plants.

Fully Rooted. A slight difference in new growth was observed for all plants treated with herbicides compared to the nontreated control plants (Table 2). Fully rooted cuttings treated with Gallery and the nontreated plants had similar root ratings, while Ronstar and Regal O-O had suppressed root ratings compared to the nontreated control cuttings, with Regal O-O suppressing root growth more than Ronstar.

342 DAS Before Sticking. Approximately 1 year after application all stem cuttings had similar growth indices regardless of herbicide treatment (Table 3). No difference in root coverage was observed between Gallery and Ronstar. All herbicide treatments had less root coverage than the nontreated control plants, with Regal O-O having the greatest root suppression (Table 3).

Lightly Rooted. Plants from all herbicide treatments were similar in shoot size or larger than the nontreated control plants when treated at the lightly rooted stage during propagation (Table 3). Gallery applied to lightly rooted cuttings had similar root coverage compared to the nontreated control plants. Ronstar and Regal O-O had less root coverage than the nontreated plants; however Ronstar treated cuttings had equal root coverage to cuttings treated with Gallery.

Fully Rooted. Gallery, Ronstar, and Regal O-O applied to fully rooted cuttings had similar growth indices compared to the nontreated control 1 year after propagation (Table 3). There was no herbicide affects in percent root growth compared to the nontreated control, with the exception of Regal O-O applied to fully rooted cuttings.

DISCUSSION

In summary, Gallery applied to lightly or fully rooted stem cuttings of 'Ruby' loropetalum did not cause any suppression in shoot or root growth. These data suggest that Gallery could be sprayed over the top of cuttings for post-emergence control of bittercress. Furthermore, application of Gallery before sticking did cause slight

Table 1. The influence of herbicide application during propagation 65 days after sticking on *Loropetalum chinense* 'Ruby' stem cuttings.

	Before sticking[z]				Lightly rooted[y]			
	Gallery	Ronstar	Regal O-O	Control	Gallery	Ronstar	Regal O-O	Control
Shoot Number[x]	3.6a[t]	1.3c	1.4c	3.0b	2.7a	2.7a	2.8a	3.0a
Shoot Length[w]	4.3a	2.3b	2.6b	4.1a	4.5b	3.8b	5.9a	4.1b
Root Number[v]	11.5ab	10.1bc	8.7c	12.6a	10.8b	10.5b	12.7a	12.6a
Root Length[u]	22.7a	15.4c	18.5b	22.0a	19.9b	21.4ab	19.8b	22.0a
Root Weight	0.6a	0.3b	0.4b	0.6a	0.6a	0.5a	0.5a	0.6a

[z] Before Sticking = herbicide prior to sticking cuttings.

[y] Lightly Rooted = herbicide applied to lightly rooted cuttings (1-2 inches).

[x] Shoot Number = number of new shoots per replication.

[w] Shoot Length = length of three longest shoots ÷ 3 (cm).

[v] Root Number = number of primary roots per replication.

[u] Root Length = length of three longest roots ÷ 3 (cm).

[t] Means (across columns within application times) with different letters are significantly different, according to Duncan's Multiple Range Test ($\alpha = 0.05$).

Table 2. The influence of herbicide application during propagation 248 days after sticking on *Loropetalum chinense* 'Ruby' stem cuttings.

	Growth index[z]			Root coverage[y]		
Herbicide	Before sticking	Lightly rooted[x]	Fully rooted	Before sticking	Lightly rooted	Fully rooted
Gallery	19.8b[w]	30.2a	28.0b	22.1b	29.5ab	30.7ab
Ronstar	20.5b	42.7a	27.2b	19.7b	27.8b	28.4b
Regal O-O	10.2c	22.1a	20.9b	9.3c	24.5b	22.5c
Control	38.3a	38.3a	38.3a	35.4a	35.4a	36.2a

[z] Growth indices = Height + width at widest point + width perpendicular ÷ 3.

[y] Root coverage was an estimate of the percentage of the rootball surface covered with roots (0-100 %).

[x] Lightly Rooted = herbicide applied to lightly rooted cuttings (1-2 inches).

[w] Means (within a column for each factor) with different letters are significantly different, according to Duncan's Multiple Range Test ($\alpha = 0.05$).

Table 3. The influence of herbicide application during propagation 342 days after sticking on *Loropetalum chinense* 'Ruby' stem cuttings.

	Growth index[z]			Root coverage[y]		
Herbicide	Before sticking	Lightly rooted[x]	Fully rooted	Before sticking	Lightly rooted	Fully rooted
Gallery	44.1a[w]	47.3a	47.1a	57.5b	63.3ab	65.5a
Ronstar	41.3a	44.2b	46.5a	56.1b	61.3b	64.0a
Regal O-O	41.1a	45.2ab	51.9a	46.2c	52.8c	53.1b
Non-treated	43.7a	43.7b	43.7a	68.9a	68.9a	68.9a

[z] Growth Indices = height + width at widest point + width perpendicular ÷ 3.

[y] Root coverage was an estimate of the percentage of the rootball surface covered with roots (0-100).

[x] Lightly Rooted = herbicide applied to lightly rooted cuttings (1-2 inches).

[w] Means (within a column for each factor) with different letters are significantly different, according to Duncan's Multiple Range Test ($\alpha = 0.05$).

suppression of root growth compared to the nontreated cuttings; however, by the end of the first growing season, shoot growth was similar to nontreated plants. Cuttings treated with Ronstar and Regal O-O also had similar shoot growth to the nontreated cuttings by the end of the 1st year. Ronstar reduced root coverage when applied before sticking and when cuttings were lightly rooted, while Regal O-O reduced root coverage regardless of application timing. From a grower's point of view, use of herbicides in propagation that causes slight reductions in root coverage at the end of the first growing season may be more acceptable than dealing with weed pressure and added labor cost throughout the life of the crop.

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Native Plants and Communities of the Piedmont of North Carolina©

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INTRODUCTION

The current plant communities in the Piedmont of North Carolina differ greatly from the original landscape that existed prior to settlers coming to the region. Almost all virgin forest has been harvested, with much of the land being used for houses and development and the remainder being used for agriculture. As this land regenerates from the harvest, the countryside has become a patchwork of multiple different stages of regeneration taking place.

Disturbance of a plant community is usually followed by recovery, which we call succession. Succession represents a sequence of populations that replace each other, resulting in community change. A typical sequence of dominant vegetation is: Summer, winter annual weeds ⇒ herbaceous perennials ⇒ shrubs ⇒ early successional trees ⇒ late successional trees.

Succession is a continuous process of change in vegetation, which can be separated into a series of phases:

- Pioneer: 0–10 years
- Sub Climax: 10–100 years
- Climax: 100–300 years

Many factors come into play in contributing to the succession process. Seeds survive for variable lengths of time and germinate at varying times over multiple years, causing the succession process to be sometimes unpredictable. Seed survival is classified as:

- Transient seeds (1 year or less)
- Short-term persistent seeds (1–5 years)
- Long-term persistent seeds (> 5 years)

Succession is a process of opportunity. It occurs where death or destruction creates an opening, e.g., a tree falling in a forest, grass dying in a field. Thus, scale is important. In a forest there is a mosaic of mini successions occurring even when the forest overall appears to be the climax community.

SUCCESSION STAGES

Pioneer: 0 to 10 years. Succession starts at the microscopic level, and the earliest stages of the colonization of bare ground are associated with the microbial, algae, lichen, and moss components of ecosystems. As succession proceeds, early pioneer short-lived species are replaced by perennial communities dominated by several grasses. Eventually, a tall-grass prairie may develop that would be dominated by other tall grasses and perennial herbs. The prairie is then invaded by shade-intolerant shrubs and trees, forming the nuclei of a forest.

Sub Climax: 10 to 100 years. This segment of succession is the most dominant phase seen in the Carolina Piedmont. Early successional trees have multi-layered

foliage. Leaves deep in the canopy are able to get enough light to be above the compensation point. They also have efficient seed dispersal systems and are precocious reproducers, e.g., eastern red cedar, *Juniperus virginiana.*

Climax: 100 to 300 years. Studies of the Piedmont in North Carolina show that oak-dominated forests establish after about 150 years. Identification of stable climax communities in the field is usually difficult, in part because of the very long temporal scale. For example, old-field succession may require 100 to 300 years to reach climax community. But in this time frame, the probability that a physical disturbance (fire, hurricane, flood, logging) will occur becomes so high, the process of succession may never reach completion. Climax is characterized by slow rates of change in an old-growth community compared with more dynamic, earlier stages. Climax communities are dominated by species tolerant of competition for resources, and late successional trees have a single layer of leaves in a shell around the tree and are more efficient in a crowded canopy. Also, seeds are larger and poorly dispersed, and the juvenile phase is long, e.g., sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*).

The piedmont of North Carolina is currently a combination of Pioneer and Sub Climax successions. Most areas are in some stage of the Sub Climax succession with recent disturbances in the Pioneer stage.

THE FOLLOWING IS A LIST OF SOME OF THE COMMON PLANTS SEEN IN THE SUCCESSION STAGES OF THE NORTH CAROLINA PIEDMONT

Pioneer. *Ambrosia artemisiifolia* (ragweed), *Andropogon virginicus* (broom sedge), *Elymus canadensis* (wild rye), *Helianthus atrorubens* (sunflower), *H. microcephalus* (sunflower), *Panicum dichotomiflorum* (annual), *Phytolacca americana* (pokeweed), *Silphium compositum* (Rosin weed), *Solidago arguta* (goldenrod), *S. erecta* (goldenrod), *Rubus argutus* (blackberry)

Sub Climax.

Herbaceous Plants Include. *Asarum arifolium* (wild ginger), *Asclepias syriaca* (common milkweed), *A. tuberosa* (butterfly weed) *Aster concolor*, *A. dumosus*, *A. paternus, Chrysogonum virginianum* (yellow and gold), *Chasmanthium latifolium* (northern sea oats), *Eupatorium album* (queen of the meadow), *Eupatorium coelestinum* (ageratum), *Geranium maculatum* (wild geranium), *Passiflora incarnata* (maypops), *Podophyllum peltatum* (May apple), *Polygonatum biflorum* (Solomon's seal), and *Trillium catesbyi.*

Understory Plants include. *Bignonia capreolata* (cross vine), *Clematis virginiana* (woodbine), *Cercis canadensis* (redbud), *Cornus florida* (flowering dogwood), *Euonymus americanus* (strawberry bush), *Hamamelis virginiana* (witch hazel), *Ilex verticillata* (winterberry), *Parthenocissus quinquefolia* (Virginia creeper), *Rhododendron eastmanii, Rhus glabra* (smooth sumac), *Viburnum acerifolium* (maple leaf viburnum)

Associated Tree Species Include. *Acer rubrum* (red maple), *A. leucoderme* (chalk maple), *Carpinus caroliniana* (ironwood, blue beech), *Liriodendron tulipifera* (tulip tree), *Liquidambar styraciflua* (sweet gum), *Nyssa sylvatica* (black gum), *Oxydendrum arboreum* (sourwood), *Sassafras albidum*.

Characteristic Tree Species Include. *Carya carolinae-septentrionalis* (southern shagbark hickory), *C. glabra* (pignut hickory), *C. tomentosa* (Nittall hickory), *Juglans nigra* (black walnut), *Celtis laevigata* (southern hackberry), *Quercus alba* (white oak), *Q. stellata* (post oak), *Q. lyrata* (overcup oak), *Q. michauxii* (swamp chestnut oak), *Q. prinus* (chestnut oak), *Q. rubra* (red oak), *Q. coccinea* (scarlet oak).

There are two famous plants the Charlotte, North Carolina region is well known for: the endangered Schweintzs sunflower (*Helianthus schweinitzii*) and the big leaf magnolia (*Magnolia macrophylla*). *Helianthus schweinitzii* is only known to exist in a couple counties in North Carolina, growing at the woods edges and thickets.

Magnolia macrophylla boasts the largest flowers and largest simple leaves of any tree native to temperate North America. The flowers, which often have purple spots at the base of the pedals, may be up to 1.5 ft in diameter, and the leaves may be 1 ft wide and up to 3 ft long. Andre Michaux reported finding this unusual tree only in the Carolina Piedmont and in the Cumberland region of Tennessee.

Aromi Retrospective©

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Dr Eugene Aromi, a University of South Alabama education professor, and his wife Jane began hybridizing deciduous and evergreen azaleas in 1969 in their Mobile, Alabama, backyard. Aromi's goals were to produce improved cultivars for Zone 8. At the time that he began his work, very few deciduous azalea hybrids were acclimated to the south. The outstanding Ghent, Knap Hill, and Exbury Hybrids were developed for the cooler European climates and could not adjust to the wet, hot conditions in the southern U.S.A. The work of American hybridizers was concentrated in the Northeast U.S.A. and primarily concerned with cold hardiness. Most hybridization of evergreen azaleas was also targeted for cold hardiness. The U.S.A. hybridization programs at the Glenn Dale station in Maryland created a race of cold-hardy Indica-like plants that performed poorly below the Mason-Dixon line. There have been few new introductions to the Southern Indica azaleas since the turn of the century in spite of the fact that the Indicas remain the best-selling azaleas in the South.

Dr. Aromi developed his evergreen hybrids between 1969 and 1976. He named 31 hybrids, mostly with Indica bloodlines. In 1976, frustrated that the growers were reducing their offerings in the market, he largely abandoned the program. Most of his work was given to Dr. John Giordano of Chunchula, Alabama, who planted them on his estate and is credited with their preservation. Dr. John Allen Smith's Magnolia Nursery offered a few hybrids, but the majority of Aromi's work was never marketed. Van der Giessen Nursery released a series of Aromi's evergreen azaleas in 2003 and is currently working with Dr. Giordano to evaluate the seedlings planted in 1976. These are primarily Zone 7 hardy Indicas with improved flower color and form.

Dr. Smith, a well-respected plantsman and azalea enthusiast, worked with Aromi to develop his deciduous hybrids until Dr. Smith's death in 2000. Dr. Smith and his nursery manager, David Ellis, registered eight cultivars in 1996. These early hybrids were widely marketed and remain the best known of Aromi's work. After Dr. Smith's passing, Linda Erdman Guy, currently of Carolina Nursery, and Maarten van der Giessen of van der Giessen Nursery continued to help Dr. Aromi market his later work. Van der Giessen inherited Aromi's program after Aromi's death in 2004 and continues to evaluate his seedlings.

Aromi made 1045 crosses between 1969 and 2003, he described over 5000 seedlings, and he named 109 deciduous cultivars. The America Rhododendron Society (ARS) named Aromi hybrid 'Glory Be' Rhododendron of the Year in 2000, and the ARS named 'Red Pepper' Rhododendron of the Year in 2006. Aromi created a race of azaleas that are disease resistant, heat tolerant, and as beautiful as any seen in the history of horticulture (Tables 1 and 2).

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Table 1. The Aromi evergreen hybrids.

Cultivar	Parentage	Form	Color
'Amelia Rose' (BL-5)	'Elsie Lee' × 'Pride of Prichard'	Double H-in-H	78A (reddish purple) blotch 60A (deep red), 83 mm (3¼ inches)
'Angel White' (YY-1)	'Pink Champagne' × Hallie GF-7	Double	White, blotch 149A (yellow-green), 55 mm (2 inches)
'Ballerina Pink' (ZK-8)	'Overture' × 'Pride of Prichard'	Single	60B (strong purplish red) blotch 71B (strong reddish-purple), 80 mm (3 inches)
'Belle of Dixie' (VW-4)	'Margaret Douglass' × 'Fascination'	Single	39A (strong red) with white center, blotch 55A (purplish red), 85 mm (3 1/3 inches)
'Crinoline Pink' (ACQ-1)	'Pink Champagne' × 'Rosebud'	Double	66C (strong purplish red) blotch 63A (purplish red), 70 mm (2 3/4 inches)
'Hallie' (GF-7)	'Elsie Lee' × 'Red Ribbons'	Double H-in-H	55A (vivid purplish red) (self), 70 mm (2 3/4 inches)
Isabella Group (HW-5)	'President Cleays' × 'Red Slippers'	Single	42A (deep reddish orange) blotch 46A (deep red), 100 mm (4 inches)
'KAM' (R-46)	'Giant Ruffles' × 'Pride of Prichard'	Single	53C (strong purplish red) blotch 53A (deep red), 100 mm (4 inches)
'Lavender Lad' (P-3)	'Elegans Superba' × *R. poukhanense*	Single	74C (light reddish purple) blotch 59A (dark burgundy/red-purple), 70 mm (2 3/4 inches)
'Lavender Lass' (GF-13)	'Elsie Lee' × 'Red Ribbons'	Single	74C (light reddish purple) blotch 71B (strong reddish purple, 85 mm (3 1/3 inches)
'Lavender Waltz' (GF-17)	'Elsie Lee' × 'Red Ribbons'	Double H-in-H	74B (vivid reddish purple) blotch 71A (deep reddish purple), 75 mm (3 inches)
'Marilynn Jane' (R-10)	'Giant Ruffles' × 'Pride of Prichard'	Single H-in-H	54A ruffled (deep purplish red) heavy blotch 53D (deep red), 90 mm (3 1/2 inches)

'Micheale Lux' (GF-16)	'Elsie Lee' × 'Red Ribbons'	Single	66C (strong purplish red/pink) blotch 63A (strong purplish red), 70 mm ($2^{3}/_{4}$ inches)
'Mixed Emotions' (KM-1)	'Giant Ruffles' × 'Margaret Douglas'	Single	43C (deep yellow-pink) blotch 52A (strong red), 90 mm ($3^{1}/_{2}$ inches)
'Overture' (SI-7)	'Glacier' × 'Elegans Superba'	Single	47D (deep pink) blotch 61B (vivid purplish red), 60 mm ($2^{1}/_{3}$ inches)
'Pink Petticoats' (W-1)	'Elsie Lee' × 'Pride of Prichard'	Double H-in-H	63B (strong purplish red) blotch 67A (purplish red), 83 mm ($3^{1}/_{4}$ inches)
'Platinum Pink' (CB-7)	'Vittata Fortunei' × 'Dream'	Single	78D (light reddish purple) blotch 60D (deep purplish red), 78 mm (3 inches)
'Purple Paragon' (A-19)	'Hinode-giri' × 'Amoena Superba'	Single H-in-H	72A (deep purplish red) (self), 38 mm ($1^{1}/_{2}$ inches)
'Red Echo' (W-1)	Sport of 'Redwing'	Single H-in-H	53B (deep red) blotch 53A (deep red), 78 mm (3 inches)
'Red Embers' (VX-1)	DM-5 × EG-10	Single	44A (vivid strong red) blotch 43A (deep reddish orange), 60 mm ($2^{1}/_{3}$ inches)
'Red Raspberry' (AEY-1)	'Red Slipper' × BY-1	Single	53C (strong purplish red) blotch 53A (deep red), 76 mm (3 inches)
'Red Ribbons' (R-2)	'Giant Ruffles' × 'Pride of Prichard'	Semi-double	58B (strong purplish red), blotch 46B (vivid red), 90 mm ($3^{1}/_{2}$ inches)
'Salmon Sequin' (ZG-3)	'September Song' × HW-1	Single	47C (light reddish purple) blotch 53B (deep red), 75 mm (3 inches)
'Sea Spray' (AK-3)	'Glacier' × 'Lilacina'	Single	White (self) 76 mm (3 inches)
'September Song' (IJ-6)	CK-10 × *R. oldhami*	Single	41A (vivid reddish orange) blotch 53A (deep red), 60 mm ($2^{1}/_{3}$ inches)
'Shipley' (Q-31)	'California Sunset' × 'Gloria'	Single, H-in-H	63B (strong purplish red), 61A (strong purplish red) blotch, 75 mm (3 inches)

'Solace' (YV-4)	P-2 × 'Sandra Ann'	Single	65B (pale purple) blotch and freckles 64A (deep reddish), 65 mm (2½ inches)
'Sophia' (DM-2)	'Giant Ruffles' × '(Elegans Superba' × *R. poukhanense)*	Single	54A (deep/strong purplish red/light yellow-pink) blotch 60A (deep red/rose), 90 mm (3½ inches)
'Temple Alexandra' (R-23)	'Giant Ruffles' × 'Pride of Prichard'	Single H-in-H	63A (strong purplish red) blotch 60A (deep red), 82 mm (3¼ inches)
'Twilight Queen' (VR-1)	EG-1 × 'Omurasaki'	Single	71C (pink) blotch 71A (deep purplish red), 76 mm (3 inches)
'White Wings' (ZK-1)	'Overture' × 'Pride of Prichard'	Single H-in-H	white flecked 74B (vivid reddish purple) faint blotch 1C (light greenish yellow), 80 mm (3 inches)

Table 2. Named Aromi deciduous hybrids.

Cultivar	Parentage	Description
'Amy Dennis' (AHF-13)	AAP-1 × 'George Reynolds'	Large fragrant light lemon (10A) yellow flowers lightly flushed red-orange (34D) on petal edges and bud tips with a strong yellow blotch
'Appalachian Gold' (QG-2).	*R. austrinum* × 'Appalachia'	Large golden (21A) flowers with a deep gold blotch
'April Fanfare' (AJN-2)	TW-2 × *R. austrinum*	2-inch fragrant bright yellow (21B) flower lightly flushed red-orange (34A) on bud tips and tubes with a strong yellow blotch
'April Follies' (AHC-19)	'George Reynolds' × *R. austrinum*	Large fragrant bright yellow (21B lightly flushed 34C) flowers with a deep yellow blotch
'April Yellow' (ADX-2)	'Sunbeam' × HM-1	3-inch fragrant bright yellow (15B) flowers with a very light flush of red-orange (34B) on the petal tips and deep yellow blotch
'Aromi Sunrise' (HM-7)	'Hiawatha' × *R. austrinum*	Red-orange buds open to yellow orange (21C) flowers with darker shading in the center, Registered

'Aromi Sunstruck' (HH-4)	*R. austrinum* × 'White Swan'	Pale yellow buds open to lemon yellow (13A) flowers with a deep yellow (23A) blotch, Registered
'Bees Haven' (AGC-3)	(*R. austrinum* × *R. alabamense*) × yellow Exbury	Small fragrant white flowers with a light pink (55A) flush on stamens and a strong yellow blotch
'Canary Islands' (HR-1)	Pale yellow *R. austrinum* × 'Golden Sunset'	Large yellow (13A) flowers flushed orange on petal tips and tubes
'Cayenne Capers' (AAR-2)	HL-7 × OH-1	1½-inch heavily fragrant deep yellow flowers (23B) with a heavy flush of strong red (46A) and deeper yellow blotch (23A)
'Centerpiece' (NF-1)	'Fool's Folly' × 'Elmer's Yellow'	Light cream buds open to white flowers with a deep yellow blotch
'Clearcreek' (AAV-1)	OF-1 × 'Centerpiece'	Translucent yellow (white flushed 11A) flowers with a darker yellow blotch
'Coral Reef' (AIJ-3)	XS-1 × 'Decidedly Pink'	Light yellow (21C) flowers with a heavy flush of dark red (53A) on petals and tubes, no blotch or fragrance
'Country Cousin' (AGY-6)	XL-1 × 'Gann's Legacy'	Deep red buds open to 2-inch white flowers flushed deep red (47A) with a golden blotch
'Courtship' (AIB-6)	ZU-2 × 'Decidedly Pink'	Large white flowers with cardinal red (53D) on petal edges and a deep yellow blotch and buds cardinal red
'Dancing Rabbit' (ADY-4)	'Appalachian Gold' × 'Goldstrike'	Fragrant bright yellow (14C) flowers with a deep yellow blotch
'Decidedly Pink' (XW-1)	KY-7 × NR-1	Large lightly fragrant white flower heavily flushed cardinal red (53B) with a deep yellow (23A) blotch
'First Love' (AGR-5)	UU-1 × 'Red Chameleon'	Large fragrant white flowers flushed dark cardinal red (53B) on petal edges and tubes with a bright yellow blotch
'Flirtation Pink' (AHZ-5)	(*R. speciosum* × *R. canescens*) × 'Decidedly Pink'	2¼-inch lightly fragrant white flower heavily flushed cardinal red (53A) on petal edges, very heavy flush on buds and tubes
'Fool's Folly' (AL-37)	'Rothschild Orange' × *R. austrinum*	Orange buds open to bright yellow flowers (21B) with a light orange (34A) flush

'Forty-niner' (AL-49)	'Rothschild Orange' × *R. austrinum*	Golden flowers (25C) with a flush of scarlet (34A) and a deep gold blotch
'Four Kings' (GM-1)	'Golden Peace' × *R. austrinum*	Red buds open to bright yellow (15B) 2-inch flowers with a faint red (47A) flush and a deep yellow (21A) blotch
'Four Sisters' (XS-3)	'June Jubilee' × NR-1	Cardinal red buds open to 1 3/4 inch fragrant white flowers flushed cardinal red (53c), strong yellow blotch
'Frontier Gold' (AL-28)	'Rothschild Orange' × *R. austrinum*	Orange-scarlet buds open to golden flowers (23B) with scarlet (34A) shading and a deeper golden blotch, Registered
'Frontier Red' (HT-2)	'Forty-niner' × 'Tintoretto'	3-inch red-orange (30A) flowers flushed bright red (43-A) with red tubes and faint orange (25A) blotch
'Gene's Gold' (TJ-3)	'Persian Mellon' × GK-2	Creamy gold flowers (23B) with tips lightly flushed with rose (34-A) and faint (24A) blotch
'Glory Be' (ADU-1)	'June Jubilee' × 'Rufus'	Many large bright yellow (15A) fragrant flowers with a deep yellow blotch
'Goldrush' (HO-2)	'Forty-niner' × 'Hiawatha'	Large golden-yellow flowers (23B) flushed red-orange (34A) with a deep gold (23A) blotch
'Goldstrike' (QY-1)	AL-48 × 'Four Kings'	Deep yellow (21B) flowers with an orange blotch
'Heads Up' (SW-2)	'Four Kings' × 'Persian Mellon'	Light yellow (17D) with a faint red (45C) flush, a golden blotch, red tubes and many buds that stand erect
'Hearts' Afire' (VC-1)	*R. canescens* × pink mollis	Large red-orange (23B flushed 45A) flowers with a deep red-orange blotch
'High Tide' (AAV-2)	OF-1 × 'Centerpiece'	Ivory flowers with a gold (23A) blotch and a light pink flush on the petal tips
'High Times' (AIR-2)	'Decidedly Pink' × 'Lemonade'	2½-inch fragrant bright yellow flower (21B) lightly flushed red-orange (34A) on petal edges, tips and tubes, strong yellow blotch
'Honey Lamb' (HX-2)	*R. canescens* × 'Rufus'	2-inch purplish-pink flowers (64C) with a deep gold blotch (25A), sterile

'Honeybee Hobnob' (ADS-3)	'Goldstrike' × 'Centerpiece'	2½-inch fragrant light yellow (16A) flower flushed bright red (47A) with a strong yellow blotch
'Indian Spring' (HT-1)	'Forty-niner' × 'Tintoretto'	Light yellow flower (16B) flushed dark red (45D) on petals and tube, yellow orange (21A) blotch
'Indian Yellow' (TK-1	FU-1 × 'Gillian's Gold'	Large light yellow (15B) fragrant flowers shaded bright red (34A) with a strong yellow blotch
'Jack of Hearts' (AGI-4)	YI-2 × YP-2	June blooming red-orange (16B flushed 53B) flowers with a yellow blotch
'Jane's Gold' (GY-2)	'Pathfinder' × 'Golden Sunset'	Cream-yellow flowers (15B) with tips lightly flushed with rose (3A), strong yellow-orange (23A) blotch
'Jeanette Ann' (LC-1)	*R. alabamense* × AL-10	White flushed pink (55B) on the petal tips, blotch 23A
'John Giordano' (WJ-1)	(AL-45 × 'Rufus') × *R. calendulaceum*	Orange (24A) flushed vivid red-orange (46A), yellow-orange blotch (23A), fragrant, 8-inch head
'Jonquil Yellow' (AJI-3)	ADS-2 × YW-1	2-inch fragrant lemon-yellow (15A) flower with a deep yellow blotch
'Jubilation' (MW-1)	'Sandra Marie' × *R. austrinum*	Large light yellow flowers (19A) flushed red-orange (34A) with a strong yellow orange (23A) blotch
'Julius Kingsley' (AGR-8)	UU-1 × 'Red Chameleon'	White flushed with deep red (53-A), faint yellow blotch (21A)
'June Jubilee' (EP-1)	(*R. prunifolium* × *R. serrulatum*) × *R. arborescens*	Late blooming small very fragrant white flowers and dark glossy leaves
'Kevin Patrick' (AIT-13)	'Spanish Main' × 'Jubilation'	Red buds open to orange flowers (19A) with a deep pink (50B) flush and a yellow (21A) blotch
'King's Jester' (ACJ-1)	('Rothschild Orange' × *R. austrinum*) × 'Knighthood'	Large fragrant yellow (22B) flowers with a red (47C) flush and deep yellow blotch
'King's Ransom' (AGL-4)	(*R. austrinum* × 'Primrose')	2-inch light yellow (16A) fragrant flowers with a red-orange (34A) flush on petal tips and tubes

'King's Treasure' (AIC-1)	TW-2 × OM-1	Large fragrant bright yellow buds flushed red-orange opening to pure yellow flowers (15A) with a deep yellow blotch
'King's Trumpeter' (AIJ-4)	XS-1 × 'Decidedly Pink'	Dark red buds open to fragrant bright yellow (21C) flowers with a heavy flush of dark red (53A) on petals and tubes
'King's Wizard' (AIP-1)	XZ-3 × **???**	2-inch fragrant bright yellow flower flushed bright red with a deep yellow blotch and heavy flush on buds and tubes
'Lacecap' (RJ-1)	*R. viscosum* × dark red Ilam	Light pink (white flushed 52A) flowers open wide in a flat truss
'Laughing Lion' (AGZ-1)	UP-1 × 'Gann's Legacy'	Light yellow(12B) fragrant flowers with a deep red (46A) flush on petal edges, heavier flush on buds and tubes, yellow (23A)blotch
'Lemon Lullaby' (ADX-3)	'Sunbeam' × HM-1	Large fragrant light yellow (15B) flowers with a deep yellow blotch
'Lemonade' (XU-2)	HG-1 × 'Sham's Yellow'	Large lemon yellow (9C) flowers with a deep yellow blotch
'Liz Colbert' (LN-1)	(*R. serrulatum* × *R. austrinum*)	Brick red buds open to light peach flowers (white flushed 52B) with a yellow-orange (16A) blotch, Registered
'Marilyn Jeanne' (AGR-6)	UU-1 × 'Red Chameleon'	White heavily flushed with deep red (53A), strong yellow (21A) blotch
'Moon Dreams' (AAV-7)	OF-1 × 'Centerpiece'	Large fragrant white flower with a deep yellow (23A) blotch
'Misty Dawn' (AJY-1)	TL–1 × AAV-8	White flowers with pink flush (white flushed 55A) on bud tips and petal edges and a yellow (21A) blotch, early
'Neon' (ADR-1)	TW-1 × TJ-1	$1^{3}/_{4}$-inch fragrant deep yellow (23A) flower lightly flushed red-orange (34A), stronger yellow (23A) blotch
'Old Rose' (AGY-5)	Xl-1 × 'Gann's Legacy'	2-inch flowers of damask rose (white flushed 47A) with a golden blotch
'Orange Cloud' (NS-2)	AL-24 × ('Gibraltar' × *R. austrinum*)	2½-inch fragrant flowers of pure orange (30D) with a deep yellow blotch
'Orange Rhyme' (WA-1)	'Gibraltar' × MV-1	Bright orange (25A) flushed bright red (47A) with a deep yellow blotch
'Pale Moon' (AAV-12)	OF-1 × 'Centerpiece'	Large very fragrant white flower with a deep yellow blotch (23A)
'Pathfinder' (AL-4)	'Rothschild Orange' × *R. austrinum)*	Orange buds open to golden flowers (23A flushed 39A) with a deep golden blotch, Registered

'Peach Glow' (ADS-5)	'Goldstrike' × 'Centerpiece'	Red-orange buds open to 2-inch fragrant light yellow (12B) flowers with a red-orange (34A) flush on the petal tips.
'Pink Carousel' (RA-1)	*R. austrinum* × 'Red Letter'	Scarlet buds (34A) open to pale pink flowers (24B flushed 34A) with a strong golden (23A) blotch, Registered
'Pink Promise' (XT-2)	('Rothschild Orange' × *R. austrinum*) × 'Hotspur'	Very large fragrant peach pink (43C) flowers with a deep yellow blotch
'Pirate's Booty' (ACB-3)	'Frontier Red' × ('Cecile' × 'Balls of Fire')	Very large deep yellow (21B) flower heavily flushed deep red (46A) with a deep yellow blotch, no fragrance
'Pirate's Pink' (ACB-2)	'Frontier Red' × ('Cecile' × 'Balls of Fire')	Very large lightly fragrant cream flower (13D) heavily flushed bright red (47A) with a bright yellow blotch
'Princess in Pink' (AHU-4)	UY-1 × 'Decidedly Pink'	2-inch fragrant white flower flushed deep pink (53D) on petal edges and tubes with a deep yellow blotch, buds deep pink
'Queen's Ivory' (AKD-1)	AAP-1 × 'Mt. Ranier'	Ivory flowers (11B) with a deep yellow (23A) blotch
'Queen's Lace' (AHU-6).	UY-2 × 'Decidedly Pink'	Very fragrant white flowers with a pink flush on the petal tips and a bright yellow (21A) blotch
'Queen's Rose' (AIE-1)	WF-1 × 'Decidedly Pink'	Rose flowers (19B flushed 53A) with a deep yellow blotch and deep red buds and tubes
'Radiant Red' (AHB-6)	(ON-3) × 'Red King'	Dark red buds open to many fragrant bright yellow (20A) flowers heavily flushed dark red (46A) with a deep yellow blotch
'Red Chameleon' (YO-1)	'Crimson Tide' × NR-1	Scarlet buds open to red flowers (47A) that fade to damask rose, strong orange blotch (24A)
'Red Pepper' (QH-1)	'Gallipoli' × *R. austrinum*	Red-orange (32A) flowers with a deeper blotch, Registered
'Red Whisk' (XG-1)	*R. arborescens* × *R. bakeri*	Light lemon yellow (21D) 1½-inch flowers with scarlet (42A) pistils and stamens. Golden yellow (17B) blotch
'Rose Soufflé' (AGI-5)	Y1-2 × YP-2	June blooming rose (43C) flowers with a golden blotch

'Smith Pink' (XT-3)	('Rothschild Orange' × *R. austrinum*) × 'Hotspur'	Large lightly fragrant salmon (47D) flowers with a deep yellow blotch.
'Southern Sunset' (AJC-1)	WM-1 × 'Red Chameleon'	Bright yellow (19C) flowers with a red flush (34A) on the petal edges and a deep yellow blotch
'Spanish Main' (HN-2)	'Tintoretto' × *R. austrinum*	Deep red buds open to red-orange flowers (24B) with a red flush (34A) on the petal edges and a deep yellow (23A) blotch
'Spring Dreams' (AAV-11)	OF-1 × 'Centerpiece'	Large fragrant white flower flushed deep pink (55C) on petal tips with a strong yellow blotch
'Spring Enchantment' (YA-1)	*R. speciosum* × white Exbury	Deep salmon flowers (19B flushed 47C) with a golden blotch
'Spring Fandango' (AIJ-6).	XS-1 × 'Decidedly Pink'	Strong yellow (21C) flowers heavily flushed deep rose (53A) with a deep yellow blotch
'Spring Fanfare' (ADX-1)	'Sunbeam' × HM-1	Bright yellow (15C) petals with a red (34B) flush on the petal tips and a deep yellow blotch
'Spring Frolic' (AIR-1)	'Decidedly Pink' × 'Lemonade'	2-inch very fragrant bright yellow (21B) flower lightly flushed red-orange (34A) on petal tips and buds with a deep yellow blotch
'Spring Pixie' (AJZ-10)	(*R. speciosum* × *R. canescens)* × 'Decidedly Pink'	Medium sized pink (white heavily flushed 53A) flowers with a deep yellow blotch and dark red buds
'Spring Sensation' (WM-1)	W-4 × *R. canescens*	Early blooming. Pastel pink (62D) flowers cover the plant. Very faint pale yellow (8D) blotch
'Spring Snowfall' (AIA-2)	'George Reynolds' × YR-1	Very fragrant large white flowers with a light yellow (13C) flush on the petal midribs and buds, plus a bright yellow (17A) blotch
'Spring Song' (AAV-14)	OF-1 × 'Centerpiece'	Large fragrant cream flower (1D) lightly flushed cardinal red (53D) on petal tips, tubes and bud tips, deep yellow blotch (23A)
'Strawberry Sherbet' (AHX-1)	QT-1 × 'Decidedly Pink'	Large white lightly fragrant flowers with deep pink (55A) flush on petal tips and buds, bright yellow (21A) blotch
'Strawberry Sundae' (AJJ-6)	WM-1 × 'Decidedly Pink'	White petals with a deep pink (66C) flush and a pale yellow (8A) blotch

'Summer Snowball' (AGH-3)	WW-1 × 'June Jubilee'	Medium size fragrant white flowers with a pale yellow (6A) blotch, flowers mass into ball-shaped trusses
'Summer Snowflakes' (AGH-5)	WW-1 × 'June Jubilee'	$1^{3}/_{4}$-inch very fragrant white flower flushed light yellow (12C) on mid-petal and buds with a light yellow (12A) blotch
'Sundown' (YJ-2)	KW-1 × NR-1	Large fragrant light yellow (15C) flowers lightly flushed cardinal red (53B) with a deep yellow blotch. Buds, tubes and stamens are cardinal red
'Sunny Side Up' (HA-9)	*R. austrinum* × 'Golden Sunset'	Pale yellow buds open to lemon yellow flowers (13A) with a darker (23A) blotch, Registered
'Tabasco' (XT-4)	AL-Q × 'Hotspur'	Bright red flowers (23B flushed 53A) with a deep yellow blotch and dark red tubes
'Temple's Toy' (AEG-1)	'Knighthood' × 'Forty-niner'	Deep red buds open to orange flowers (16B) with a deep red (53A) flush on the petal edges and a strong yellow blotch
'Tensaw' (HD-2)	*R. austrinum* × 'Oxydol'	2-inch bright yellow (13B) flowers with a deep yellow (23A) blotch
'Tipsy Tangerine' (XA-1)	GN-1 ×	Scarlet buds open to flowers with several tones of orange on each petal (21A flushed 34A) and a deep yellow blotch
'Touch of Pink' (AAV-5)	OF-1 × 'Centerpiece'	Large fragrant white flower with petal tips and tubes flushed deep pink (55A) and deep yellow blotch
'Tradewinds' (AHC-16)	(*R. austrinum* × 'George Reynolds'	Very fragrant large light yellow (15A) flowers lightly flushed orange (34A) on petal edges, bud tips and tubes with a deep yellow blotch
'Twilight Pink' (AIQ-3)	UQ-1 × 'Decidedly Pink'	Pink flowers (white flushed 53B) with deep red buds and a golden blotch
'Twinkles' (AJJ-1)	WM-1 × 'Decidedly Pink'	White petals with a red flush (white flushed 53D) on the petal edges with a yellow blotch and red tubes
'White Star' (AAH-2)	LB-3 × MX-1	Large white star shaped flower (10D with a very light pink 55B flush on the petal tips), yellow (23A) blotch

[1]Listing courtesy of Eugene Aromi.

Multiple Propagation Techniques of Simpson Nurseries©

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INTRODUCTION

There is some aspect of propagation going on at Simpson Nurseries during at least 10 months out of each year. Multiple propagation techniques have enabled us to grow and adapt to changes in the nursery business over the last hundred years. I will briefly cover four techniques of propagation used by our nursery.

PROPAGATION BY WHIP GRAFTING

Bench Grafting (Apples and Crabapples). We order 1-year domestic seedling apples from Washington State and receive them in January. Bundles of 1-year seedlings are cut into root and root stem pieces on a table saw. We start cutting 2 cm (0.75 inch) above the original soil line, cutting the roots into 5-inch long pieces. The root or root/stem pieces are made just long enough for the grafter to be able to hold them and make the desired cut. The same is done with the scion wood. After the long 1-year-old shoots are removed from the apples and crabapples, the leaves are stripped off and the shoots are cut into 13-cm (5-inch) long sticks using a table saw. The scion and understock are stored at approximately 60 °F, in waxed boxes filled with moist vermiculite.

The scion wood and understock are removed from the storage boxes as needed. The bench grafter selects a root to match the diameter of the scion wood as closely as possible so the cambium layer can be lined up on both sides. One smooth sloping cut should be made ranging in length from 3 to 4 cm (1 to 1.5 inches). The surface on the understock and scion need to be flat and, preferably, the same length. A second cut, the tongue, is made on both pieces starting approximately one third of the way down from the tip on both pieces so the tongues will interlock tightly and smoothly. If the diameter and the cuts on both the scion and understock are exactly the same, the cambium layer will line up exactly on both sides. If that is not possible, the cambium layer is to be matched on one side only. The graft is then passed on to a "wrapper" who will wrap the graft union with 1-cm (0.5-inch) wide adhesive tape and place it in a waxed box with moist coarse vermiculite to be stored at approximately 16 °C (60 °F) for 30 days. At that time the boxes are placed in our walk-in cooler [3 °C (38 °F)] until planting time. We have also bench-grafted some pecans using the same method, but have had mixed results.

Field Grafting (Pecans and Japanese Persimmons). For the pecan understock we plant the varieties "Candy" or "Elliott" seed in rows of two, which are 28 cm (11 inches) apart. The double rows are 1.8 m (6 ft) apart, center of double row to center of double row. The seed are planted in December or January and grown for 2 years before we graft them. We begin grafting in January and start by cutting the scion wood from our stock trees. We also purchase wood from other pecan growers. The scion wood is cut into 20-cm (8-inch) long pins and tied in bundles. The tops are dipped in wax to seal them and keep them from desiccating. As the grafters enter

the field the "digger," as we call them, has already pulled the soil back from the seedling and has wiped the seedling down, removing the dirt from the stem. The grafter makes the same cut as the bench grafter, except usually longer, 1 to 5 cm (0.5 to 2 inches) long. The longer cut, along with the tongue cut, is made, and the scion placed in the understock. Following the grafter is the "wrapper," who wraps the graft with green 1-cm (0.5-inch) plastic tape, then ties it off. The wrapper then mounds the soil back up on the graft, leaving only the top 1/3 of the pin showing. The soil keeps the graft moist and somewhat warm while the graft healing (knitting) process begins. We graft between 20 to 25 cultivars of pecans and usually around 100,000 per year. The grafting process for Japanese persimmons is similar to that of pecans, except that the persimmon seed is planted in three rows in 1.2-m (4-ft) raised field beds. We graft approximately 15,000 persimmons per year.

PROPAGATION BY SEED

Seed in Containers (Oaks, Redbud, Chinese Pistache, Bald Cypress, and Eucalyptus). We plant approximately 100,000 containers with seed. We order the majority of our seed from four different seed companies. The rest we collect and clean ourselves. Depending on the seed, we have various methods of cleaning, treating, and storing. Some, such as live and Shumard oaks are planted fresh. All other seed must be treated in some manner. We moist stratify the remainder of the oaks, pistacia, bald cypress, pear, and persimmon seed. We dry stratify the redbud and eucalyptus. Before we plant the redbud seed we scarify with 70% sulfuric acid for approximately 4 to 5 h, then soak it in warm water overnight.

The majority of our seed, approximately 85,000, is planted in 32 cell Rootmaker® pots measuring 6 × 6 × 10 cm (2.25 × 2.25 × 4 inch) per cell. We continue to plant about 16,000 in bottomless containers measuring 5 × 5 × 13 cm (2 × 2 × 5 inch). Relying on our experience, we know how many seed we need to plant in each pot to give us a good stand. In most cases that means more than one seedling per pot. We pull the smallest, weakest plants out, leaving a strong, healthy plant in the middle of the pot. The oaks, pistacia, redbud, and bald cypress are planted in pots in the greenhouse in January. They are thinned in March and April and potted in 19-L (5-gal) containers in May and June. The earlier we plant the more growth we get by fall. Approximately 30% to 50% of our oak, pistacia, and redbud will be saleable by fall, and 100% of the bald cypress.

Seed in Beds (Pear and Persimmon). Pear and persimmon seed are planted in raised field beds in March and April. The pear seedlings will be chip budded in the fall around September. The persimmon seedlings will be grafted in the spring around March and April.

PROPAGATION BY SOFTWOOD CUTTINGS

We stick approximately 1.3 million softwood cuttings a year. One hundred seventy thousand (170,000) are stuck in Rootmaker 32-cell trays. We also stick 1.1 million softwood cuttings in #881 Jiffy peat pots, which measure 5 × 5 × 8 cm (2 × 2 × 3 inch). The insert holds 81 peat pots and fits perfectly in the 46 × 46 cm (18 × 18 inch) Nursery Supplies flat. Our propagation mix consists of fine milled pine bark [≤ 1 cm (0.5 inch)], coarse perlite, Canadian peat moss, and coarse sand (6 : 2 : 1 : 1, by volume).

Buster Corley, our propagator, oversees all of our softwood propagation as well as our raised field bed production. Buster's softwood propagation team starts getting their cuttings early, between 7:30 and 9:00 AM. His crew of four, sometimes five, women will cut and stick as many as 24,000 cuttings per day. Their goal is 75,000 per week. Most of the cuttings are gathered from our container production area. The shoots they take are piled on a nursery trailer and wrapped in wet burlap. They are off-loaded into a heavily shaded, protected area where they are heavily misted. As the team needs cutting material they remove an armful of shoots and place them in a bathtub filled with water and Zerotol. The Zerotol is used as a disinfectant. After dipping, the cutting material is placed on tables. The tables are sloped towards the middle and tilted away from the cutters so the liquid will drain away from them. We have three women who make cuttings, while a fourth dips the cuttings in rooting hormone and sticks them.

Most of our cuttings are 7 to 13 cm (3 to 5 inches) long, with the bottom 2 cm (0.75 inch) stripped clean of leaves. Some of our cuttings, such as oaks and southern magnolias, are scarred on the ends. The cuttings are then dipped in rooting hormone and placed in trays. When the trays are filled, the cuttings are taken to the mist area and stuck in the appropriate propagation container. The cuttings are to be stuck 2 cm (0.75 inch) deep and no deeper than 2.5 cm (1 inch) on the large cuttings.

The open shade area holds approximately 440,000 cuttings, and the four greenhouses hold about 40,000 cuttings each. The numbers vary depending on the propagation container. We fill our shade area and greenhouses two or three times each summer because of limited space. After the plants are rooted they will either be planted in the raised field bed area or in containers.

PROPAGATION BY CHIP BUDDING

Chip Budding (Fruiting Pears, Flowering Pears, Purple Leaf Plum, and Japanese Persimmon). We chip bud in September and again in March and April. For our understock we plant 1-year liners in 1.2-m (4-ft) raised field beds in February and seed in March and April. The plants will grow until September, when they will be chip budded. As the chip budding season approaches, we prepare the understock by removing any lower branches or leaves from the main stem and cut the tops back. Seven to ten days later we begin cutting the scion wood from our container production area or stock blocks. The shoots, which closely match the diameter of the understock at 1 to 2.5 cm (0.5 to l inch), are cut into sticks approximately 30 to 38 cm (12 to 15 inch) long. Then the leaves are trimmed off. The sticks are rolled in bundles of 30 to 35 in wet newspaper. The bundles are stored in the walk-in cooler until needed.

A chip of bark is removed near the base of the understock and replaced by another chip from the budstick containing the desired cultivar. The chip cut out of the understock and the replacement chip should be as close to the same size as possible. Both chips are cut out making the exact same cut. The first cut is made just below the bud and barely down into the wood at a 30° to 40° angle. The second cut starts approximately 2.5 cm (1 inch) above the bud. The cut is made inward and downward behind the bud until it meets or intersects the first cut. The chip from the understock is removed and replaced by a chip from the budstick. Just as is done in grafting, it is important to match the cambium layer of the chip with that of the understock. If the budder can make similar cuts in similar-size scion and understock

wood, the cambium layer on both sides of the chip will line up with the cambium layer of the understock. If that is not possible then one side should be lined up.

The next step is for the "wrapper" to follow close behind and wrap the chip. It is very important that the chip bud be wrapped to seal the cut edges as well as to hold the chip tightly in place. We use a clear tape that completely covers from below the chip all the way up above the chip. The tape is removed in approximately 28 days. If this process is done in the fall the top is not removed until the following spring. During the first 2 weeks in March the live-budded trees are cut back just above the live chip. The plants with dead chips are left alone and rebudded at the end of March or early April. We chip bud approximately 90,000 plants per year.

Lusting for the New — Is There a Market Beyond Branding?©

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INTRODUCTION

The logistics and talent to propagate a hundred thousand or more of a plant is mind boggling to me. One hundred or less is within my experience. With very limited numbers and a premium price, we have found success with new introductions to our customers. Just selecting marketable plants is a challenge in itself. In this talk I wish to point out some plants and qualities that I've found customers yearn to have and how we have lured them to buy — without branding. Branding definitely profits those who find or create a winner. But it takes big numbers and lots of money to support and advertise this kind of venture. Not all of us have the wherewithal to pull this off. For sure, hot "new" plants draw customers and keep you on their radar screens.

Money is the bottom line in all our efforts. If the retail customer isn't interested, the money stops flowing all the way back down the horticultural line. Our job in retail is to make our customers delirious — well, satisfied — with their purchase and hopefully increase their interest to return for more. Retailers' sales depend on receiving excellent plant material including the right information for the hardiness zone and climate in which it will be grown in the ground.

We promote the best time to plant trees, shrubs, and perennials (in the ground) in our area is late fall through winter. However this is the very time a customer may have to select among "twigs" in containers. With such names as 'Autumn Blaze' and 'Florida Flame', a customer's imagination is truly stretched. They want to believe you — but will that twig really become a tree and in how many years? Signs help give pertinent information salesmen might not even know. It behooves all involved in producing a new plant to provide as much useful, customer-friendly information as possible if we want to sell it. Consider your wholesale salesmen taking what's new to a retail nursery employee meeting for a preview. What an opportunity to foster excitement among those who sell this material to the public.

About 15 years ago, I planted a shumard oak that was initially destined for the compost pile. Its life in an 11-L (3-gal) container had been distressed; it was a non-salable "Charlie Brown" tree. Within a very few years, it grew into a very nice shade tree — just what many of our customers desire in our unrelenting hot summers. They watched this one grow large and handsome and could readily visualize what a dormant 11-L (3-gal) containerized shumard or nuttal oak would become. A prominently planted specimen becomes a "silent" salesman.

Likewise, perennial flowers go dormant at the very time we encourage planting them. It's a hard sell convincing a customer to buy a container with no visible flowers. Digital photography makes it possible for both grower and the retailer to "sell" dormant plants. Inventories written with highly descriptive language trump simple specs, but pictures are worth a thousand words. Too often a new plant will not sell solely because your retail buyer does not have a clue what it is or what it looks like in its mature state. Its botanical name may add to the mystery. You will increase

your sales if you can provide a picture of what the containerized plant promises to become. Are you familiar with *Dianthera nodosa*? This is a good example of a perennial probably not widely known. With its picture, you can clearly see its flower power and growth habit. This is certainly more impressive than listing or verbalizing its botanical name.

Odontonema cuspidatum, which is commonly called fire spike or cardinal's guard, exemplifies what customers want. It thrives in sun or shade and produces showy red inflorescences over a long period in late summer and fall. Its glossy green foliage makes a good foil for shorter perennials. Hummingbirds are attracted to it. It is pest free and easy to maintain. Once established, it tolerates drought relatively well. Customers want something pretty, useful, and easy to grow and maintain. They need to know why they should buy it, how to use it, and how to make it thrive. Communicating what makes a product so wonderful is the key to selling new material.

The market for hydrangeas is huge. Everyone has jumped into this honey pot. More and more cultivars are appearing. But how many is enough? Dr. Gary Knox at the University of Florida, North Florida Research & Education Center, has a huge hydrangea collection, some remontant, some not, which are planted out for trialing. I visited at the tail end of the heaviest flowering season and unscientifically noted that H. 'Mrs. Blackburn', a cutting taken from a local Quincy, Florida, garden, seemed to be the best performer. Branded taxa in our steamy climate have been disappointing in their performance during this past extraordinarily dry year. However, evaluation over several years will separate the real winners. There is room for new unusual ones that retain clean foliage and have recurring flowers, but maybe this market is close to saturation. An informal survey confirms blue mopheads outsell all others. Tallahassee Nurseries had over 23 hydrangea cultivars last spring; what sold was whatever was blooming, but blue mopheads led sales by far. The big question is will retail customers come back to buy enough of these new unusual cultivars to warrant the sales space?

Likewise, loropetalums stormed onto the horticultural scene. Now that they are ubiquitous in our area, new uses are going to be needed to keep them marketable. Here is an example in Orlando, Florida, of using them as a low hedge in a commercial setting.

Do you remember Allen Bush's Holbrook Farms here in North Carolina? Once a week he cleverly gave tours of his beautifully maintained display gardens. After which you bought as many 4-inch or 1-gal perennials as money or car space would allow. It was here that we first saw *Abelia chinensis*; growing into a small tree with cascading branches and terminal white flower clusters, it makes a very nice choice as a small "patio" tree. But in the container it often looks unremarkable next to *A.* × *grandiflora*. Take a picture of it flowering for your customers and be sure to promote it for its outstanding cut flowers and as an excellent species for attracting butterflies.

Pittosporum shrubs are a little like junipers, useful but somewhat boring. However, they can be pruned into attractive small trees. New uses can revitalize old plant material.

A Mexican manager at a Greensboro, Florida, wholesale nursery grows on the side 11-L (3-gal) spineless opuntias, which he sells to many Mexicans in the area who primarily use them for cooking. These opuntias are attractive, different, and salable. Perhaps we should look for more plants with specific ethnic interests in

mind. Our area has many Mexican, Asian, and Caribbean groups who are also customers and have money to spend on products they want. Edibles often are ornamental but may be overlooked by growers. We have enjoyed good sales with ornamental peppers as an example.

There is a renaissance of rhizomatous, angel wing, cane and hybridized begonias. What beautiful and varied flowers and foliage they have! While some are hardy when planted in the landscape in North Florida, they make excellent container specimens performing over a long season. I see this market continuing to grow because they bring customer satisfaction and are a great show for their cost.

Some genera are avoided because there are thugs in their ranks. For example, clerodendrums in Florida have a bad reputation caused by a few species. Their flowers are alluring, while their growth habit is aggressive to seriously invasive. No grower wants to promote a rogue. Dr. Rick Schoellhorn insisted I take cuttings from his 2.4-m (8-ft) specimen, *Clerodendrum wallichii,* which had not flowered. Trusting this would not be a wandering ogre, I soon was awed by its magnificent flowers in October. It defies the reputation of the genus, having never seeded and spread, but reliably flowering with appealing dark green foliage and a narrow upright growth habit. You may be overlooking some great species because you avoid certain genera.

The north is beginning to embrace more tropical plants. Flamboyant and often unique, they have attracted new fans and good sales despite many lacking cold hardiness. Basjoo banana withstands cold, I have heard, all the way to Connecticut. It goes dormant wherever freezes occur, but returns reliably to Zone 7. My introduction to this came from a teensy plug from Agri-Starts, who would guess this would turn into a colony of 5-m (16-ft) giants. Edith Edelman's use of "bodacious" aptly describes this. You may remember she is another North Carolinian and renowned perennial garden designer. Perhaps shipping constrictions may be a reason more growers shun this ornamental banana. Tissue culture has revolutionized access to the tropical world, providing growers with the kind of numbers they need to even bother with growing a specific crop.

Some gingers, which can be easily shipped, are still not very visible on the market. These tropicals certainly fill a niche in the heat of late summer through early fall. They are stunning.

Alan Shapiro of Grandiflora Nursery introduced me to *Aloysia virgata*, sweet almond bush. I am very impressed with its vigor and terminal fragrant white inflorescences flushing over a very long flowering period. Our customers love fragrant plants. With proper pruning, it can be sized to a very nice landscape specimen of 1.8 to 2.1 m (6 to 7 ft). Furthermore, the foliage feels like sandpaper.

Mahonias are gaining more interest with breeders and growers. *Mahonia gracillipes*, originally from Heronswood Nurseries, has beautiful blue-green foliage with tiny pink flowers in early fall. It is a very handsome ornamental. Awareness of this and other new mahonias are definitely worth considering for new crops.

Bulbs are, I am sure, expensive to grow and sell. But if you want to try this, you will need to encourage your retail clients to plant some in their display areas or a highly visible municipal park. Three lycoris bulbs (white, red, or yellow) in a bulb pan will certainly sell when flowering. And price them for the specialty they are. For years, a retired local man has grown *Scadoxus multiflorus* (syn. *Haemanthus multiflorus*) in 3.7-L (1-gal) containers, selling at retail for $6.99 each. All of them

sell. What can you buy today for as little as $6.99 that will continue to bring pleasure for years to come? More attention from breeders and growers is being paid to crocosmias. 'Walberton Yellow' seems to have an edge on many of the cultivars available; the genus has loads of potential. They're colorful with good sword-like foliage in contrast to so many other perennials.

Vines usually grow so quickly they can become a labor-intensive nightmare for the grower not to mention the logistics of shipping. But more and more people are living in condos or smaller houses, where vertical gardening is a good choice, and vines are an excellent option. Two vines worth noting for their color, vigor, and overall showiness are *Thunbergia grandiflora* 'Variegata' and *Mascagnia macroptera*. Vines deserve a closer look by industry.

Color pots are over the top. Boldly colored nursery containers can detract from what is really being sold. Recycling colored cans with branding hasn't worked well yet in our area. Monrovia Growers is taking back their Monrovia pots and perhaps others are too. A biodegradable container might be one answer. I believe customers want to be dazzled primarily by the plants themselves.

Visit and evaluate plant material at your local university and commercial trial gardens. There is vast knowledge to be had and new potential winners. How fortunate we have been to have our palette of plants hugely expanded by passionate horticulturists like Drs. Dirr, Armitage, Knox, Bowden, Rick Schoellhorn, the late J.C. Raulston, and many others. Their generosity has spread excitement and new possibilities for all of us.

Temperature Control and Water Conservation in Above-Ground Containers©

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INTRODUCTION

Excess heat in above-ground containers has long been recognized as a major problem. The challenge has been to find a practical way to moderate temperature. Harris (1967) measured temperatures in California 8 cm (3 inch) below the surface and 2.5 cm (1 inch) from the exposed edge of metal containers painted black or white, covered by aluminum foil, or shaded by wood. Exposed sides of black containers reached 46° C (115 °F) and remained at or above 38 °C (100 °F). There were no roots in about 33% of the container volume due to excessive heat. Painting the container white reduced temperature only 3 to 4 °C (5 to 7 °F), while aluminum foil reduced temperature about 5.5 °C (10 °F), but temperatures were still above the lethal point for roots. Shading containers with wood was the most effective treatment; none of these treatments were commercially feasible.

Whitcomb (1980) compared injection molded containers made of white or black plastic and found the white container only about 3 °C (5 °F) cooler. Temperature reduction was minimal because white containers were translucent. The light penetration not only increased temperature, but also produced a thick algal slime on the inside. Whitcomb (1983) and Whitcomb and Mahoney (1984) reported that white on black co-extruded plastic containers were 4 to 7 °C (7 to 12 °F) cooler than black containers, which reached a maximum of 56 °C (132 °F) on the sun-exposed side in Oklahoma. Temperature reduction was insufficient to allow roots to survive.

As temperature in container growth medium increases, so does the rate of evaporation and transpiration, while root function and the portion of container volume suitable for root growth declines. Under summer conditions in Oklahoma, plant water uptake for a 24-h period ranges from 16% to 32%, while the remaining 84% to 68% is lost to evaporation.

All irrigation waters contain low to high salt levels. Salts are all compounds soluble in water. Some salts used for fertilization are desirable, such as potassium sulfate and ammonium nitrate, since potassium, sulfate, ammonium, and nitrate are all essential for plant growth and beneficial unless applied in excess. On the other hand, salts like sodium chloride (non-essential element), and excess amounts of calcium bicarbonate and calcium chloride are undesirable and can be detrimental to plant growth. When water evaporates, residual salts are left behind.

The RootTrapper® (patent pending) container is made of an insulating black fabric with a bonded coating of white polyethylene on the outside. The container sidewall is impervious to water loss and root penetration. The RootTrapper has vertical sides and a flat bottom which aids stability and reduces blow over (Fig. 1). In addition, the RootTrapper stops roots from circling by trapping root tips in the fabric inner wall and stimulates root branching. Root tip trapping was discovered to be the factor that stimulated additional branching in polyethylene bags with

Figure 1. White RootTrapper® containers are cooler and conserve water.

gusset-folded bottoms (Whitcomb 1979, 1983, 1988, 2003). Root-tip trapping was later used to reduce root circling and stimulate root branching in stair-step pots (Whitcomb and Williams, 1983). By reducing root zone temperatures by 11 to 14 °C (20 to 25 °F), the RootTrapper containers reduce water loss by evaporation. Unlike conventional containers, drainage is through thousands of small holes around the bottom. By having very small drain holes, more water is retained and nutrient loss by leaching is minimized (Fare, 1998). Greater water retention in the container also reduces potential non-point-source pollution and simplifies water recycling (Fare, 1998 and 1999).

Containers made of porous fabric have previously been studied and found to have water loss rates two to three times greater than conventional plastic pots in Oklahoma (Whitcomb, 2003). The increased evaporation is due to the pervious nature of the fabric. In addition, the porous fabric containers turned green with algae near the bottom and white with salts above. The soluble salts come from fertilizers used in the growth medium and irrigation water. Pruning of roots on the sidewall may be due to high salt concentrations, causing root death as well as dehydration pruning (Whitcomb, 2003). The RootMaker® air-root-pruning container openings make up less than 2% of the sidewall, while RootBuilder air-root-pruning openings make up about 5% of the sidewall.

Water availability is of increasing concern, as well as taking steps to minimize nutrient runoff from nurseries (Fare, 1999). Several states, including Florida, California, and Texas, have begun water-monitoring programs and are likely to restrict water use by nurseries in the future. Likewise, water runoff, fertilizer leaching, and effects on recycling water systems are important considerations when selecting

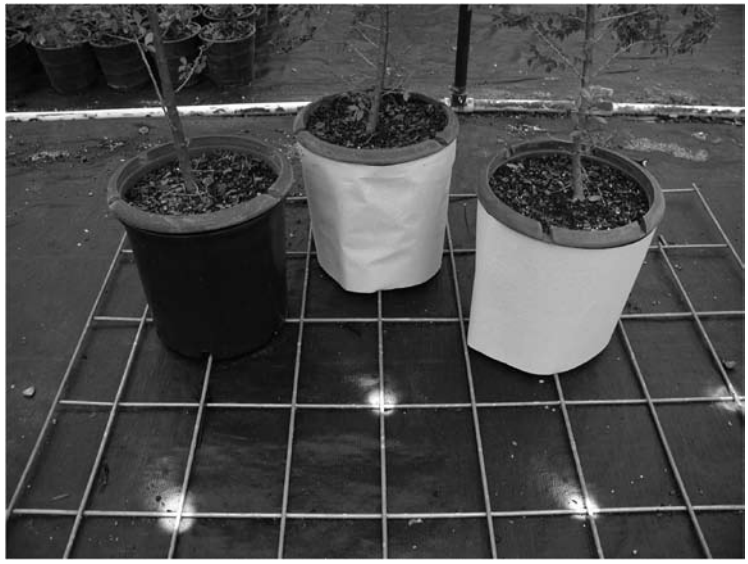

Figure 2. RootSkirts® made of the same white-on-black insulating fabric as the RootTrapper® container can be installed directly on production containers or on permanent support pots into which production containers are inserted.

the most suitable container. One study found 86% less nitrate leaching when the drainage hole in a conventional container was reduced from 2 to 0.5 cm (0.8 to 0.2 inches), with no adverse effect on plant growth (Fare, 1998).

MATERIALS AND METHODS

Four studies were conducted dealing with temperature control and water conservation in above-ground containers.

Experiment 1. Containers (32-L, 7-gal) with different sidewall composition were compared for rate of water loss. The container sidewalls were: (1) conventional black plastic, (2) a porous fabric that readily allows water evaporation through the sidewall, (3) a white laminated fabric impervious to water (RootTrapper) with exposed mix surface, and (4) a white laminated fabric impervious to water (RootTrapper) with surface protected by a fabric disc of the same material.

The containers were filled with an air-dry pine bark, peat, sand growth medium (3 : 1 : 1, by volume) to the same depth and weight. The containers were then watered repeatedly by hand to thoroughly wet and settle the mix. Weight of the containers was then determined every hour for 8 h. Wetting and water loss measurements were repeated five times. All water loss was due to evaporation since there were no plants in the containers.

Experiment 2. In order to determine the composition of the accumulated salts and effects of the high rate of water lost on movement of nutrient elements, a comparison of 57- and 114-L (15- and 30-gal) containers made of black porous fabric versus

white, impervious fabric (RootTrapper) were studied. The containers were filled with a mix of pine bark, peat and sand (3 : 1 : 1 by volume) and planted to several species of trees. Watering was by overhead irrigation.

Experiment 3. Temperatures were compared between 26-L (7-gal) white RootTrapper containers versus conventional black plastic containers. All container temperatures were measured between 13:00 and 15:00 along the inside wall exposed to full sun and at 8 cm (3 inches) below the surface. Species tested were shumard oak (*Quercus shumardii*) and catalpa (*Catalpa bignonioides*). Growth medium was pine bark, peat, and sand (3 : 1 : 1, by volume). Watering was by overhead sprinklers.

Experiment 4. Temperatures were monitored on 11-L (3-gal) containers, as reported in Experiment 3. Treatments were: (1) conventional black plastic container, (2) conventional black plastic container inserted snugly in a support pot to prevent blow over, (3) conventional black plastic container setting inside a larger container with a space between the container walls, (4) RootMaker #3 air-root-pruning container alone, (5) RootMaker #3 containers fitted with insulating RootSkirt® made from white, laminated RootTrapper fabric (Fig. 2), and (6) RootMaker #3 container in a support pot fitted with RootSkirt.

RESULTS

Experiment 1. The conventional black plastic 27-L (7-gal) containers held 11.2 pounds of water 1 h after the last thorough watering. The water held by the standard 27-L (7-gal) plastic container was assigned 100%. Water held initially and rate of loss from other containers was plotted relative to the standard black plastic pot.

Water loss from the container with porous fabric sidewall was greatest. One hour after watering, the porous fabric container lost 11% more water than the standard plastic pot. On the other hand, after 1 h containers made of white laminated fabric impervious to water (RootTrapper) held 12% more water that the standard plastic pot with surface exposed and 16% more with surface covered. After 8 h the container with porous fabric sidewall had lost 32% of the total water held, whereas the standard black plastic pot had lost 15%, while the white laminated fabric container had lost only 10% with its surface exposed, and 5% with surface covered. Saving 22% to 27% of irrigation water applied after 8 h is a significant reduction in water use.

To put these findings in perspective, a nursery with 5000 plants in #7 containers made of porous fabric would lose by evaporation 2,162 gal or 2.1 times more water every 8 h under the conditions of this study, compared to loss from a standard black plastic pot (1,021 gal), and 3.2 times more water compared to containers made of white impervious sidewall (RootTrapper) with a loss of only 660 gal. In 8 h, conventional black plastic containers lost 1.5 times more water compared to white RootTrapper containers.

Experiment 2. Containers with porous fabric sidewalls quickly turned from black to grayish-white due to evaporation and accumulation of salts. At the end of the growing season samples of salts washed from the fabric sidewall revealed that the main components were calcium, sulfur, and bicarbonates, with lesser quantities of potassium, ammonium, and other elements (Table 1). Because the trees were watered by overhead sprinklers, the more soluble nitrate, potassium, and magnesium were likely washed off, through the porous ground cover cloth and into the soil below.

Table 1. Analysis of salts accumulated on outside of porous uncoated black fabric bag after four months with overhead irrigation. A 0.3 m^2 (1 ft^2) section of fabric was removed from the container, soaked in distilled water (approx. two parts water to one part sidewall material by weight), then the solution analyzed.

NH_4-N	NO_3-N	P	K	Ca	Mg	Na	S	Fe	Zn	Mn	Cu	Bicarb	Cl-
Black fabric outer surface													
19.1	0.6	14.5	66.3	583.9	30.3	11.6	480.1	0.1	0	0.8	0	242	11.3

Note: Values are in parts per million (ppm)

Table 2. Analysis of growth media in two types of containers after 5 months. A 0.1 N HCl was used as the extracting agent for nutrients. Soluble salts were determined using 2:1 water to media and expressed as $mmho \cdot cm^{-1}$.

NH_4-N	NO_3-N	P	K	Ca	Mg	Na	S	Fe	Zn	Mn	Cu	Salt level	pH
Black fabric 1 inch inside wall													
358	293	302	1205	6321	584	151	448	312	116	164	49	2.1	4.8
Black fabric, 6 inches													
124	53	278	786	2370	486	101	412	156	79	100	38	0.69	4.4
RootTrapper® 1 inch inside wall													
99	62	205	522	2548	485	84	138	229	72	94	31	0.95	4.6
RootTrapper 6 inches													
114	53	196	509	2526	503	87	101	210	79	88	29	0.89	4.6

Table 3. Root-zone temperatures in black versus white RootTrapper containers monitored on 5 summer days. All container temperatures were measured against the inside wall exposed to full sun and 7.6 cm (3-inches) below the surface during times from 13:00 to 15:00.

Date	Air temperature (°F)	Black container temperature (°F)	White RootTrapper temperature (°F)
26 May	84	107	88
22 July	104	127	109
16 Aug.	98	124	101
31 Aug.	92	119	96
12 Sept.	94	125	96

To better understand the effect of a high rate of water evaporation from a container sidewall, samples of growth medium 1-inch in diameter were removed just inside the fabric wall and 15 cm (6 inches) inside on containers with porous and white nonporous sidewalls. Water movement from inner areas of the growth medium to the sidewall of the porous fabric container transported from high to modest quantities of nutrient elements (Table 2). Nitrate-N was 5.5 times and ammonium-N 2.9 times higher near the sidewall versus at 15 cm (6 inches). Potassium, calcium, and iron were 1.5, 2.6, and 2.0 times higher, respectively, near the sidewall versus the internal 5 cm (6 inches) of the container medium. Soluble salts were three times higher near the sidewall and reached toxicity levels (Ann., 1997 and Whitcomb, 2003) compared to the internal 5 cm (6 inches) of the container medium (Table 2). White containers with impervious sidewalls had similar nutrient and soluble salts levels.

Experiment 3. Temperatures against the sidewall were reduced from 10 °C (18 °F) during May and July and 13 to 16 °C (23 to 29 °F) during Aug. and Sept. (Table 3). When the sun was directly overhead, temperature moderation was less (May and July readings). As the sun moved southward during the later part of summer, and contacted container sidewall more directly, the temperature reduction was greater.

When root development was evaluated on 18 Sept., there were no roots on the exposed side of the black container. Approximately 30% of the container volume was wasted. By contrast, there were many roots with white root tips on the exposed side of the white RootTrapper container.

Experiment 4. When RootSkirts were installed either directly on production containers or on support pots in which production containers were located in order to prevent blow over, temperature reductions were similar to those observed in Expt. 3 (Table 3). When production containers fit snugly against the inside wall of the support pots and no RootSkirts were used, the support pot provided little or no temperature moderation. On the other hand, if there was a space of 1 to 2.5 cm (0.5 to 1 inch) between the side of the support pot and the production container and no RootSkirt was used, a temperature reduction of 3 to 5 °C (5 to 9 °F) was measured. This difference is due to direct transfer of heat through the two plastic containers when touching compared to the "chimney effect" between the two containers when some space occurred. The chimney effect resulted from the air between the containers being heated and rising, which drew in cooler air, lowering the container temperature.

DISCUSSION

Benefits of containers made of white on black laminated and insulating fabric include:

- White, laminated fabric (RootTrapper) containers used 1.5 times less water than conventional black plastic containers and 3.2 times less water than porous fabric containers.
- White laminated onto black fabric blocks out light and stops internal algae growth.
- Conserves water by reducing temperature.
- Conserves water and nutrients by slowing exit of water.
- Trapping of root tips stimulates root branching.
- Additional root branching back in the growth medium increases absorption of water and nutrients.
- No root circling was observed.
- Tough and durable, RootTrapper can be dropped, shifted, lifted, or dragged.
- Broad, flat bottom reduces blow over problem.
- Broad, flat bottom increases heat dissipation to the earth in summer and heat absorption in winter.
- Accelerates growth of some species.
- Accelerates establishment into the next size container or into the landscape.
- Containers are easily removed and may be reused.
- Easy to fill and handle.
- Lightweight and easy to ship.
- There are no sharp edges to damage other plants during shipping.
- No toxic copper or other chemicals.
- Economical, particularly in sizes of 10 gal or larger.

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Propagation at May Nursery©

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INTRODUCTION

I have a crew of 12 women who collect and stick their own cuttings. They can do 18,000-40,000 a day depending upon the taxon. We go out first thing in the morning while there is either dew on the plants or just the coolness of the morning has the cuttings in a fresh state. We stop cutting and harvesting and come into an air-conditioned propagation room by 10:00 AM. We have to be careful that the moisture level does not get too low since the air conditioning removes the moisture from the air. We keep the temperature at 22 °C (72 °F). As we take the cuttings, they are brought in every 20–30 min, watered down, and placed on a screened rack. We do not dip them in a fungicide because we have a weekly spray program for the propagation area. If cuttings are from clean, healthy plants, a fungicidal dip is not necessary.

We place newspapers on the table where the cuttings are prepared, then throw away the paper at the end of the day. This is done so that if by chance a cutting has a disease problem, it will not be carried over into the next day's cuttings. Each bag has the employee's name on it, and each employee is assigned a number. As they stick their cuttings, they place a tag with their number in the area they are sticking. We do this for quality control; if there is a problem, we know who stuck those cuttings and can make corrections. This is also good for success, so you can share with other workers what the particular employee did for their results.

As they are sticking an area, they put sandwich baggies over the sprinkler nearest them so they can stick cuttings without having to stop the misters in adjacent areas; thus, the cuttings stuck the previous day will not dry out.

We use Research Organics to supply the 10,000 ppm IBA solution to which water is added to dilute the solution to fit the concentrations needed for cuttings we are sticking that day. I try to stick plants that use the same concentration of auxin and root in the same time frame.

We use trays with 36 or 64 inserts depending on the size of the cuttings. These trays are thrown away after use. We place the trays either on raised pipe benches in houses or on 0.3 × 1.6-m (1 × 6-ft) boards in the shade for drainage and aeration. The same women, who do the propagating fill their own trays. They divide into two groups — six fill and six place the propagation trays into their location.

The mix we use is perlite and aged bark (2 : 3, v/v). This is mixed in a 6 yd^3 Davis Mixer. We add 6 $kg \cdot m^{-3}$ (15 lb/yd^3) of 18N-6P-8K Nutricote Type 360, 2.4 $kg \cdot m^3$ (4 lb/yd^3) each of Epson salts ($MgSO_4$) and limestone, and 0.15 $kg \cdot m^{-3}$ (0.25 lb/yd^3) of Subdue. We use this formula with all plant species, except azaleas, which does not have lime incorporated.

We use a spinner-type nozzle for mist, which does well for the rooting process and growing stage. We are in the city limits of Havana, Florida, so we use city water for the propagation area. We also have a well tied into the propagation area in case the city's pressure drops below 60 pounds of pressure. We have a natural-gas-operated generator that automatically cuts on should we lose power. A 24-h time clock is

hooked up to a Phytotronics (http://www.phytotronics.com) mist controller. It comes on 2 h after sunrise and cuts off 1 h to 30 min before sunset, depending upon the time of year. The first 2–3 days after sticking, the mist comes on every 4 min in the morning, and in the afternoon it comes on for every 2 min for 10 sec. After that, it comes on every 8 min for 10 sec until rooting starts to occur. After that, the hardening off process begins. The cuttings are pruned during preparation for sticking and at least once or twice before potting. Every 6 weeks, we put out a granular herbicide and there is a weekly fungicide and insecticide application. All houses and shades are covered with 30% shade cloth.

Larger Plants from Liquid-Based Micropropagation: A Case Study With *Hydrangea quercifolia* 'Sike's Dwarf'©

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INTRODUCTION

Liquid-based Micropropagation. Virtually all commercial micropropagation in the U.S.A. uses semi-solid "gelled" medium (agar or similar polymers) to support plantlets on medium surface. Gelling agents are the most expensive component of media. They slow laboratory operations, including medium preparation, dishwashing, subculture, and moving plants to greenhouse. Gels also slow plant growth by limiting the availability of water and nutrients. A variety of liquid bioreactor systems have been designed for micropropagation. The "motorized" function of these bioreactors is to provide oxygen to the propagules while their entire plant surface is wet with liquid medium. Cost and complexity are the largest barriers to commercial utility.

Our lab has shown a simple rocker system yielded more and larger plants than agar with herbaceous perennials including hosta (Adelberg, 2005), elephant ear (Adelberg and Toler, 2004), and daylily (Adelberg et al., 2005). Subsequent transfer to greenhouse and nursery yielded robust plants with high rates of survival. Woody plants, however, often become hyperhydric (waterlogged) if grown immersed in liquids. Hyperhydric shoots do not acclimatize to ex vitro greenhouse or nursery conditions. Temporary immersion systems (TIS) have been successful in avoiding hyperhydricity in large numbers of woody plant genera (Berthouly and Etienne, 2005). Our experience with woody plants on rocker (*Clematis, Hydrangea,* and *Nandina*) shows hyperhydricity occurred during partial submersion on the floor of the vessel.

Micropropagation of *Hydrangea quercifolia*. *Hydrangea quercifolia* is a four-season woody ornamental plant native to North America. Improved clones have been selected for compact stature, large flowers, brilliant fall color, and exfoliating bark. Commercial laboratories currently produce several cultivars of *H. quercifolia* on agar-based medium with some reports published on axillary shoot proliferation, rooting, and acclimatization (Sebastian and Heuser, 1987; Ledbetter and Preece, 2003).

Our objectives were to: (1) develop a liquid-based micropropagation system with *H. quercifolia* Bartr.'Sike's Dwarf' as a model plant; and (2) compare growth of plantlets from agar and liquid medium during greenhouse acclimatization.

MATERIALS AND METHODS

Explant Preparation. Shoots were collected in November from mature specimens at South Carolina Botanical Gardens. Large, dormant buds were cut from stems and stripped of pubescence with 70% ethanol. Several layers of bud scales were removed while immersed in 1 : 1 mix of commercial bleach to water. Buds were then rinsed in sterile-distilled water and individually planted in test tubes containing 5 ml of Murashige and Skoog (MS) medium, 1μM benzyladenine (BA), 30 $g \cdot L^{-1}$ sucrose and

Table 1. Size of *Hydrangea quercifolia* 'Sike's Dwarf' plantlets and shoots from two harvest periods, in Summer 2006.

		Plantlet length (lab) [cm]	Shoot length (greenhouse) [cm]	Large leaves (no.) [greenhouse]
Early summer	Agar	0.9 c	2.6 c	1.5 c
	Liquid	2.1 a	4.4 b	3.7 b
Late summer	Agar	1.7 b	5.0 b	3.9 b
	Liquid	2.2 a	6.0 a	5.1 a

Note: a, b, and c indicate treatment means within columns were different at p=0.05.

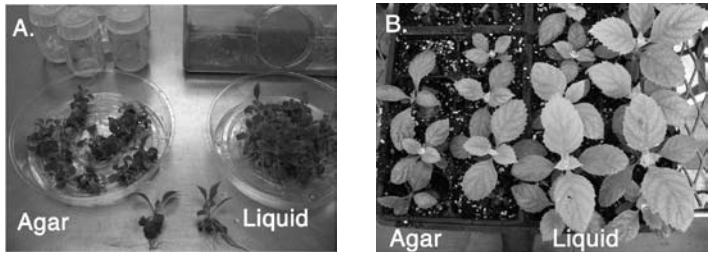

Figure 1. Plantlets from agar and liquid at planting (left) and after 3-weeks in mist (right).

solidified with 0.6% agar. Axillary divisions were replanted as single node cuttings every 6 to 8 weeks in 180 ml baby food jars containing 35 ml of medium with 3 to 6 nodes per jar. After about four transfers, 2.5 μM 2-iP was substituted as cytokine.

Liquid Systems. Liquid medium was same as above without agar. A rocker platform (Adelberg and Simpson, 2004) with an articulated shelf creating a 1-rpm swing every 15 min with the vessel remaining inclined for 14 min. Large rectangular rocker vessels (11 × 30 cm; Southern Sun Biosystems, Hodges, South Carolina) contained 210 ml of medium lined with germination paper (Anchor Paper Co., St. Paul, Minnesota) supported on a capillary mat (polyester fiber needle-punched to a density 150 $g \cdot m^{-2}$, Clemson University Non-woven Fabric Laboratory).

Comparison of Plants Produced on Agar and Liquid. Five nodes were placed in each of 35 jars containing agar gelled medium, as above. Thirty-five nodes were placed in each of five rocker vessels on germination paper supported by capillary mat. Shoots were grown for 6 weeks in the laboratory and used to establish a second repetition of the experiment. Plantlets not used for repetition were measured (shoot length and mass). Sugar level in residual medium was measured on a refractometer as % BRIX (BRIX = 1 g sucrose per 100 ml medium; Atago Instruments, Tokyo, Japan). Residual media was rinsed from the roots, and plantlets were placed in moist soilless mix (Fafard 3B, Fafard Inc., Anderson, South Carolina) in 1204 cells under intermittent mist (6 sec on every 6 min during day) for 3 weeks. Plants were moved to greenhouse for another 3 weeks and hand-water fertigated, as needed, with Peter's Peat-lite 20N–10P–20K (Scotts, Marysville, Ohio) at 100 ppm N. Plants from

Figure 2. Plants after 3 weeks in mist and 3 weeks in greenhouse range.

the first repetition (early summer) went to mist frame 10 June, and the second repetition followed on 25 July (late summer). Greenhouse plants were measured for stem length (cm) and number of large leaves (> 3 cm leaf blades) per plant. Plant size was graded by creating a numerical score (numbers of large leaves + stem length). Scores were sorted into five size categories by Statistica 7.1 (Statsoft, Tulsa, Oklahoma).

RESULTS AND DISCUSSION

Developing a Liquid System. 'Sike's Dwarf' shoots multiplied on agar-based medium in baby food jars. Agar could be replaced by floating a sheet of paper on top of the liquid medium on a sealed air raft (Osmotek Ltd, Rehovot, Israel). This produced a mixture of normal and hyperhydric shoots by allowing internode elongation to occur in gaseous headspace of vessel. We replaced the floating raft with a capillary mat infused with liquid medium that supported the paper. When placed on rocker shelf, a bead of liquid medium would intermittently wet the base of the shoots.

Comparison of Shoots Grown in Agar and Liquid. Both agar and liquid culture produced elongated shoots with fibrous roots that were ready for acclimatization to greenhouse (Fig. 1). Plantlets were not hyperhydric when grown in liquid on the paper/mat system. Shoots produced in liquid culture had longer stems than shoots produced in agar culture at both harvest dates (Table 1). There was a large amount of variation in shoot size from both treatments, and plantlets from the second harvest of agar were longer than plantlets from the first harvest on agar. Shoots from agar and liquid systems had similar fresh and dry weights when they left the lab (data not shown). There was a significantly higher concentration of sugar residual in agar medium than liquid medium at harvest (4% vs. 3% BRIX). This indicated that either less water was available to plants while growing in agar or plants in agar used less sugar.

Nearly 100% of plants survived acclimatization and subsequent transfer to greenhouse bench from both agar and liquid. The greatest difference between agar and liquid cultured plantlets was seen in the mist-bed and greenhouse nursery. Plants from liquid grew more quickly on the mist bed (Fig. 1b). Plants from agar were noticeably smaller than plants from liquid, and there was a large variation in plant sizes among treatments (Fig. 2). Plants from liquid had longer stems and more large

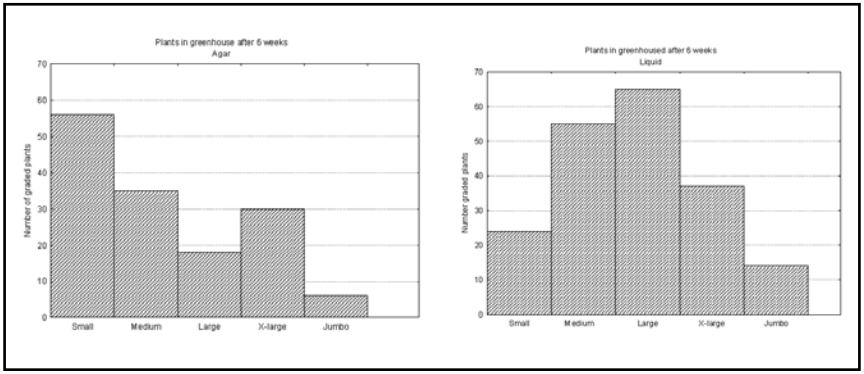

Figure 3. Five size grades (stem length + large leaves) were assigned to 336 plants.

leaves per plant (Table 1). Shoot and root fresh and dry weights of plants in greenhouse were also greater from prior liquid medium treatment (data not shown).

Variation in plant size is a common occurrence in commercial micropropagation. Industry labs usually sort liner materials in the greenhouse to ensure delivery of a uniform product. We conducted a scoring procedure to sort plants from agar and liquid by adding plant height to the numbers of large leaves. Plants from agar were represented in the five categories. The greatest numbers of plants from agar were in the "small" category and the population was skewed (Fig. 3). Plants from liquid produced a normally distributed population with the greatest number of plants being "large." There were more and larger plants produced from liquid than agar.

Hydrangea plants from liquid had greater greenhouse growth than plants from agar. We can speculate as to several possible reasons. Compared to agar, plants on liquid had greater access to water and sugar in the lab thus they possessed more stored carbohydrate available for new growth in greenhouse. Alternatively, there may be less root damage when rinsing liquid media than removing agar residues, during planting. Lastly, the taller shoots from liquid may have a morphological advantage for photosynthetic growth in greenhouse. We conclude that other woody species would benefit from liquid micropropagation systems, when hyperhydricity is controlled. These benefits become apparent during increased subsequent growth in greenhouse.

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Redneck Lupines on a Roll: Breeding Advances in the genus *Baptisia*©

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INTRODUCTION

My love for baptisias began many years ago, but it was in 1994 that I went off the proverbial deep end for this herbaceous genus of glorified peas in the family Fabaceae (Leguminosae). Perhaps it was my numerous unsuccessful attempts to grow other Fabaceae genera such as *Lupinus* that led me to the virtually indestructible genus *Baptisia* and its 16 currently recognized species. It is obvious from their native range that baptisias are extraordinarily drought tolerant lovers of hot weather. Consequently, gardeners growing them in cool climates will benefit from siting them in the hottest of garden locations.

Baptisia is an Eastern North American genus of prairie plants that range from Canada south to Florida and west to Texas. The genus *Baptisia* made its debut in 1808, although it was not formalized until 1811 by Robert Brown. Species that had been described decades earlier under the genera *Sophora* and *Crotalaria* slowly began their migration into the new genus. While taxonomy in *Baptisia* has come a long way, there are still differing opinions between taxonomic lumpers and splitters.

My study of the genus was greatly aided by the 1940 *Baptisia* monograph, authored by the late botanist Mary Maxine Larisey, former instructor at Wellesley College. The monograph is particularly detailed, not only with species descriptions, but with locations of each population. By the end of 2005, I had made 31 trips across the U.S. to find and collect baptisia specimens. When we travel in flower season, we collect cuttings, while later season trips are for seed collections.

You may find it strange that plants documented from the 1930s can still be found in their original locations, but fortunately, baptisias often grow in areas now used for livestock production or military bases. Since baptisia are unpalatable to livestock and durable to tanks, many of our best specimens are from the midst of extensive fields. Many farmers have fortunately given up trying to rid their fields of these "weeds." I have certainly tried to do my part to help and have more than one unintentional barbed wire tattoo to remind me of that effort.

Baptisia foliage is primarily trifoliate with the exception of three simple-leaf species: *B. arachnifera*, *B. simplicifolia*, and *B. perfoliata*. Baptisia species come in three basic flower colors: blue, white, and yellow (creamy and bright). Now that some of the natural hybrids are being propagated as well as intentional crosses made, it won't be long before we see reds and pinks joining the mix. Although the blue species are best known in gardens, they are in actuality the rarest color in the genus. The flowering time for baptisia is from late March to August, while their floral display ranges from terminal inflorescences to axillary flowers.

THE BLUE-FLOWERED SPECIES

The most commonly cultivated baptisia is *B. australis*. While *B. australis* is certainly a garden worthy plant, it is far from being the star of the genus. Native to riverbanks from Vermont south to the Shenandoah Valley of Virginia, *B. australis*

is one of the larger species, making a 0.9 m (3 ft) tall × 1.5 to 1.8 m (5 to 6 ft) wide mound of glaucous blue-green foliage. The flower spikes emerge atop the newly emerging foliage in mid-April. By late April, the flowers begin to open, ranging from a good blue to purple color. Most seed strains of *B. australis* produce tall flower spikes, which, like a good drunk, can become a bit wobbly with age.

The most garden-worthy of the blue-flowered species is *B. minor*. *Baptisia minor* is virtually unknown commercially, because some moth-ball-inhaling herbarium taxonomist decided it was synonymous with *B. australis*. A few taxonomists still call it a subspecies of *B. australis*, while many now elevate it to species status, with which we concur. The disjunct U.S. East Coast remnant populations are now considered *B. minor* var. *aberrans*, while the main U.S. Midwest populations are now *B. minor* var. *minor*.

Baptisia minor is a much smaller plant than *B. australis*, rarely exceeding 0.6 m (2 ft) tall. The leaves are much smaller, presenting a more lacy textural appearance. The best feature of *B. minor* is the 30 to 46 cm (12 to 18 inch) tall spikes of large blue or lavender flowers, which don't become lax like *B. australis*. I enjoy *B. minor* in seed as well, since the huge pods turn a magnificent pure black when mature. In the wild, a clump of *B. minor* will usually have only two to five flower spikes, a number that increases slightly in cultivation. We grew seed from numerous populations and have so far selected one cultivar, *B. minor* 'Blue Pearls', from a collection north of Dallas, Texas. *Baptisia minor* 'Blue Pearls' is significantly more floriferous than typical, with over 50 flowers spikes per plant.

One of my most exciting baptisia finds occurred when a North Carolina botanist friend, Craig Moretz, took me to a remote population where we found three pink-flowering plants of *Baptisia minor*. We were successful in propagating these from cuttings and now have them on trial.

THE WHITE-FLOWERED SPECIES

The white-flowered species have suffered from being taxonomically muddled. Due to errors in the original 1940 monograph, incorrect names have made their way into the trade and have left gardeners wondering exactly which white baptisia they are growing. The most commonly seen names are *B. alba, B. leucantha,* and *B. pendula*. When the smoke from the taxonomist guns had cleared, *B. alba* became *B. albescens*, *B. leucantha* became *B. alba* var. *macrophylla*, and *B. pendula* became *B. alba* var. *alba*. The white-flowered species are much later flowering than most of the blue- or yellow-flowered species, with only a few exceptions. *Baptisia alba* var. *macrophylla* (formerly *B. leucantha*) has a huge native range from Minnesota south to Tennessee. It is also one of the tallest species, ranging from 1.5 to 2.1 m (5 to 7 ft) tall. Although each clump doesn't produce many flower spikes, the ones that are produced are stunningly beautiful. Plants from the northern end of the range do not emerge until June, while plants from the southern end of the range emerge in late April.

Baptisia alba var. *alba* (formerly *B. pendula*), or thick pod wild indigo, is the southeastern form of *B. alba*. It is easily recognizable from *B. alba* var. *macrophylla* (*B. leucantha*) due to its large black pendant seed pods and shorter stature to 0.9 to 1.5 m (3 to 5 ft) tall. It is native throughout the southeast from North Carolina to Florida. After growing plants from across the range, we introduced a stunning 1.5-m-tall (5-ft-tall) selection from a population in Wayne County, North Carolina, that we named *B. alba* 'Wayne's World'.

A third white species is the southeastern native, *Baptisia albescens* (formerly *B. alba*), ranging from Tennessee to Florida. This airy-textured species is prized both for its smaller leaves and shorter stature, usually 1.2 m (4 ft) tall or less. It can be distinguished from the other white-flowered species by its narrow seed pod that turns tan when dry instead of black. One *Baptisia albescens* specimen that I saw in central North Carolina was growing 2.1 m (7 ft) tall on a dry road bank; just imagine what it would do in good garden conditions.

THE CREAMY YELLOW-FLOWERED SPECIES

One of my favorites is the little known *B. bracteata*. *Baptisia bracteata* is often divided into two varieties: *B. bracteata* var. *bracteata* and *B. bracteata* var. *leucophaea* (syn: *B. leucophaea*). *Baptisia bracteata* var. *leucophaea* occurs from Texas north to Minnesota, while *B. bracteata* var. *bracteata* is its southern counterpart and only occurs from North Carolina south to Alabama.

All members of the "bracteata" group are very early flowering, often starting in late March to early April in North Carolina. Instead of having upright flower stalks, they emerge horizontally like giant clusters of creamy-yellow grapes. Many regional forms of *B. bracteata* var. *leucophaea* emerge with a dark purple cast to the new foliage that disappears as they come into flower. We have introduced a very dwarf form that we found in Oklahoma under the name *B.* 'Little Texas', and will follow up shortly with an extraordinarily heavy flowering form named B. 'Butterball'.

While most of the light-yellow-flowered species have pendulous inflorescences, B. *nuttalliana* is an exception. Although the May-produced light-yellow flowers of this deep southeastern U.S.A. species are axillary, their naturally spherical form gives them good garden presence. We hope to have a vegetatively propagated selection of this species to market in the near future.

THE BRIGHT YELLOW-FLOWERED SPECIES

It's easy to agree that the most horticulturally worthy of the yellow-flowering species is *B. sphaerocarpa* (syn: *B. viridis*). It's hard to find any other *Baptisia* that has as much flower power as this species, found from Texas to Missouri. In situ, it grows as well in dry fields as in wet swales. In cultivation, a single specimen will attain a height of 76 cm (30 inches) with a spread of 0.9 m (3 ft) and can produce over 130 flower spikes at once! When *B. sphaerocarpa* comes into flower in mid- to late April with its large bright yellow flowers, it's truly a photographic moment. After flowering, *B. sphaerocarpa* produces its namesake distinctive, nearly indestructible, spherical marble-size seed pods. *Baptisia sphaerocarpa* 'Screamin' Yellow' (1996) is a green-leaf selection from Arkansas introduced by native plant expert Larry Lowman. The Arkansas forms are distinguished from the narrower and more glaucous foliage that the species possesses as it moves south into southern Oklahoma and Texas.

While none of the other yellow species are as showy in flower, there are certainly some that stand out for their foliage. The rare coastal Georgia native *B. arachnifera* is so rare that it has been declared a U.S. Federally Endangered Species. If you can manage to find nursery-propagated *B. arachnifera* for your garden, select an open spot in the rock garden for best performance. *Baptisia arachnifera* has round silvery webbed foliage on a small plant that rarely exceeds 38 cm (15 inches) in height. The inconspicuous small yellow flowers appear in the leaf axils in August.

Baptisia perfoliata is another unique foliage specimen. This glaucous green-foliaged endemic to a couple of southern highways, in particular Interstate 20 in South Carolina and Georgia, is also often mistaken for eucalyptus. Clumps of *B. perfoliata* will eventually make a 0.7-m (30-inch) tall × 0.9-m (3-ft) wide clump of amazing foliage. The April-produced axillary yellow flowers give way to small round seed pods that dry next to the leaf. The foliage of *B. perfoliata* turns brown in late summer, leaving amazing brown eucalyptus-looking stems that have tremendous floral arrangement possibilities. We have introduced a particularly vigorous selection from an herbicide-decimated South Carolina population that we named *B. perfoliata* 'Survivor'.

For small spaces, the North and South Carolina sandhills and coastal plains native, *B. cinerea*, is a great choice, but one that is often overlooked. It resembles a short and less showy *B. bracteata* var. *leucophaea* that rarely exceeds 30 cm (1 ft) in height, and is adorned with horizontal flower panicles of bright yellow in early spring, usually April. The more southerly version of *B. cinerea* is *B. lanceolata*, which is found from Georgia south to Florida. It also produces interesting small spikes of bright yellow flowers in April/May. Both of these species go dormant early, and the foliage turns brown, often by August.

Another good garden specimen is the widespread *B. tinctoria*, which ranges from Canada to Georgia. The tiny foliage and equally small terminal spike of yellow flowers are far from showy but serve as a wonderful 0.6- to 0.9-m (2- to 3-ft) tall border filler. Depending on which part of the range your plants originate, this species goes from being a tight clumper to a vigorous spreader. With a little selection for foliage and flowering characteristics, this airy-textured species could easily become a garden standard.

The other truly unique member of the genus is *B. simplicifolia*. This Florida endemic has not only proven reliably hardy in Zone 5, but has the strange habit of not emerging before July. While this is understandable for a Zone 5 native, it makes no sense for a plant from Florida. Our guess is that it was part of a larger ancient glaciation's dump from a more northern climate. Once it does emerge, the glossy green simple leaf looks very un-baptisia like. *Baptisia simplicifolia* is topped with terminal spikes of yellow from July to August in our garden.

SELECTIONS AND HYBRIDS

In addition to species selections, several bi-specific hybrids have begun to enter the trade. Since baptisias are sexually quite promiscuous, there are probably many hybrids already present in gardens that are masquerading as species. Unfortunately, many of these hybrids are not improvements on the native species. There are, however, times when a hybrid is better than the parents, such as two introductions from the late Rob Gardner of the North Carolina Botanical Garden (NCBG) in Chapel Hill, North Carolina.

With an extensive baptisia collection in their garden, it should not be surprising that some horticultural hanky-panky would occur. The first introduction in 1996 was a cross between *B. minor* var. *aberrans* and *B. albescens*, which was given the name of *B.* 'Purple Smoke'. *Baptisia* 'Purple Smoke' picked up the tall charcoal flower stalk from *B. albescens* and the purple flower color from *B. minor*.

The second of the NCBG releases, introduced in 2002, is *B.* 'Carolina Moonlight', a cross between *B. sphaerocarpa* and *B. albescens*. This amazingly vigorous plant has upright spikes of light buttery yellow and is the first baptisia with creamy

yellow flowers held on anything other than a pendulous spike. Well-grown plants of either of these hybrids will hold their own against any lupine and, in time, will far bypass them in duration.

I am still amazed that *Baptisia* hybrids have not hit the market earlier, but this shows the lack of communication between botanists and horticulturists. In my early research, I read about a group of naturally occurring baptisia hybrids that were documented in Oklahoma and Texas as early as the late 1930s. After tracking down the 1996 Botanical Research Institute of Texas (BRIT) publication that showed color pictures of these same bicolor hybrids (blue and yellow and red and yellow), I was on the phone to the author to inquire about cuttings. I was told that the plants had been accidentally sprayed with weed killer the year prior by the landowner. But, the botanists proudly proclaimed, "We have dried herbarium specimens." How did these plants escape being propagated, while being known for 60 years?

On the bright side, we have since found a number of other naturally occurring hybrid populations and have now been able to duplicate the Texas hybrids in cultivation. *Baptisia* 'Chocolate Chip' from Minnesota's Hans Hansen was the first of these bicolor purple and yellow hybrids to enter the market in 2005.

Dr. Jim Ault of the Chicago Botanic Gardens released *B.* 'Midnite' in 2006, which we have just begun to grow. *Baptisia* 'Midnite', like many other bicolor F1 hybrids, produces short flower spikes that are covered by the emerging foliage. We have found that this trait can be minimized in the F2 and future generations. I look forward to growing more of his upcoming releases that have yet to be named.

We have now incorporated three to four species in many of our own hybrids and have an array of colors and forms, some of which may eventually reach the market. Although it's hard to imagine why it took so long for breeders to tackle this wonderful genus of plants, the future certainly looks bright.

PROPAGATION

Propagation of baptisias is relatively easy once you understand a bit about the plants. Most baptisias are currently propagated from seed. This is fine as long as the seed blocks are isolated, but rarely is this the case. As I mentioned earlier, baptisia are very promiscuous in the garden, at least with other baptisia. I'll bet that if all the *B. australis* in gardens were DNA tested, few would be found as the true species.

Fresh sown baptisia seed germinates quite easy and quite fast, usually in 2 weeks. Old stored seed, on the other hand, is very difficult and slow to sprout. I recommend that all old baptisia seed be placed in a Styrofoam cup and doused in boiling water and allowed to cool prior to planting. This will begin to break down the seed coat and encourage germination. We have even tried this on seed that was sown but showed sporadic germination. Un-germinated seed were sifted from the potting mix, drenched with boiling water, and resown, with amazing results.

Another propagation method for baptisia is stem cuttings. Most baptisias root easy in late spring and early summer when the growth is soft, but the success rate drops off to zero as the plants harden. Cuttings should be dipped in a rooting hormone and then kept in high humidity until they root, usually about 8 weeks.

A commonly encountered problem with cutting-propagated baptisias is one of overwintering. If plants grown from cuttings do not get large enough before they go dormant, they will not produce enough energy to form new growth buds for the following spring.

Additionally, it is important to stick one to two nodes under the soil. If not, you will find a mass of roots in spring that will fail to send up any foliage. I like to keep newly rooted containerized plants in a warm greenhouse or on a windowsill until the new buds develop at the base, after which time they can be allowed to go dormant. New advances such as tissue culture propagation of baptisias have done wonders to increase numbers more rapidly and overcome some of the overwintering issues that we have faced with conventional cuttings.

With all the advances in selecting, breeding, and propagation of baptisias, the future of this genus looks very bright. Perhaps in a few more years, we'll be taking orders for the newly published "Gardener's Guide to Growing Baptisia" at our local Baptisia Society meeting.

Fern Propagation Strategies at Casa Flora©

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INTRODUCTION

Casa Flora has traditionally specialized in production of tropical and hardy ferns over its 39-year history. That represents a long learning curve and a willingness to take risks. We have come a long way from those early days of producing tropical ferns from runner tips in beds of peat. We have gotten where we are today by introducing new taxa, insisting on quality, and pioneering new production methods. Fourteen years ago we bought a large tissue culture lab and two smaller ones in Florida producing tropical ferns. In 2 years we were producing 2 million plants. Two years later and with much difficulty, we started producing hardy ferns in the lab as well. Now we consistently ship over 106 fern taxa year round, many with their own protocols.

Ferns, going back 300 million years, are much more primitive than most of the plants commercially propagated, and so have unique opportunities and problems. Much of coal is made up of fern fronds, and many of the ferns today are represented in fossils. Unlike higher plants, ferns exhibit alternation of generations. Alternation of generation simply means that the cells that produce the gametes (egg and sperm) make up a whole independent plant instead of being contained in and wholly dependent on the parent. As you might suspect, being a gametophyte — being haploid — makes the plant look different than its diploid parent. In almost all ferns, this gametophyte starts out as a single-celled organism surrounded by a hard shell — a spore — that enables the cell to survive harsh environments until conditions are right to begin to grow. It then grows into a single cell layer, basically a heart shaped plant called a prothallus. When it is mature and environmental conditions are right, it releases sperm (pollen) that swims to and fertilizes an egg, which develops into a diploid (normal) plant — a sporophyte. When this plant matures and the conditions are right, it produces spores that start the cycle over.

Some ferns for one reason or another have developed other propagation methods as well. Some have branching stems that increase the number of growing points over time. Others have modified stems (stolons) that specialize in developing a growing point away from the parent. Still others form bulbils on the leaf veins or have buds on the leaf that grow when conditions are right. About the only vegetative propagation structure ferns don't have that higher plants do are well-developed axillary buds. Because of this you just can't take cuttings.

THESE DAYS CASA FLORA USES TWO PRIMARY METHODS OF PRODUCING FERNS — SPORE AND TISSUE CULTURE

Production from spore, in most cases, means you get sexual recombination of genes with the resultant phenotypic variation. Since this is the primary way most ferns reproduce, production is relatively straightforward and large numbers of plants can be propagated in a small space.

Spores are readily available from hobbyists if you want to produce small numbers of plants, but production on a commercial scale requires significant investment in stock maintenance. Most temperate ferns have spore that ripens once a year, therefore you must have sufficient stock plants to get enough spore for the following year. Spores ripen at different rates along leaf and care must be taken in harvesting the spore so you don't collect immature spore. The spore is mobile, so foreign spores can land on leaves and then be collected along with the desired spore — creating a mixture. Most spores looks alike, mixtures are only apparent when sporophytes get larger. I am sure any of you that have gotten spore-sown material have noticed a few odd ones.

Spore loses potency as it ages and must be stored correctly. Spore also seems to have distinct time windows in which it germinates and develops best. There are two windows of 4 or so weeks in the spring and fall when temperate spore seem to perform best. The weeks to transplantable sporophyte varies with taxon, time of year, and environmental conditions. Spore derived plants are variable just as seed derived plants are.

Ferns have developed many of the same strategies higher plants have for fertilization. There are those that share their genes with other individuals, those that only share with themselves, and those that don't share at all. The prothalli of a given population are specialized for the environment they usually develop in. In those species that germinate in areas where a favorable environment persists for months, trading of genes between individuals is common. As the environment gets less favorable, prothalli tend to become male and then female, fertilizing others by chance but fertilizing themselves just to make sure. Finally, there are species that are apogamous — no sexual recombination at all, the maternal mother cells never divide to form an egg, forming a plant instead — the progeny is identical to the parent — usually. This seems to be an adaptation to dry conditions where little free water is available for fertilization. While you might think that self-fertilizing prothalli would produce a homogeneous population, the high ploidy levels and what appears to be a propensity for faulty recombination of genes actually yields as much diversity as in those ferns that trade genes.

While some spore can remain viable for decades, in general fresher is better so we keep spore refrigerated in sealed containers so it doesn't desiccate. Green spore like *Osmunda* must be sown immediately. Many different substrates can be used for germination. An old Cub Scout project germinated spore on a brick. Black basalt dust is used in Germany. However, we use a good quality peat lite bark mix with an over layer of high quality peat. Pasteurization with boiling water or by microwave seems to be the best way to pretreat the substrate. Autoclaving will destroy the antibacterial and antifungal properties of the peat as well as foster the bloom of whatever fungal contaminates there are on the spore. We filter our spores with lens paper, upholstery cloth, or 200 mesh screens. This excludes most trash. Spores can be distributed by water or dilution with fine particles. Cover with translucent/transparent covers such as shrink wrap or zip lock bags to let light in, keep humidity in, and keep contaminants out. Germinate in a cool dry area with dim filtered light. Germination usually occurs in 2 to 6 weeks with sporophytes appearing in 3 to 6 months. Some can take 2 years. Free water is required for mating in non-apogamous taxa. If the prothalli density is too high the prothalli may stop developing at the male stage so only sperm will be produced, severely decreasing the yield

of the containers. Fungus gnats and snails can be a problem if they get into the containers. Fungus, bacterial, and various slime molds are always possible. Transplanting must be done at the correct developmental stage and care must be taken to wean the plants from their high humidity environment.

Casa Flora used to produce all of our Boston fern types from stolons. Many of these plants had sterile spore or were clonal in nature. Stolons (or runners) allowed production of true-to-type plants. Unlike spore production or tissue culture, the propagules per unit area were low resulting in single crown liners and quite a bit of our greenhouse committed to stock production — beds of peat moss, lines of pots — all to produce and convert enough runners to plants. We produced millions this way.

Stock plants were either grown in the substrate or above the substrate. Stolon tips were allowed to come in contact with the substrate, usually high-grade peat, where they stop elongating and develop leaves. Once a plant is initiated on the stolon, development is rapid. *Nephrolepis* taxa take 6 weeks to become large enough to transplant.

A few ferns can be propagated by bulbils, buds on the rachis, plants arising de novo on the leaf surface, or by buds present at the apex of the frond. Propagules are true to type, develop rapidly, and don't require special handling since they are survival structures. The numbers of propagules these plants produce tend to be small so a lot of stock space is required for commercial quantities. We only produce one selection ('Oriental Chain') this way. In this case, we have a small demand for this selection and the specimen plants we keep are sufficient. If demand were to increase, we would put it into tissue culture to ensure availability.

PRODUCTION BY DIVISION IN THE GREENHOUSE

This is only needed if there is a problem with production by spore. Low division rates and adverse response to growth regulators result in large space requirements for stock. To overcome this, we propagate by division in the tissue culture lab.

TISSUE CULTURE PROPAGATION

Tissue culture (TC) allows propagation of a large number of plants in a small area. Since you can start with a single specimen, selected characteristics can be captured. In some cases, TC allows dissemination of sterile hybrids, i.e., *Dryopteris* × *australis*, a cross between *D. celsa* and *D. ludoviciana*. When first tissue cultured, there were relatively few in the entire world. Within 2 years, 50,000 had been produced. Because of the small propagule size, multiple crown clumps are usually produced. Since propagation is done in a constant environment and growth rate controlled by hormones, year round production can be achieved.

On the other hand, TC requires special facilities and specialized knowledge. Because of the initiation costs and time spent building up stock, it is too expensive for small numbers of product. There is a lag time for buildup, conventional propagation will beat TC in the first 12 months — the 13th month TC will exceed the total output of the year of conventional propagation. There is no horticultural check for mixtures and mutations during propagation of ferns. With conventional propagation, you see the adult plant characteristics at the start of each propagation cycle. With TC, the production cycle is so long and has so many propagation cycles that large numbers of plants are produced without ever seeing an adult plant and so a single mixture or mutation can replace a good portion of the propagation material

before it is identified. Replacing a TC crop that is mixed or mutated is expensive in both discarded product and replacement time. The ability to initiate material into the laboratory varies with type and season. It is not always possible to initiate product when you need to.

Whether we are starting from spore or an organized structure, the plant material must first be disinfested of any organisms that will grow in the TC medium. We usually use chlorine-based aqueous solutions. Generally, if a taxon comes true from spore, it is easier to derive plants from these than from more complex structures although it usually takes a few more months before clonal product comes out of the lab. Interestingly, ferns do not have a highly organized apical region and so there are no periclinal chimeras. Nor do they have developed axillary buds so initiating from organized tissue is a hit or miss proposition.

There are two basic propagation strategies with ferns. You can either propagate gametophytic or sporophytic tissue. Both require buildup of stock and conversion of that stock to the greenhouse. Gametophytic tissue really means growing and multiplying prothalli. Since prothalli cells are totipotent, subdividing them increases their numbers. Once they are mature, they can be transplanted to the greenhouse and allowed to form sporophytes. While vast numbers can be produced this way, timing the crop in the greenhouse is impossible and therefore impractical for large-scale production. We have recently discovered that the haploid prothalli cultures can mutate over time and need to be restarted on a regular basis.

Production of sporophytes basically means suppressing leaf growth and forcing the meristematic structures to branch rapidly. This yields a large number of propagules in a very small volume and thus lending itself to automation. In our case, we convert whole plants to meristematic clusters, then manipulate those clusters in various ways and then convert them back into plants. Ensuring that tissue having no unique visual characteristics is what it is supposed to be can be challenging. We have chosen to replace the propagation material very frequently in order to flush out any mutations or mixtures. This requires a support program that consistently supplies known true-to-type material at regular intervals and a postproduction program that finishes product periodically to ensure that it is true to type.

Once the TC material is of sufficient size to survive in the greenhouse (Stage 3), it is divided and transferred to nurse trays. This is done in a high humidity room with frequent misting so material does not desiccate. From there it is moved to a humid nurse house to root before it is hardened off in a brighter, drier environment. When ready to transplant, they are brought to the transplanter. The transplanter plants 12 at a time into the 72-cell tray. The tray is then inspected for misses and uniformity and any corrections are made. The tray is initially watered in with a preventative mix of fungicide and larvacide and accumulated on carts. They are then placed on production benches. Our benches are a combination of watering mats and ebb and flood. They are all rolling benches. They are kept fairly dry to encourage rooting for the first few weeks and then fertilized with each watering. Since we water from the bottom and only enough to saturate the plug, the salt concentration in the fertilizer solution does not change nor do we get a buildup of fertilizer on the surface of the plug. Bottom watering also helps us prevent common diseases on the ferns by keeping the foliage dry.

One of the worst disease problems is black rot of the foliage caused by *Pythium*. While controllable with Captan, it is easier to prevent its occurrence by keeping

the foliage dry when watering and having good air movement at night. A high peat content in soil helps keep bacterial and fungal problems to a minimum.

Two pests we treat for regularly are fungus gnats and shore flies. While shore flies are more numerous and are the ones that hit your hand when you wave it over a flat, their larvae eat algae and live under the benches and other areas algae accumulates. Fungus gnat larvae do the actual plant damage but for us, the adults are not as numerous. We use a rotation of Adept and Enstar II as well as Nemashield — a beneficial nematode drench. We have seasonal problems with caterpillars on 72-cell liners. You can smell them before you see the damage. Treating with Dipel or 0.5X strength Orthene is satisfactory.

Benches are scouted daily for problems, to monitor treatments, and to correct imperfections in the trays. We find that it is much easier to make corrections to a flat when it is partially grown than just before shipping when small plants are hard to see and time pressures abound. Having done that, when we come on Thursday and Friday to pull flats for Monday shipment most of the corrective work has already been done. Regardless, we check the flats an additional time, water them, and then give them a preventative spray to make sure we don't have problems in the shipping box. Shipping actually started on Thursday with the pulling of flats and the making of boxes and shipping labels. Monday morning box filling starts.

Sunlight Management©

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INTRODUCTION

Sunlight management is the process of manipulating the sunlight quality and quantity to which plants are exposed. A new generation of agrotextiles has been developed and tested over the last 10 years. They allow the grower to choose both the duration of light as well as the particular wavelength that will produce the desired effect from the plants at all stages of development.

Albert Einstein won his Nobel Prize for describing the photoelectric effect. He proved that beams of light are made up of particles and wavelengths. He called the particles photons. He stated that we could neither affect nor measure both at the same time. Therefore, in order to manage light, we will need materials to affect the photons (light energy/intensity) and different materials to affect the wavelength (light quality).

There are currently three fabrics that manage photons and two fabrics that affect wavelength. For photon management, use aluminized, gray, and pearl fabric and to manage wavelength, use blue and red materials.

The aluminized fabrics are constructed from high-density polyethylene (HDPE) plastic tapes that are fused with aluminum and coated with UV inhibiters. These tapes are knitted together with the tapes twisted between each row of knots. Aluminized fabric manipulates light by reflection. It acts as a collection of tiny mirrors reflecting light photons in all directions at once. They also bring sunlight down to your plants over all daylight hours, thus increasing the photoperiod.

Aluminized knitted fabric is especially effective when placed over a greenhouse glazing such as poly. The mirrors maximize the perpendicular light needed to penetrate any greenhouse glazing. This increases the volume of light to which your plants are exposed, but more importantly, it is all usable light to the plants. The aluminized agrotextile has the added advantage of reflecting away heat in the daytime and blocking infrared from the ground at night, creating a thermo-reflective barrier of protection for your plants.

As an example, let's use the most recommended 50% aluminized material. It allows in 50% direct sunlight through the openings in the fabric. It reflects down 65% redirected light; the act of reflection breaks down the UV intensity. Full spectrum light beams down upon the plants from sunup to sundown. During midday the heat and light intensity are dispersed. This creates an environment of maximized photosynthetic light in the greenhouse, as well as temperature control.

There are four light-managing fabrics in different colors. The elements that create their abilities are imbedded in the plastic. The manufacturer mixes elements and UV inhibitors into the clear HDPE plastic. The colors we see are not dyes, but are created by the imbedded elements. This is called color by subtraction. Most of the colors we see are from absorption. Plants are green because they absorb the blue, yellow, and red visible light that they need for growth and then reflect back the green visible light they do not use. Color by subtraction is caused by refraction. The beams of light that hit the material are refracted or bent to a particular wavelength.

The tapes that are stretched between the knots of the knitted fabric become sunlight filters. At the stated net percentage of 50%, there will be a direct sunlight block of 50%, but photosynthetic light will penetrate the fabric. This adds as much as 20% more light of the targeted quality. More importantly, a 50% rating on these nets is a close shading approximation for all daylight hours. With black shade cloth a 50% rating is the shade at geographic noon; during the rest of the day the shade percentage is higher. Therefore, light managing net puts more stress-free photosynthetic light onto the plants.

The gray material diffuses the photons. It scatters light through the crystalloid structure that is inside the net. This mimics tree canopy light — the light plants receive in natural shade. The most noticeable difference in your plant will be the increase in flush. You will see more branching and more foliage, with less stretch. It also creates a thermo-reflective barrier, causing cooler days and warmer nights for the plants. The gray material moderates temperatures and increases the photoperiod for all plants.

The newest addition to the light managing nets is pearl material, which disperses photons much like the aluminized fabric, but without the thermo-reflective barrier. The element inside the pearl fabric is responsible for the reflective properties. Your plants benefit from the extended photoperiod provided by this fabric. Trials have shown that full sun vines demonstrate rapid growth under this material.

The red and blue materials are pure wavelength management. That is, they manipulate the light spectrum that the plants see. Clouds block blue light and only allow the red light to penetrate. Therefore plants see more red light on cloudy or rainy days and more blue light when there are clear skies.

The blue material refracts all the light that penetrates its filters to blue light. Blue light mimics dry days or blue skies. The blue wavelength slows the rhythm of the plant. The plants will exhibit compact growth, deep green foliage, and excellent budding. The bloom will be delayed. Growers have been able to market their annuals as growth-regulator-free and still have a 3- to 4-week window to sell their plants before they bloom. When the budded plants are exposed to full sun, they bloom within 1 day. The blue fabric is very handy for any plant that needs a dry season trigger for desired results.

The red material refracts all the light that penetrates its filters to red light. Red light mimics rainy season light conditions. The red wavelength stimulates the growth of the plant. Many plants will show increased growth rate, greater root mass, longer stems, and early flowering. Propagators have enjoyed higher rooting percentages and healthier plants with less time in the greenhouse. Tropical foliage, especially palms, responds vigorously to red light. The red fabric brings out the best in plants that crave cloudy skies.

These sunlight management fabrics allow the grower to simulate an environment that brings out the desired characteristics in their plants. They can be used in combination, one on top of the other, to control day length and spectrum specifications. They have been installed in tandem, one next to the other, over and under different glazing to provide an even distribution of light over the plants. Many propagators have used the aluminized fabric over their roofs and red in the rafters to simulate spring light year around.

This new agrotechnology reduces light variables and decreases the growers' dependence on chemicals to produce quality plant material. Growers can now choose the quality and quantity of sunlight to which the plants are exposed.

The Propagation of Plant Diseases©

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INTRODUCTION

Almost all commercial ornamental production utilizes vegetative propagation to increase plant numbers. As such, the risk of inadvertently propagating disease-infected plants is on the rise. If a plant is infected with a root or crown rot disease, it usually dies or shows symptoms that prevent its propagation via cuttings or division. However, many foliar diseases do not kill the plant and can be present within symptomless leaf or stem tissues. There are several diseases that have become increasingly common on ornamental plants primarily due to either the lack of recognition of disease symptoms or the lack of symptoms at the time of plant propagation. In addition, with the increased use of off-shore production of herbaceous and woody plants, there is an increased risk of introducing new diseases into ornamental nurseries in the U.S.A.

DAYLILY RUST

Daylily rust on *Hemerocallis* is a classic example of how to propagate a disease. Daylily rust was first identified on infected plants in the U.S.A. in late Summer 2000. By Summer 2001, it had spread to 26 U.S.A. states, the U.K., and Australia. The disease is now endemic in the southeastern U.S.A. and has changed how daylilies are produced forever. The pest-free status of this popular perennial is gone. The disease is identified by the yellow spots or streaks produced on the upper leaf surface. Directly beneath these spots, the rust fungus, *Puccinia hemerocallidis*, produces bright orange spore pustules that rupture through the leaf epidermis. The disease will eventually be controlled through the use of resistant cultivars, but until then sanitation and regular use of fungicides will have to be used. Often infected plants may remain symptomless during the summer months as high temperatures reduce rust sporulation. As temperatures cool in the early fall, rust infection becomes very evident as spores are seen on the leaves and are spread to adjacent plants. Symptoms can develop within 7 to 14 days following inoculation. Removal of rust-infected leaves can reduce disease spread. Usually daylily rust does not survive freezing temperatures, but it could survive within nurseries on winter-protected plants (i.e., inside cold-frames, covered houses, or greenhouses). It is often reintroduced into nurseries via infected plants produced off-shore or in the Southern U.S.A. (USDA Hardiness Zones 8–10). Fungicides containing triadimefon, azoxystrobin, chlorothalonil, flutolanil, trifloxystrobin, propiconazole, or mancozeb can protect plants from infection.

Other leaf rust diseases occur on *Canna*, *Iris*, *Heuchera*, *Solidago*, *Aster*, *Campanula*, *Pennisetum*, and many more. Most leaf rust diseases are spread from naturally infected nearby plants or from alternate hosts.

DOWNY MILDEWS

Downy mildew diseases are very interesting and difficult to control. The fungal-like organisms that cause downy mildew diseases are very host specific. Therefore,

the downy mildew on rose will not infect any plant other than rose and possibly closely related species. Downy mildew is often seen on woody plants such as rose and viburnum. It also affects numerous herbaceous perennials including *Coreopsis*, *Rudbeckia*, *Veronica*, *Aster*, *Centaurea*, *Lamium*, as well as annual bedding plants including snapdragon and pansy. Within the past few years, it was identified for the first time on *Solenostemon* (syn. *Coleus*), *Impatiens*, *Salvia*, and *Argyranthemum*.

Downy mildew infection can cause both local and systemic symptoms. Local infection results in yellowish to purple leaf lesions associated with white to grayish, "fuzzy" sporulation directly opposite the lesion on the underside of infected leaves. Systemic infection results when the downy mildew pathogen invades the vascular system and causes stunting, leaf and stem distortion, and overall foliage discoloration symptoms. Downy mildew infection and disease development is favored by moist, humid, and cooler temperature conditions.

Control can be difficult. Infected plants should be discarded because of the systemic nature of the disease. Removal of the symptomatic stems or shoots will not remove the disease from the plant, and it can be spread via symptomless cuttings from infected plants. Avoid irrigating susceptible plants in the early morning hours as the downy mildew pathogens produce copious spores in the early morning, predawn hours that are easily water-splashed to adjacent plants. Fungicides such as foselyt-Al, azoxystrobin, mancozeb, dimethomorph, and phosphites (or phosphanates) can provide good control when applied preventively. Fungicide resistance can develop with downy mildews; therefore, rotating chemical classes is essential. Mefenoxam can be used as a soil drench for downy mildew control, but only once since resistance is a problem.

ASTER YELLOWS

Aster yellows is caused by bacteria-like organisms, called phytoplasmas. Infection is often sporadic because it is spread primarily by aster leafhoppers feeding on infected plants and transmitting it into new plants. Most infections occur as the leafhoppers migrate north from Mexico and the Southern U.S.A. However, it also can be transmitted via grafting and propagation of infected plants. The disease is often seen on *Echinacea*, *Veronica*, *Aster*, *Coreopsis*, *Dahlia*, *Dianthus*, *Gaillardia*, *Phlox*, *Rudbeckia*, *Salvia*, *Tagetes*, and *Catharanthus* (vinca).

Symptoms are striking. The phytoplasma grows in the phloem of infected plants, disrupting plant hormone flow and causing growth distortions. Plant yellowing, bronzing, stunting, witches brooms (abnormal proliferations of shoots), flower sterility, and flower greening (phyllody) are common symptoms. Dramatic symptoms often seen on coneflower (*Echinacea*) are tiny, distorted, lime green petals and short stems developing in the center of flowers. There is no control other than removal and discarding of infected plants. Keeping leafhopper populations low can reduce spread, as can avoiding propagating or dividing infected plants.

HOSTA VIRUS X

Hosta Virus X has become a major problem for hosta growers worldwide within the past few years. This is primarily because the symptoms are now recognized as a virus disease. The disease is prevalent wherever *Hosta* is grown. Plants are often symptomless, with symptoms developing weeks, months, or even years later. Large numbers of infected hostas are currently being sold in nurseries and are

growing in gardens across the country. Symptoms can vary with hosta cultivar, making it more difficult to recognize virus infection; it often resembles natural leaf variegation. A definitive diagnosis requires laboratory testing. The most diagnostic symptom is an irregular color feathering along the leaf veins. The cultivars Gold Standard, Striptease, and Sum and Substance are commonly infected. Some cultivars have even been described based upon virus infection, such as Breakdance, much like color-break virus infected tulips and variegated *Abutilon*.

The virus is primarily spread by propagating (dividing) infected plants. Contacting a healthy plant with the sap from an infected plant also spreads the virus. Simple acts of dividing hostas, scape removal, and removing leaves can potentially spread the virus. Plants are not killed by the virus. Control depends upon exclusion and sanitation. Infected plants need to be removed and destroyed. Adjacent plants should also be destroyed since the virus-infected plants can remain symptomless for long periods of time. Some hosta cultivars are resistant or immune to infection, including Blue Angel, Color Glory, Frances Williams, Bressingham Blue, Frosted Jade, Love Pat, Great Expectations, Sagae, and *H. sieboldiana* var. *elegans*.

Canna yellow mottle virus is another problematic virus that affects *Canna* cultivars. Symptoms are often mistaken for natural leaf variegation and include a yellow or necrotic mosaic pattern on leaves or color streaking or bleeding along leaf veins. Control the virus by removing and discarding infected plants.

FOLIAR NEMATODES

Numerous herbaceous and woody ornamental plants are susceptible to foliar nematode (*Aphelenchoides fragariae* and *A. ritzemabosi*) infestation. Often symptoms of foliar nematode infestation are misdiagnosed as bacterial leaf spot diseases, downy mildew infection, or nutritional disorders. Commonly infected plants include *Abelia*, *Hosta*, *Anemone*, *Begonia*, *Heuchera*, *Rudbeckia*, *Hypericum*, *Phlox*, *Salvia*, *Paeonia*, *Helleborus*, and many others. The foliar nematode is a microscopic roundworm that lives most of its life inside infested leaves. As it feeds it kills cells, causing necrosis of infested leaves. Developing lesions may be yellow, tan, brown, reddish-purple, or black. The lesion shape is determined by leaf vein pattern. Leaves with angular or netted veins develop angular lesions. Those with parallel veins, such as *Hosta*, develop a stripe-like lesion. The main distinguishing feature that differentiates foliar nematode infestation from other leaf spot diseases is that the lesions will show a color gradient from lightly to darkly colored areas as the nematode population and feeding increases within the affected area. The nematodes cannot penetrate through major leaf veins and therefore must exit the leaf through stomata in a film of water, "swim" across the leaf vein, and re-enter the leaf through another stomata. As the nematodes move across the leaf they can be water-splashed to adjacent leaves and plants. Affected leaves will eventually die and drop from the plant. However, the nematode can still survive in the desiccated leaf for long periods of time, even years.

Since most of the nematode's life cycle is spent within infested plant tissues, it can be easily spread via vegetative propagation. However, this also aids in its control. Removal and discarding of infested leaves and stems will eventually reduce foliar nematode populations. Removal of fallen leaf debris and good sanitation also will reduce nematode survival. There are few chemical control options available for nematode control. The miticide chlorfenapyr is labeled for foliar nematode control.

However, it should not be relied on exclusively for effective control since some efficacy trials have not shown it to be very effective in reducing foliar nematode populations within infested plants.

CONCLUSION

If you propagate from disease-infected plants, you will end up with a diseased crop. This new crop will cost more money in labor and chemical costs, as well as result in a greater number of unmarketable culls. If you are uncertain about symptoms you are seeing on your crop, get help with the diagnosis of the problem from university, state, or private disease diagnostic laboratories. A proper and quick diagnosis will save you money in the long run.

Please note: *All fungicide chemical names used in this article are provided for reference and do not constitute a recommendation of one product over another. Please consult local extension specialists, crop advisors, or consultants for current recommendations in your area. Always follow label directions for rate and use guidelines when using any pesticide product.*

Highlights of The Daniel Stowe Botanical Garden©

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INTRODUCTION

The staff of Daniel Stowe Botanical Garden in Belmont, North Carolina, was thrilled to host I.P.P.S. when they met in Charlotte in October 2006. Attendees had a quick stroll through the gardens before enjoying a catered dinner in the Robert Lee Stowe Visitor Pavilion.

This presentation is in two parts: first an overview of the Daniel Stowe Botanical Garden from a horticulturalist's perspective, and second, a look at a number of notable plants and groups of plants. Included in this second half are several suggestions of possible nursery crops that to this gardener's mind could be worthwhile additions to the nursery trade.

Daniel Stowe Botanical Garden is primarily a horticultural display garden. The oldest gardens opened on 8 Oct. 1999. Our focus is creating the most aesthetically pleasing gardens of year-round interest. Within this framework we work with the whole range of plants: permanent trees and shrubs, winter-hardy herbaceous perennials (including grasses and ferns), tender perennials that are treated as annuals, true annuals, bulbs, and tropical plants that are on display in containers during the frost-free growing season. The collection of plants totals over 4000 taxa. Though the focus is on display, the plants are also essentially on trial. A computer record of plants is kept, as is a weekly bloom journal. Construction of its first public Conservatory is to start in fall 2006 and will feature orchids and other tropicals.

The layout of the garden was designed by the landscape architectural firm Marshall-Tyler-Rausch (MTR) of Pittsburgh, Pennsylvania. The design of the plantings within this framework was collaboration between Edith R. Eddleman and Douglas Ruhren. Exiting out the back of the Visitor Pavilion, one enters the Four Seasons Garden. Here the focus is first and foremost on plants of winter interest, and it is the strongest season in this garden. A garden need not be dull in the winter months, especially in the milder parts of the Southeast where there are quite a few plants that bloom during this second of two growing seasons, the growing season when frost is likely; the other growing season being the frost-free one. Beyond the winter-blooming plants are colorful berries, evergreens of varied hues, colorful and curious twigs, ornamental grasses, and architectural plants. The Four Seasons is bordered on two sides by the pergola covered Color Walks. Here the plantings are totally changed twice per year and feature a very varied range of annuals suited to that particular season.

Continuing into the next garden one enters the Cottage Garden which is a garden of plants that were typical of gardens in the Piedmont of the Southeast during the late nineteenth and early twentieth centuries. Many of these plants are still garden-worthy in the early twenty-first century. It is planted in a cottage-garden style, meaning largely that we struggle to forget that we are garden designers and instead garden the way most of us garden at home: "there's a hole, let's plant it there." The effect is of delightfully exuberant randomness.

Next comes the Canal Garden, whose name derives from the nearly 300-ft-long canal that starts with one fountain of many separate jets and ends with a 20-ft-tall geyser fountain. Here the effect that is striven for is a tropical one. The backbone of this garden is built on winter-hardy permanent plants that suggest the tropics, such as winter-hardy bananas, palms, elephant ears, cannas, ginger lilies, and giant ornamental grasses. Annuals and tender perennials really pump up the color display through the summer months. A highlight of this garden at the time of this visit were the multiple ruby clouds of the purple muhly grass, *Muhlenbergia capillaris*, in the center beds bordering the canal.

The four perennial gardens follow this one. If all of the separate beds of the perennial gardens were put end to end they would run 2/3 mile long. And many of these are quite wide, running 20 to 30 or more feet wide.

Three of the four perennial gardens are distinguished by their color schemes: the Allee Garden of yellow and violet, the Rib Garden of red, orange, and yellow, while the Serpentine Garden is the cool end of the spectrum, blues, violets, and purples. The Scroll Garden lacks a color scheme and instead plays more with shapes and textures as well as focusing on plants that attract pollinators and plants that have interesting winter forms. These gardens are so large that woody perennials (shrubs and trees) are a significant part of the plantings.

Heading back up to the Visitor Pavilion one can enjoy the Fall Azalea Garden, which features almost 600 plants of Encore™ azaleas and all 24 of the currently available cultivars. Nearly all have been outstanding performers, blooming for 2 to 3 months in late summer into fall as well as in spring. Furthering the look of spring-in-fall are repeat-blooming bearded irises and autumn-flowering cherries both of which bloom in October. The last garden of note is the Nellie Rhyne Stowe White Garden, which opened in the summer of 2003 and is off the west side of the Visitor Pavilion.

INDIVIDUAL PLANTS OF NOTE, FIRST SOME NATIVES

Magnolia macrophylla, the bigleaf magnolia, is a native deciduous magnolia with the largest simple (that is: undivided) leaves of any North American native. It is of easy culture despite its being a fairly rare native and is most worthy of wider cultivation because it is a plant of year-round beauty. The huge, white, delightfully fragrant flowers are much like those of *M. grandiflora*. The almost banana-leaf-like leaves are dramatic, and every breeze reveals their nearly white undersides. The winter aspect of this plant is of a landscape-sized silver candelabrum, with the large terminal buds the flames. *Ilex decidua*, the possumhaw holly, is of garden merit equal to that of the winterberry holly, *I. verticillata*, and is sufficiently distinct as to not be redundant. For one, it is more of small tree size, to about 20 ft tall. Its strikingly beautiful silver stems also set it apart from the black stems of the winterberry, which also goes by the name of black alder. Its leaves are also much smaller. As with winterberry, it is highly recommended that one seek out improved selections of *I. decidua* for the best fruit displays. Simpson Nursery in Vincennes, Indiana, has probably made the most and best selections of this species. All have been superb performers. Possumhaw is equally tolerant of the heavy wet soils that winterberry thrives on, yet also seems to be more drought tolerant.

Yes, the native buckeyes, *Aesculus*, are slow but we will try to educate the public about their highly ornamental early spring display, their drought tolerance, their importance to the hummingbirds, which first return at the time of their bloom

(a mutually beneficial arrangement, no doubt) if the nursery industry will make them available. Their drought tolerance makes them easier plants to establish and maintain than flowering dogwood, *Cornus florida*, and they are far more permanent than redbud, *Cercis canadensis*.

Zenobia pulverulenta is the melodious name for the dusty zenobia or honeycups, a Southeast native related to blueberries and azaleas. Gorgeous in bloom in spring, and especially attractive through the summer months in the glaucous-leafed cultivar 'Woodlander's Blue', it becomes a knock-your-socks-off display of the most brilliant scarlet and crimson in December. Perhaps not of the easiest culture as it seems to insist on evenly moist, but well drained soil. Plant it high in aged pine bark, and it is highly likely to thrive.

Those who live where the following species is native might laugh at the idea of promoting *Sabal minor*, the dwarf palmetto. But it adds such a dramatic architectural shape to the landscape that borders on being a thicket of green exclamation points! It is quite hardy. Here it sailed through 4 °F without any foliage damage.

Butterfly gardens are highly popular with the public, and from this has come an interest in other pollinators. In bloom the mountain mint, *Pycnanthemum incanum*, becomes a veritable insect zoo, and it is in bloom for months. It is very ornamental in bloom, and so are its charcoal-grey seed heads. The East Coast forms of this species spread a mile a minute and so are hard to use in home gardens, but the Midwest forms don't run. So you see I hadn't lost my mind in recommending this plant. Propagate the Midwest forms. The white-bracted sedge, *Rhynchospora latifolia,* blooms all summer and is highly recommended for sunny damp gardens. With the popularity of rain gardens it might find much use.

Most flowering plants spend most of the year out of bloom, so if they have other ornamental features they are of much greater value in garden displays. *Helianthus salicifolius,* the willow-leafed sunflower, is a striking foliage plant for months before it blooms, looking like a pale green feather duster. The one in the perennial border at the J.C. Raulston Arboretum at North Carolina State University might be worthy of naming as a distinct cultivar since it has especially narrow leaves. I might suggest it be named for Edith Eddleman, the designer of this border.

Eryngium yuccafolium, the rattlesnake master, is a strikingly architectural plant in silvery pale-green. A great garden ornamental, surely the cut flower trade would also wildly accept it as they do a number of European *Eryngium*. If you can grow daffodils you can grow Virginia bluebells, *Mertensia virginica*. It probably blooms for 2 months and then dies away quicker than daffodil foliage so it is a more valuable ornamental than the average daffodil. And it is easy to propagate, by root division, seed, and I have to think by tissue culture because so many of its relatives in the Borage family are tissue cultured. Sure, some wonderful native nurseries are producing it, but what I am saying is that this needs to be mainstreamed. And then maybe wild-collected offerings of this U.S.A. native won't "need" to be sold back to us by foreign vendors.

Isopyrum biternatum, the false rue anemone, might be burdened by its scientific name and not much better common name, yet it is of easy garden culture and here blooms from December into May. Enough said?

A FEW MORE PLANTS OF NOTE, THIS TIME NON-NATIVES

Stachyurus praecox needs a great common name. Is there one out there? I am sorry, but its Japanese common name is not going to help. In late winter or earliest spring

its bare branches are draped with 3- to 6-inch long chains of lime-green flowers. It thrives in Piedmont Carolina growing conditions, grows rapidly, and softwood cuttings are easily rooted. The variegated cultivar 'Magpie' adds additional ornamental interest.

Clematis cirrhosa starts blooming in October and continues into January despite the cold. It does defoliate in summer, an adaptation to its Mediterranean origin, so spring-rooted cuttings are more difficult to get through their first summer dormancy than fall- and winter-rooted ones. Its foliage is very handsome all winter, spring, and fall. It is vigorous, to 6 m (20 ft) tall.

Iris unguicularis, the Algerian iris, is another great winter bloomer. In its best forms it starts in November and blooms during any mild spell all winter into March. Division is best in late summer, because it initiates new root growth then. It is easy from seed, and if one wants to produce one's own seed it would best to protect the flowers from freezing temperatures so that they are not destroyed before pollination is effected.

A FEW RANDOM IDEAS TO EXPLORE

Those breeding compact *Loropetalum* are to be applauded, yet before we totally discard the full-sized cultivars, lets consider growing the very best of these as trees. *Loropetalum chinense* f. *rubrum* 'Zhuzhou Fuchsia' is such a gorgeous thing, why not give it the room it needs to become a large multi-stemmed crepe-myrtle-size tree? Gardens need more good small flowering trees.

There is great value in testing tropicals for hardiness. Every now and then one proves to be reliable and thus moves from being a houseplant to a hardy perennial. *Philodendron selloum*, for one, is reliably winter hardy wherever cannas and elephant ears are likely to overwinter.

It is funny how some bulbs, whether they are winter hardy or frost tender, exist either solely in the bulb trade or solely as container-grown stock. Certainly some such as dahlias and crocosmias are grown and marketed in both forms. Let's move more and more bulbs strictly from the dormant bulb trade to the container-grown trade. The majority of bulbs could be handled as container grown, and for example, spring-flowering bulbs could fit into the impulse shopping habit of garden center customers who forgot to plant them in the fall. Some bulbs such as winter aconites are almost impossible to establish from dormant bulbs yet are easy in containers from garden divisions.

Someone needs to use *Lilium formosanum*, the Formosa lily, in a breeding program. This species blooms in 1 year's time from seed (some other lily species don't even germinate in 1 year). It blooms late, August for us. It grows everywhere, wet, dry, and even in the cracks between bricks in the walks. In other words, take this ease of culture and extreme vigor and produce a wide range of garden hybrids.

Jenks Farmer got us growing winter vegetables to add variety to fall-planted pansies. Want still more diversity? There are quite a few hardy annuals that normally germinate in the fall, grow through the winter months, and flower in spring. Many, such as annual poppies and larkspur, do not transplant well if dug up in the garden but totally tolerate being sown directly in cell-paks and planted from the cell-paks at the time that pansies are planted. Other proven performers are baby blue eyes (*Nemophila*), forget-me-nots, English daisy, love in a mist (*Nigella*), poached eggs (*Limnanthes douglasii*), and wall flowers. Sow all of these in September.

And last but not least, in looking forward don't forget to look to the past, for there are some superb heirloom plants that can hold their own or better amongst their modern counterparts whether we are talking about crinum lilies or heirloom iris such as 'Perfection', which was introduced in the 1800s, or the occasional older rose cultivar such as 'Monsieur Tillier' that not only is as healthy and floriferous as some of the best new landscape roses but also a great deal more beautiful. Ah, never a dull moment at Daniel Stowe Botanical Garden. Please come back to visit!

A Comparison of Nutrient Requirements Between Pine Chip and Pine Bark Substrates©

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The objective was to determine the response of Japanese holly (*Ilex crenata* Thunb. 'Compacta') grown in ground pine chips (PC) or milled pine bark (PB) substrates to fertilizer rate. The PC substrate was prepared by further grinding coarsely ground debarked whole loblolly pine logs in a hammer mill. Plants were potted on 17 Aug. 2005 and fertilized by incorporating Osmocote 15N-9P-12K at 3.5, 5.9, 8.3, or 10.6 kg·m^{-3} (6, 10, 14, and 18 lb/yd^3) in PC or PB. Plants were glasshouse grown until 22 Nov. 2005. After severing the shoots for dry weight determination, substrate respiration rates (CO_2 µmol·m^{-2}·s^{-1}) were determined for the treatments using a LI-6400 soil CO_2 flux chamber. Maximum shoot dry weight for PB- and PC-grown plants occurred at 5.9 kg·m^{-3} (10 lb/yd^3) and 10.6 kg·m^{-3} (18 lb/yd^3), respectively. Maximum shoot dry weight for PC-grown plants was 23% higher than for PB-grown plants. Substrate respiration rates were higher in PC compared to the PB substrate. The reason that PC-grown plants required a higher fertilizer rate to achieve maximum growth than PB-grown plants may be attributed to increased nutrient leaching and microbial nutrient immobilization.

INTRODUCTION

Producing substrates from wood products can make it possible both to limit the use of expensive materials like peat and to utilize a renewable forestry resource. Due to the relatively low cost and high availability of wood products, serious consideration should be given to the development of this material as an alternative, organic container substrate. Previously, ground melaleuca trees (*Melaleuca quinquenervia* Cav.) were shown to be an acceptable substitute for bark or sedge peat when used to grow a number of woody and herbaceous plants (Conover and Poole, 1983; Ingram and Johnson, 1983). No phytotoxicity problems were evident in these studies as long as the proportion of melaleuca did not exceed 50% of the substrate. Kenna and Whitcomb (1985) demonstrated that *Pyracantha* 'Mohave' and *Liquidambar formosana* Hance. grew as well in a substrate of woodchips, peat, and sand (3 : 1 : 1, by volume) as in a substrate composed of bark, peat, and sand (3 : 1 : 1, by volume). Wood chips for their study were produced by grinding entire trees including leaves, twigs, bark, and wood of *Quercus stellata* Wangh. and *Ulmus pumila* L. Noncomposted sawdust from Douglas fir (*Pseudotsuga menziesii* Mirb.) and western hemlock (*Tsuga heterophylla* Raf.) have also been used to grow a wide range of herbaceous and woody container crops in Canada, where sawdust is plentiful (Maas and Adamson, 1972). Most recently, Wright and Browder (2005)

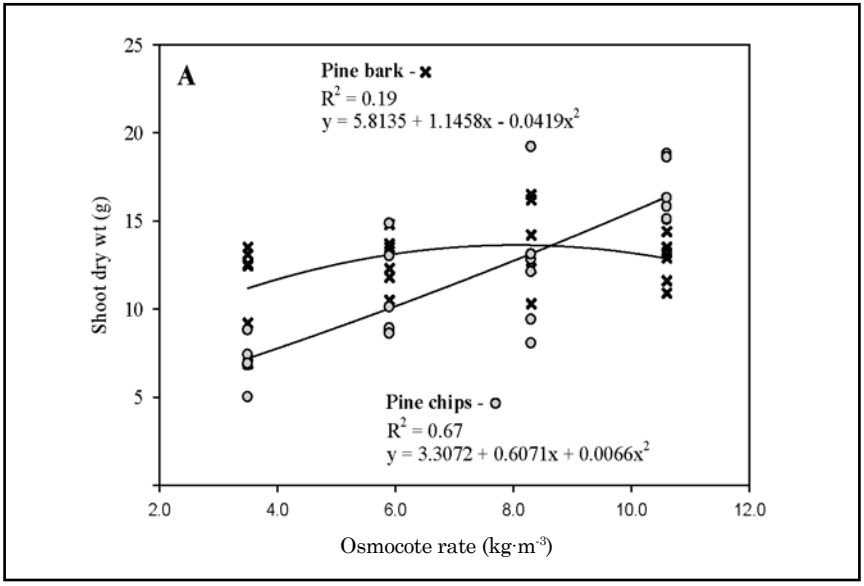

Figure 1. Shoot dry weights of Japanese holly grown in pine bark (PB) or pine chips (PC) incorporated with four different rates of Osmocote 15N-9P-12K.

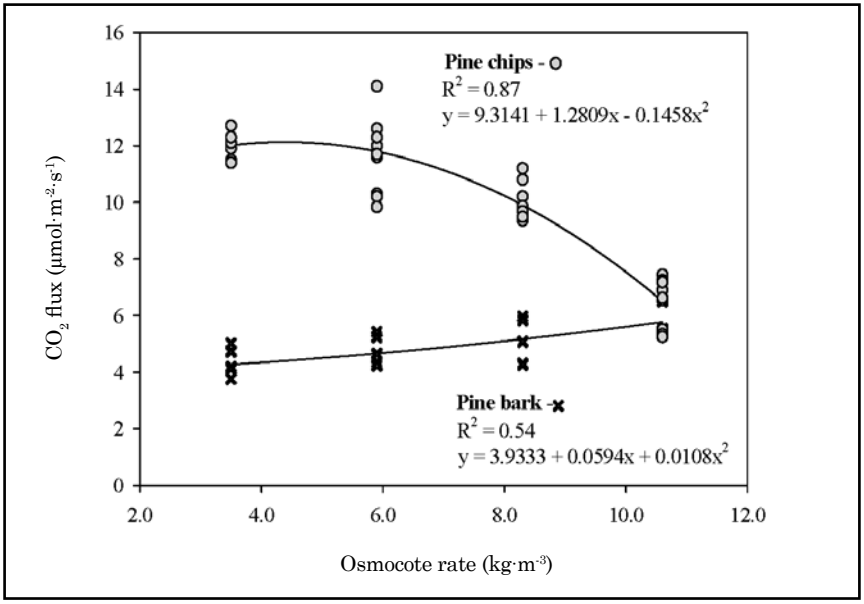

Figure 2. Substrate respiration rates (CO_2 µmols·m^{-2}·s^{-1}) for pine bark (PB) and pine chips (PC) incorporated with four different rates of Osmocote 15N-9P-12K.

demonstrated that woody and herbaceous plants could be grown in 100% PC substrate produced from a debarked loblolly pine log (*Pinus taeda* L.), compared to a 100% PB substrate. More research is needed to determine the feasibility of growing plants in a substrate composed of 100% wood material, including the fertility rate required over the production cycle of container-grown nursery crops.

The objective of this research was to study the effect of increasing fertilizer rate on growth of Japanese holly (*Ilex crenata* Thunb.'Compacta') in 100% PC compared to PB.

MATERIALS AND METHODS

Pine chips were produced by taking chips from roughly ground debarked pine logs and further grinding them in a hammer mill to pass through a 6.35-mm (0.25-inch) screen. Pine chips were amended with 5% (by volume) 16/30 particle size calcined clay (Oil-Dri Corp., Chicago, Illinois) and 0.6 $kg \cdot m^{-3}$ (1 lb/yd^3) $CaSO_4$. No pre-plant amendments were added to PB since none are needed for standard Japanese holly production. Treatments of Osmocote Plus (15N-3.9P-10K) (O.M. Scott Horticulture Products, Marysville, Ohio) were incorporated in PB and PC at rates of 3.5, 5.9, 8.3, or 10.7 $kg \cdot m^{-3}$ (6, 10, 14, and 18 lb/yd^3), respectively. Japanese holly liners were potted in 3.8-L (1-gal) plastic containers containing either PB or PC and grown on greenhouse benches in Blacksburg, Virginia. This study was a completely randomized design with six single container replications per treatment.

Physical properties of each substrate were determined according to Tyler, et al. (1993) on three replicate samples of each substrate at the beginning of the experiment. Cation exchange capacity (CEC) was determine by A & L Eastern Laboratories, Richmond, Virginia (AOAC Official Method 973.09, CEC for peat). At the end of the experiment, shoot dry weights were determined as well as substrate respiration rates (CO_2 $\mu mol \cdot m^{-2} \cdot s^{-1}$) for each substrate and treatment using a LI-6400 soil CO_2 flux chamber (LI-COR, Lincoln, Nebraska). All data were analyzed by ANOVA using SAS and subjected to regression analysis using SigmaPlot (version 9.01 SPSS Inc., Chicago, Illinois).

RESULTS

There was a significant substrate × fertilizer rate interaction for shoot dry weight: at fertilizer rates of 3.5 and 5.9 $kg \cdot m^{-3}$ (6 and 10 lb/yd^3) shoot dry weight was higher for PB than PC; at 8.3 $kg \cdot m^{-3}$ (14 lb/yd^3) dry weight was about equal for the two substrates; at 10.6 $kg \cdot m^{-3}$ (18 lb/yd^3) dry weight was higher for PC than PB (Fig. 1). Substrate respiration rates (CO_2 $\mu mol \cdot m^{-2} \cdot s^{-1}$) were higher in PC than in PB with the magnitude of difference decreasing as fertilizer rate increased, primarily due to a large decrease in respiration for PC and a slight increase in respiration for PB as fertilizer rate increased (Fig. 2).

DISCUSSION

This study demonstrates that a higher rate of fertilizer is required to achieve plant growth in PC comparable to plant growth in PB. The reason for this difference may be two-fold. First, PC is more porous and has a lower CEC compared to PB (Table 1), which could result in more nutrient leaching from PC. The second may relate to the higher substrate respiration for PC (Fig. 2) due to its higher C/N ratio compared

Table 1. Physical and hydraulic properties of two container substrates. Data were collected from three samples per substrate and represented as means.

Substrate	Total porosity[z]	Air space[y]	Container capacity[x] (% vol)	Bulk density ($g \cdot cm^{-3}$)	Cation exchange capacity ($cmol \cdot L^{-1}$)
Pine bark	82.9 b[w]	26.9 a	56.1 a	0.20 a	17.9 a
Pine chips	88.4 a	30.2 a	58.2 a	0.15 a	2.1 b

[z]Based upon percent volume of 7.6 × 7.6 cm core at 0 kPa.

[y]Total porosity-container capacity.

[x]Measured as percent volume of a 7.6 × 7.6 cm core at drainage.

[w]Means were separated using Duncan's Multiple Range Test ($P < 0.05$).

to PB, leading to increased microbial N immobilization with PC (Bollen and Lu, 1957; Tisdale et al., 1993). Similar to our results (Fig. 2), previous work has shown a reduction in substrate respiration as fertilizer rate increased (Maas and Adamson, 1972). Investigating ways to increase the CEC of PC as well as reducing PC porosity to prevent leaching may prove beneficial. The influence that PC substrate respiration has on nutrient immobilization and on substrate decay over longer production periods also deserves consideration.

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Nitrogen Nutrition of Southern Seaoats (*Uniola paniculata*) Grown in the Float System©

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Southern seaoats (*Uniola paniculata* L.), a major coastal dune species, was grown by seed in a greenhouse using the tobacco float system with nitrogen (N) in the nutrient solution at 10, 60, 120, 180, or 240 mg·L^{-1} (ppm). Transplants were produced successfully using this means of culture and N at 135 to 150 mg·L^{-1} (ppm) maximized vegetative growth.

INTRODUCTION

Southern seaoats is a perennial dune grass that in most of its natural range is the dominant sand-binding plant species (Ricciuti, 1984). The plant is generally subtropical, and its native range is determined by climate because it is intolerant of extremely hot summers or cold winters (Ricciuti, 1984). In Virginia and North Carolina, southern seaoats is at the northern limit of its range, and the plants usually die back to ground level and resprout from rhizomes in the spring. Seed germination occurs in the late spring, and little growth takes place until adequate sand surrounds the culms, usually by the end of the second year (Woodhouse and Hanes, 1966). Seaoats has the ability to resist erosion upon establishment by utilizing culms to trap sand, which in turn helps improve plant growth (Latham, 2001). Thus, it has been planted extensively to build and stabilize coastal sand dunes (Woodhouse and Hanes, 1966).

Limited research has examined the fertility needs of southern seaoats. Due to the infertility of seaoats native environment, Broome et al. (1982) recommended macronutrient fertilization (10N–10 P_2O_5–10 K_2O) in the spring at a rate of 732 kg·ha^{-1} (653 lb/acre). Hester and Mendelssohn (1990) reported fertilization with nitrogen (N), phosphorous (P), and potassium (K) resulted in significant increases in aboveground biomass in seaoats with a maximum foliar N concentration of 2.1%.

Currently, former tobacco farmers are seeking alternative crops that can be grown similarly to production of tobacco (*Nicotiana tabacum* L.) transplants (Latham, 2001). Frantz and Wellbaum (1998) reported most tobacco farmers grow tobacco transplants in a vermiculite-based soilless medium using Styrofoam plug flats that float in a nutrient solution. These float-bed irrigation systems are used by tobacco growers to produce transplants in early spring, but the float beds are not utilized the rest of the year. Frantz and Wellbaum (1998) also noted if other crops could be produced successfully using the tobacco float system, float systems could potentially produce high-value horticultural crops to supplement farm incomes. David Nash, an Agricultural Extension Agent in New Hanover County, North Carolina, has been growing seaoats successfully utilizing the tobacco float system (Latham, 2001). Initially, he attempted to grow southern seaoats in containers utilizing an

organic substrate. However, he encountered many problems, particularly with foliar fungal pathogens due to irrigating over the tops of the plants. He switched to using the float system, which dramatically reduced foliar infestations. However, despite successful culture of southern seaoats using the float system little, if any, quantitative information has been published on various aspects of this method of culture. Therefore, the following research was conducted to study the influence of N nutrition on vegetative growth of southern seaoats when grown in the float system.

MATERIALS AND METHODS

Standard Carolina Greenhouse 288 cell float trays (Carolina Greenhouse Co., Kinston, NC) [42 × 34 × 6.5 cm (17 × 13 × 3 inches)], with each cell having a volume of 14 cm^3 (0.9 in^3), were cut (reduced) on 9 July 2004 from 24 × 12 cells to 15 × 12 cells. These modified trays were filled with Carolina's Choice Tobacco Mix (Carolina Soil Co., Kinston, North Carolina), a vermiculite-based hydroponic mix. The medium-filled trays were then floated in gray plastic tubs [50 × 36 × 12 cm (20 × 14 × 5 inches)] filled with 10 L (3 gal) of tap water. On 12 July 2004, seeds of a North Carolina provenance of southern seaoats were removed from storage at 4 °C (39 °F) and surface disinfested with a solution of 2.6% sodium hypochlorite for 15 min. Following treatment, seeds were sown in the float trays at three seeds per cell in a 6 × 6 cell cube in the center of the trays [center was determined from the top (shorter dimension side) of tray counting five cells right and four cells down]. After seeding, each seed-filled tray was refloated in 10 L (3 gal) of tap water with a particular N treatment and were maintained in the Department of Horticultural Science Greenhouses at North Carolina State University under natural photoperiod and irradiance. Treatments included five rates of N [10, 60, 120, 180, or 240 mg·liter^{-1} (ppm)] from an 8N–32P_2O_5–5K_2O liquid slow-release fertilizer (Growth Products, Ltd., White Plains, New York). The nutrient solution was replaced weekly. Nutrient sources were urea, methylene urea, potassium carbonate, and diammonium phosphate. The experiment was conducted in a randomized complete block design with four replications. A tub was considered a single experimental unit. Tubs were oriented on a greenhouse bench parallel to the cooling pads to direct even airflow across all treatments. As seeds germinated, they were thinned to one seedling per cell. During the study, daily day/night air temperatures averaged 27/21 °C (81/70 °F), respectively, whereas daily nutrient solution temperatures averaged 26 °C (79 °F).

Before recording data, the seedlings in the outermost row of each float tray were discarded to remove edge effects, which left a 4 × 4 square consisting of 16 plants. Three plants were randomly chosen from the 4 × 4 square. On 9 Sept. 2004, the study was terminated and various data recorded including leaf, stem, and root dry weights following drying at 60 °C (140 °F) for 48 h. Total plant dry weight was calculated as leaf + stem + root dry weight. Root to top ratio was calculated as root dry weight ÷ top dry weight (stems + leaves). Tops (stems and leaves) were also analyzed for mineral nutrient concentrations. All data were subjected to analysis of variance procedures and regression analysis. When significant, simple linear and polynomial curves were fitted to data. The maximum of the polynomial curve was calculated as a first order derivative of the independent variable where the dependent variable equaled zero.

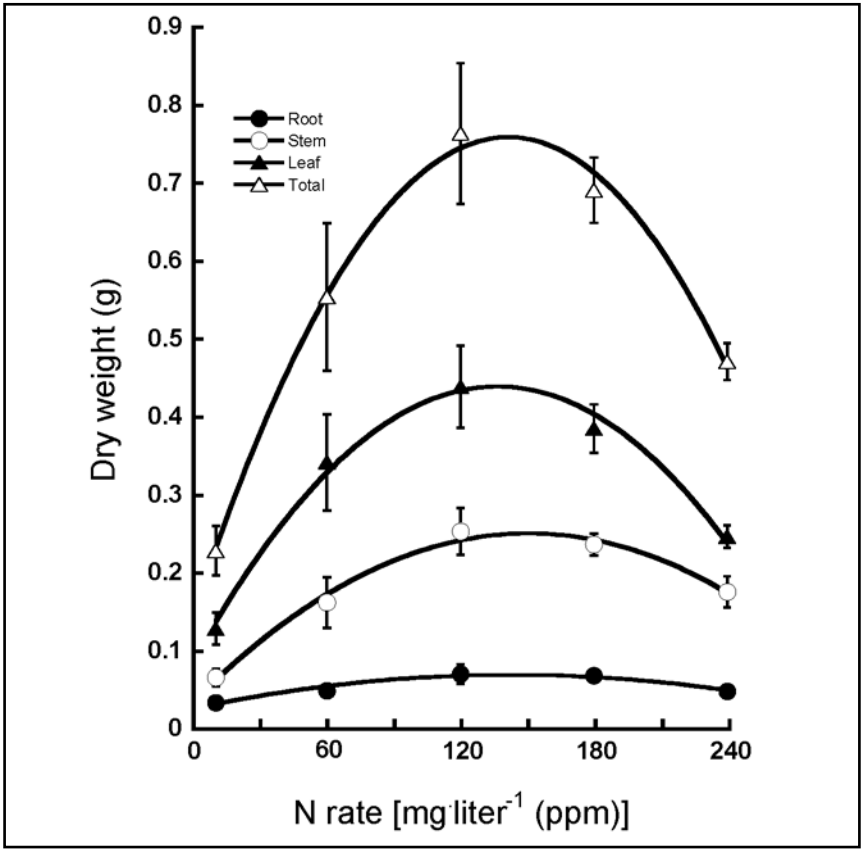

Figure 1. Influence of N rate on root, stem, leaf, and total plant dry weights of southern seaoats grown in the float system. Data points are means of 12 observations, and vertical bars = ± 1 SE. Regression equations are: root dry weight $y = 0.03 + 0.0006x - 0.000002x^2$, $R^2 = 0.98$; stem dry weight $y = 0.04 + 0.003x - 0.0000095x^2$, $R^2 = 0.99$; leaf dry weight $y = 0.09 + 0.005x - 0.00002x^2$, $R^2 = 0.99$; total plant dry weight $y = 0.15 + 0.009x - 0.00003x^2$, $R^2 = 0.99$.

RESULTS AND DISCUSSION

Root, stem, leaf, and total plant dry weights of southern seaoats responded quadratically to increasing N rate with maximum root, stem, leaf, and total plant dry weights calculated to occur at 143, 151, 137, and 141 mg·liter^{-1} (ppm), respectively (Fig. 1). Root to top ratio was unaffected by N rate (data not presented).

Foliar mineral N and P concentrations increased quadratically with increasing N rates, whereas foliar K increased linearly (data not presented). The predicted N rate for maximum foliar N (3.2%) was calculated to be 180 mg·L^{-1} (ppm). Maximum top dry weight also occurred at 3.2% N, which is considerably higher than the 2.1% reported by Hester and Mendelssohn (1990). Thus, foliar N concentration $\geq$ 3.2% should be considered adequate for maximum plant growth.

In summary, southern seaoats can be produced successfully using the float system with optimum N rates of 135 to 150 $mg \cdot L^{-1}$ (ppm). Due to the relative nutrient sterility of the dune environment, Broome et al. (1982) noted that dune grasses, such as seaoats, respond positively to fertilization, even though their extensive fibrous root system allows them to exploit the low nutrient conditions in their natural habitat. Culture of the species using the flat system may allow tobacco farmers to utilize their float beds at times of the year when the beds are not in use. Also, seaoats may serve as a possible alternative crop to tobacco or an additional crop to supplement farm incomes.

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